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Development of Dynamic GEO-Line Software for Learning Geometry: A Usability Assessment

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Abstract: Educational software reinforces the learning process in high school. This way, GEO-line software for learning geometry will strengthen teenagers' skillset between 15 and 16 years old while using this new application. The SCRUM and ADDE methodologies applied include the analysis, design, implementation, and evaluation phases as the core principles for software development. The technological toolset selected was the NEXTJS framework with server-side rendering technology. Strapi API CMS handled the content used on the model, view, controller (MVC) patterns, and REST architecture for communication and the PostgreSQL database. ISO/IEC 25010 metric was considered for the usability evaluation and applied with a pool of 80 students who were surveyed using the adapted USE and PSSUQ QUESTIONNAIRES with a Likert scale. The findings demonstrate that GEO-line software meets the satisfactory higher standards usability level by measuring pedagogical capacity, ease-of-use, and ease-of-learning parameters. This research turns the geometry learning reinforcement tool for students into a fun and operational way to increase the student's skillset.

Keywords: Educational software, GEO-line, geometry, usability

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Introduction

The learning process of mathematics and related sciences is a core subject characterized by the learning complexity level and embedding difficulty, especially in Geometry and Measurement, due to covering concepts of representation and analyzing properties of the shapes and their relationships, which can be graphic and symbolic (Feudel & Dietz, 2019; Jiménez & Reyna, 2016). While learning geometry, three cognitive activities must be considered: a) construction related to the design of geometric elements; b) reasoning, which links discursive and argumentative processes; and c) visualization, focused on spatial representation (Diaz-Nunja et al., 2018). The traditional teaching methods used by instructors or faculties only reinforce the subject's memorization of knowledge in students. It generates mechanical learning without adequate analysis, reducing the abilities that geometry allows to develop, such as problem-solving, critical thinking, reasoning with logical argumentation, and spatial visualization (Herbst et al., 2017; Marmolejo-Avenia & Vega-Restrepo, 2012). In the case of Ecuador, the 2018 PISA evaluation tests established that 70% of the students did not reach the basic level required to understand mathematics and geometry, classifying it as a learning challenge with an unenjoyable study method and a high level of rejection in the school curriculum (Herbst et al., 2017). In this scenario, they use digital technologies as alternative tools that allow students to explore and consolidate the knowledge acquired, reinforcing the educational process and aptitudes that increase students' perception of Geometry. This way, incorporating these technologies provides the students with different pathways of understanding and reasoning, reinforcing mental structures that expand and reorganize their cognitive resources (Reyes, 2020).

The use of educational software in Geometry is limited due to teachers' lack of training or knowledge of how dynamic geometry programs can be applied in a classroom. These facts present a new way of learning approach through the modeling, visualization, manipulation, and construction of geometrical shapes such as objects, points, lines, and circles, which present a certain level of difficulty to do manually (Aydos, 2015). The most widely used geometry program is GeoGebra, which is very suitable as a learning medium that helps students to understand the relationship between mathematical models and their graphical representation. The program also allows the demonstration, visualization, and dynamic modification of geometry contents (Ziatdinov & Valles Jr, 2022). However, in van-Borkulo et al. (2021), some difficulties that students present when using GeoGebra are exposed, for example, lack of previous training using the program, specifically syntax rules, the layout design of the objects within the program environment, and problems executing commands. Therefore, the learning process could confuse inexperienced students and take time to become familiar with the commands and functions within the program (Saputra & Fahrizal, 2019).

In this environment, the purpose of developing educational software GEO-line is to create didactic materials for teaching Geometry based on the contents approved by the Ministry of Education of Ecuador, incorporating formative feedback to enhance learning in high schools. With the implementation of the GEO-line tool, it will be possible to design and organize an outstanding teacher curriculum and syllabus with instructions, challenges, examples, technical notes, evaluations, and bibliographic information feedback through an interactive e-learning platform to reinforce the learning process. Also, this study was intended to analyze the usability of educational software using multiple choice questions designed on USE (Usefulness, Satisfaction, and Ease of Use) and PSSUQ (Post-Study System Usability Questionnaire) questionnaires (Lund, 2001; Rosa et al., 2015), based on the ISO 25000-SQuaRE standard.

Related work

Kukey et al. (2019) studied previous teachers' experiences using educational software and digital materials in the classroom. The participating teachers used Lego MoretoMath to create didactic material based on students' needs. Thus, the study verified that using educational software minimizes the previously analyzed difficulties, and the students learn while interacting with the software, increasing reasoning skills for problem-solving. The high impact that dynamic geometry systems (DGS) have on mathematical skills is exposed in Juandi (2021) and Saputra and Fahrizal (2019). They used educational Geometry software for the elaboration of interactive material. The results show a significant improvement in the students' evaluations who reinforced their learning skills while using this software. Geometry learning methods applying games also present positive results, improving students' creative capacity through adventure activities, and motivating the student in the educational process (Navruz & Tasdemir, 2019; Zeng et al., 2021).

Geo-line Software

The methodologies applied for the GEO-line development process were the Agile SCRUM and ADDE (Analysis, Design, Development, and Evaluation) methodologies that allow the software to adapt naturally to the functional and educational requirements of the users, working iteratively and incrementally (see Figure 1).

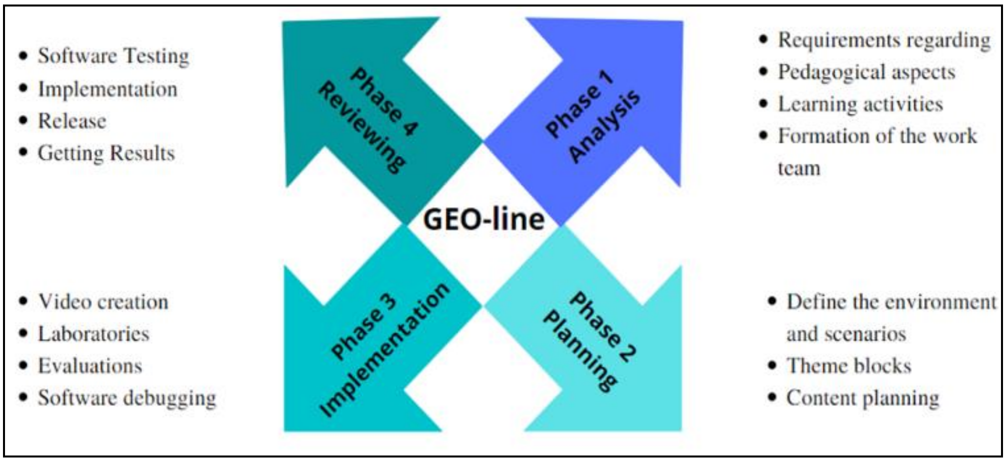

Figure 1. Simplified development phases of GEO-line based on SCRUM & ADDE (Avila-Pesantez et al., 2018)

A. Analysis

The GEO-line software concept was defined as an educational genre that obtains practical and constructivist learning skills in young men. In this phase, a preliminary study was conducted by meeting teachers and students to collect the desired functionalities. Then, the technical and economic resources were considered while analyzing and verifying the feasibility of implementing this project. Finally, the risks that could arise during the development process were identified to avoid later inconveniences.

B. Planning and estimation

As the next step, we established the functional user with access to the software and the T-Shirt estimation method. A schedule of activities was created with their respective subtasks, people involved in the project, and their roles. With all these elements defined, the product backlog was made, which contains all the requirements defined in the user stories and techniques for educational software. In the Sprint Backlog, the number of iterations for this project was detailed.

C. Implementation

The architecture design of the GEO-line software was created based on the user's needs. The client is intended to use the NEXTJS framework with server-side rendering technology to ensure a fast user experience. As shown in Figure 1, the client-server approach allows students to use the application through a web browser, while the source of responses to student requests will be the server. Finally, Strapi API CMS was used on the server-side to implement the model, view, controller (MVC) patterns needed, the REST architecture for communication, and the PostgreSQL database (see Figure 2).

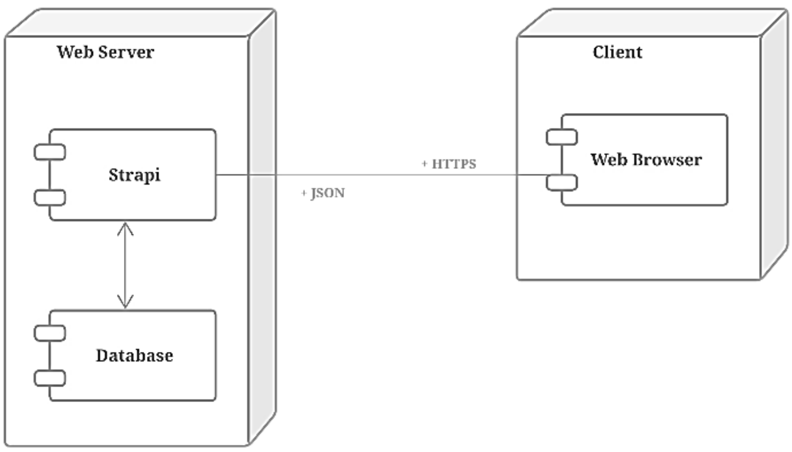

Figure 2. Educational software architecture

For the visual representation of the functionalities structure, Wireframes were used (see Figure 3), which guarantees compliance with the agreed purposes, focusing on the content's organization, function layout, navigation, and ease of use. After the designs were concluded, the educational software was encoded based on the product backlog, which had 24 user-stories and 5 technical-stories through 4 iterations of 2 weeks each one.

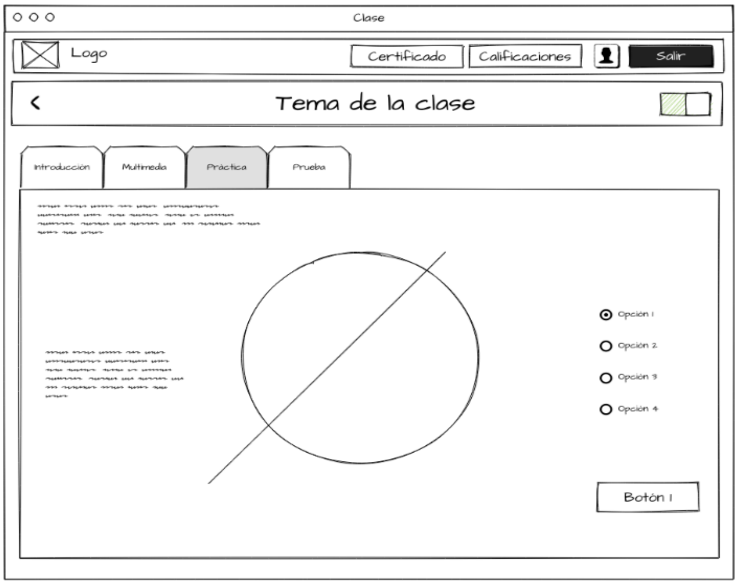

Figure 3. Class Screen Wireframe (Dynamic Geometry Educational)

D. Reviewing and releasing

In the last stage, functional tests were performed with teachers and students to verify the content's organization and presentation. During the evaluation process, the students received an introduction to the educational software (see Figure 4). A topic was selected to start a class demonstration, which began with the theoretical foundatiions' review and a tutorial video (see Figure 5 and 6). With the theoretical bases established, the interaction of the geometric model continued (see Figure 7) and ended with a learning evaluation with multiple-choice questions (see Figure 8).

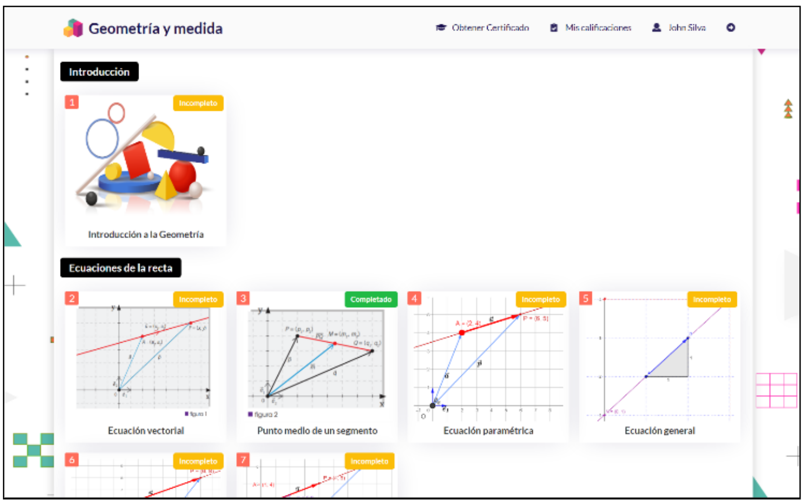

Figure 4. Screenshot of Homepage (List of classes)

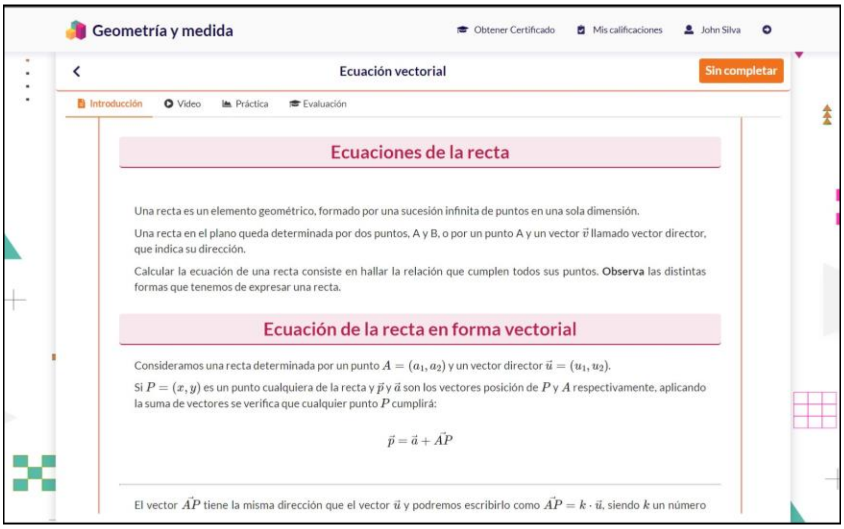

Figure 5. Theoretical foundations section

Method

Usability Assessment

An experiment was carried out to measure GEO-line's usability level (https://e-geometry-js.vercel.app/login), with the participation of 80 second-year high school students from 7 high schools in Riobamba – Ecuador, with a population sample between 15 and 16 years old (M=46 and F=34) with previous parents' permission granted to start up the experiment. Teenagers' participation was randomly established in each class for 6 weeks using online educational software, reviewing proposed Geometry content. In the seventh week, the Usability evaluation was carried out through 3 sub-characteristics (pedagogical ease, pedagogical ease, ease of use) based on the ISO 25000-SQuaRE standard.

Figure 6. Video tutorial on the topic

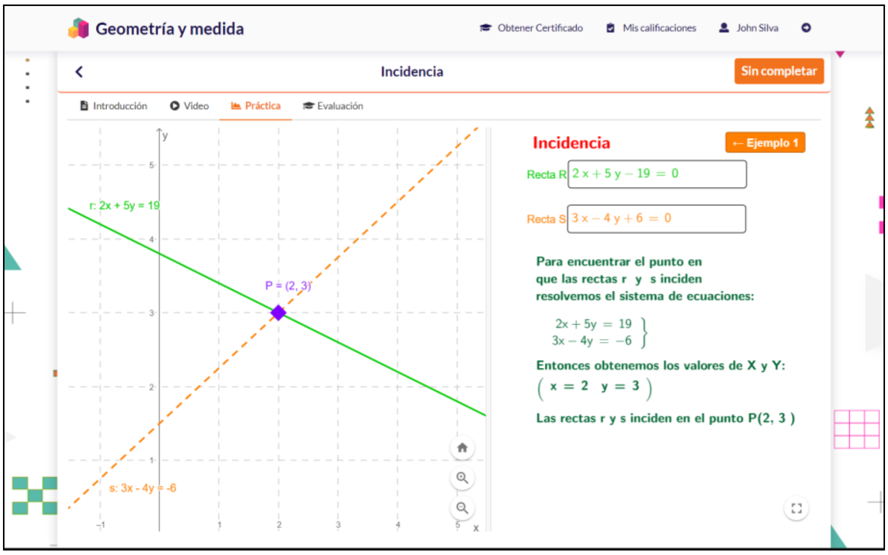

Figure 7. Interactive geometric model

For data collection, PSSUQ and USE questionnaires were adapted to determine the level of satisfaction concerning the educational software. A 5-point Likert qualitative scale was used for each question in the questionnaire (Strongly agree = 5, Agree = 4, Neither agree nor disagree = 3, Disagree = 2, Strongly disagree = 1).

Results

Table 1 presents the results for the sub-characteristic of easy pedagogical understanding. It is observed that question 3 has the highest score, highlighting the feedback on the learning process implemented in the educational software.

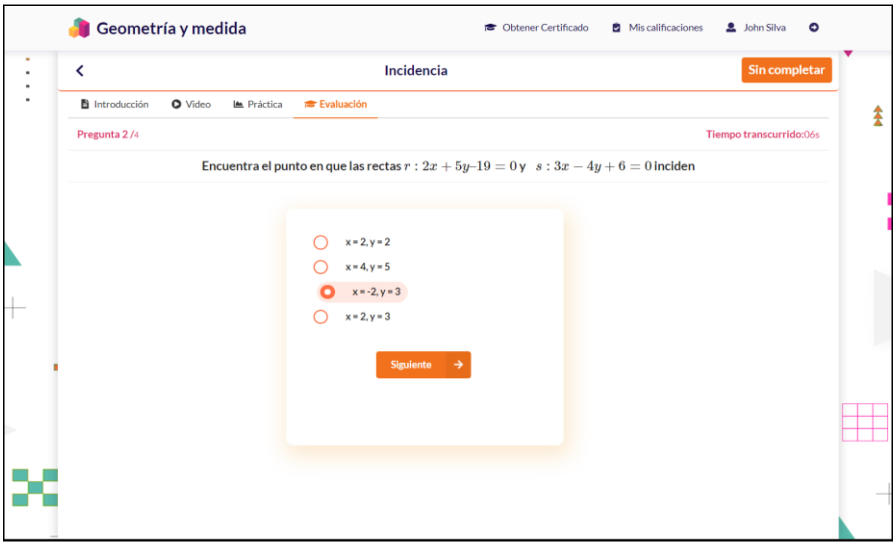

Figure 8. Learning assessment

About the sub-characteristic of ease of understanding or comprehensibility, it was established that interactivity, user interfaces, and a friendly environment allow students to reinforce their abilities to assimilate content through this new technological strategy (see Table 2).

Table 1. Pedagogical facility

Question	**Average over 5**
The information in the introduction and the video for each class is clear and easy to understand.	4.6
The evaluation of each class has questions according to the subject matter, and I can answer them without any problem.	4.3
At the end of the evaluation, I can check my correct or wrong answers, and the procedure or way to solve each question is explained.	4.7
Average	**4.51**

Table 2. Ease of comprehension or understanding

Question	**Average over 5**
The display of the classes is pleasant.	4.4
I enjoyed interacting with the interactive figures.	4.6
I had complications in accessing my grades screen.	4.3
The information in the introduction and video of each class is clear and easy to understand.	4.4
I could go back to where I was before by **watching** the different screens.	4.3
I would recommend this educational software to a friend	4.6
Global average	4.43

The results for the ease-of-use sub-characteristics are shown in Table 3. A general average of 4.45 is determined, highlighting the ease of interacting with the GEO-line. Percentage weightings were assigned for each evaluated subcategory to obtain the level of usability of the educational software (see Table 4), defined in the work of G. Quichimbo et al. (2021). Weights were then weighted to each subcategory, shown in Table 5.

Table 3. Ease of use or operability

Question	**Average over 5**
I had no errors while using the educational software.	4.4

If I made a mistake, I could go back and continue navigating.	4.2
A message was displayed after completing a class or updating my profile.	4.3
A message explaining the error was displayed when entering the wrong e-mail address to log in.	4.4
It is convenient to navigate from the "Introduction" section of the class to the "Test" section.	4.6
It is easy to interact with all educational software.	4.8
Global average	**4.45**

Table 4. Usability weighting

Subcharacteristic	Average	Percentage achieved	Weighting
Pedagogical facility	4.51	27.07%	30%
Ease of comprehension or understanding	4.43	35.44%	40%
Ease of use or operability	4.45	26.70%	30%
Total		**89.21%**	**100%**

Table 5. Quality level indicators

Measuring scale	Score	Satisfaction rate
87.5%-100%	Fulfills the requirements	Highly satisfactory
50 % - 87.4 %	Acceptable	Satisfactory
27.5% - 49%	Minimally acceptable	Unsatisfactory
0-27,4%	Unacceptable	

With these results, it is determined that the GEO-line educational software obtains a usability percentage of 89.21%, corresponding to a Highly Satisfactory level (see Figure 9).

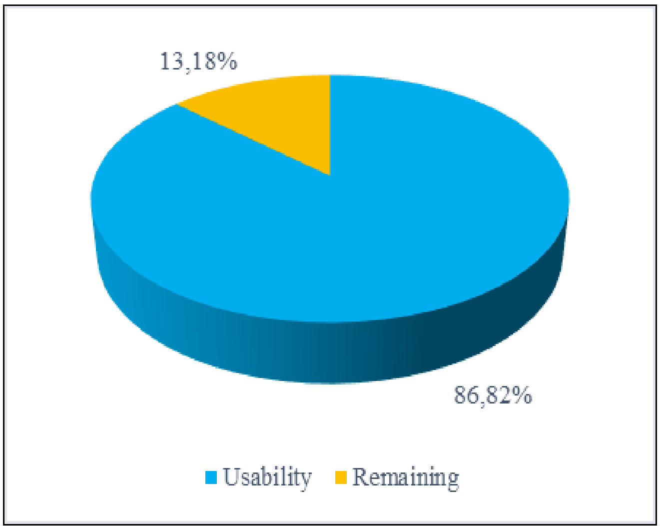

Figure 9. Usability level achieved

Conclusions

This study aimed to develop educational software that reinforces the learning of geometry and measures the level of usability for first-year high school students in the city of Riobamba. The project management was accomplished with the SCRUM methodology complemented with ADDE, which effectively allowed the users' requirements. The selected architecture was client-server, using NextJS technologies for the visual part and Strapi API CMS for content management in a straightforward and easy-to-understand way. Creating interactive geometric objects was done with GeoGebra components, which were imported into the corresponding curriculum. In the experimentation, through a descriptive analysis using the data collected from the questionnaire, a highly satisfactory level of usability of the educational software was determined using parameters such as pedagogical ease, ease of understanding, and ease of use. It demonstrates the academic reinforcement that GEO-line offers in the learning process of Geometry at the high school level.

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Development of a Decision Support System for Evaluating the Competencies of Educators

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Abstract: Higher education institutions should rely on the success of educators to deliver quality education in an increasingly economic context. The definition of the competencies necessary for an effective educator rest on top higher education management. Institutions of higher learning may also enhance cognitive abilities. The development of cognitive talents can be aided by qualified teaching abilities. Educators should have a thorough understanding of the subjects they are teaching. Educators should also have real-world experience to enhance the attraction of their teachings. The purpose of this study is to evaluate the abilities of educators using self-assessment tests and to identify any training needs by applying a survey to the educators. The Decision Support System was used to assess the testing procedure and establish the proficiency of the higher education instructors. Decisions were made regarding the necessity of more educational training. ECOEDSS tool was developed using HTML, PHP, JavaScript, and a MySQL database. The philosophy of competency, competencies management, and the DSS concept are all covered in this study. Additionally, ECOEDSS may support and foster educator self-development of skills.

Keywords: Assessment, Competencies, Decision Support System (DSS), Educators, Self-assessment,

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Introductıon

Information Technology (IT) has become one of the principal success drivers for any business enterprise. The function of IT was expanded to decision-making and strategy-building purposes. It will improve the company's use of the Management Information System (MIS) and Decision Support System (DSS). As in (Wahba,2010), (Manurung, 2019) notes that DSS will assist executives in extracting vital knowledge from big data as required. (Dulebohn, 2013) as (Wahba,2010) states that organisations need human resources with a different set of values and competencies,which should be productive, creative, responsive and adaptable to the fast-changing business environment. Hence, this paper discusses the DSS tool to evaluate competencies. (Mohd, 2018) state that the proper application of decision-making tools increases productivity, and efficiency and gives many advantages and benefits to the organisation. Competency-based training helps recognise the behaviours, information, skills, and abilities required to enhance the out- put of a successful learning process. Competencies will often support the learning by concentrating on key skills, providing guidelines for evaluating employee efficiency and capacities, providing a mechanism for defining learning options for the fulfilment of employee and organisational needs, encouraging efficient prediction of administrative activities and developing standards to assess how well learning has occurred. Some of the common benchmark competency-based practices are assessments against competencies.

The following scenarios are possible during this assessment: (1) Self-assessment: The norm for measuring the output of the employee is to evaluate each variable using a standardised rating scale based on the behavioural assessments for the skills and ability levels required within the target role. The accuracy and consistency of each person's self-evaluation are ensured by these behavioural examples. As a result of their increased self-awareness, their intrinsic motivation. The findings highlight the strengths and weaknesses of the employees' skills. An personalised learning plan is then encouraged to be carried out using this information. (2) 180-Degree Assessment: A 180-degree assessment expands on this by taking the employee-under-own appraisal's assessment into account. Before the performance review meeting with their upper management, the employee usually completes a self-evaluation form, evaluating themselves and offering input on how they feel about their performance. (3) 360-degree/multi-source: The technique of self-assessment is comparable to multi-source or 360-degree feedback, which includes multiple evaluators. The procedure must, at the very least, include the employee and his or her supervisor, and it may also include other people the employee interacts with on the job (International Atomic Energy Agency, 2016).

In order for educators to take charge and commit themselves to the support of a system of education, a transformation is necessary. It is significant because educators are the agents and implementers of the educational system and because education is fundamentally tied to demographics (Mohemad, 2018). Furthermore, they don't have techniques available, so how can the competency criteria be assessed? To incorporate the relevant knowledge of requirements at businesses into education, educators must have these approaches available and be proficient in them (Hanifatulqolbi, 2019). Even worse, due to a lack of resources, educators are unaware. Through the use of simulated teaching, observational recording, and checklist completion, the evaluation will ascertain whether the educator is competent (Prasetio, 2019). In order to evaluate educators' talents in higher education, traditional methods are also used (Yew, 2019). The form is still used, and the manual score measurement is still done using the rubric. Without taking into account their needs, the training was provided to meet KPI.

Decision Support System in Different Areas

DSS is implemented in a variety of fields, including forensics (Noor, 2019), agriculture (Rupnik, 2009), aquaculture (Doucette, 2009), medical (Rajoo, 2009), education (Mohemad, 2020), (Mohd, 2019), and sustainable development (González, 2013). For instance, AgroDSS (Rupnik, 2009) has been used in the agricultural industry. Data analysis was done using data mining to identify trends, distributions, and patterns that are hard to spot with the human eye (Mohd, 2019). Users may be able to comprehend the specifics, observe time shifts, and make future behaviour predictions with this tool. The main production usage of the AgroDSS will yield results based on the data provided without needless user intervention. Although AgroDSS employs data mining algorithms, these are approachable algorithms. Example data include phenomenon prediction, goal variable prediction, shift identification, seasonal analysis, and more. These data make it simple for farmers to conduct and comprehend the study (Rupnik, 2009). First Aid Decision Support System (FADSS) has been created in the medical industry to enable users to locate information about first aid instances that are available as an application tool. The FADSS uses data extraction, mathematical models, decision trees, and real-time knowledge measurement to produce a decision-making process. The major objective of the tools is to give individuals and junior staff members in First Aid Centers a useful tool for locating the information resources that are available (Ahmed, 2020).

The DSS for Environment Assessment of Marine Finfish Aquaculture was introduced in aquaculture. The goal of the Marine Finfish Aquaculture Decision Support System (MFADSS) is to enhance uniformity in the evaluation of environmental data included in marine finfish lease applications and to offer Habitat Managers systematic scientific guidance to assist them in making decisions. A lease application comes with most of the necessary information. The user enters the data into the MFADSS, which then returns results (Doucette, 2009). A DSS for Sustainable Tourism: Three municipalities close to Lake Garda have a plan for sustainable tourism that was developed using the SFIDA Project as a tool in the tourism industry. The DSS can be used to generate data and encourage involvement, making the decision visible, repeatable, and participative.

Several stages of the planning process are supported by the DSS's components, including the management of decision-maker disagreement, the definition of the plan method, the impact representation, the evaluation and comparison of the alternatives, and the management of the environmental and socioeconomic analyses (Laniado, 2004). There is a DSS for Construction Prequalification in the construction industry (Alias, 2011), (Noor, 2010). An expert/decision support system for contractor prequalification called CP-DSS is described in the study as a prototype. The approach starts by assessing contractors' competence in accordance with parameters particular to the project. The risk that might be brought on by contractors is then determined. Finally, contractors are evaluated based on their expected performance, managerial skills, available resources, forward movement, competitiveness, and activity. For prequalifying contractors, a three-level decision support has been developed (Ng, 1994).

Educators' Competency Dss Tools

To determine a teacher's proficiency, some DSS tools are employed. For instance, the DSS for best instructor performance utilising the Multi-Objective Optimisation approach based on Ratio Analysis (MOORA) method (Manurung, 2019). (Hanifatulqolbi, 2019). This research resulted in a web-based DSS that was used to assist decision-makers in choosing the best instructor performance. Since the results of the assessment serve as a benchmark for determining the incentive level and warning letter for instructors, it strives to promote and enhance the quality of their performance. A DSS is required to assist in choosing the best instructor performance in order to prevent making the incorrect choice. This programme used MOORA. It facilitates the swift and impartial selection of the top performing instructor for Islamic boarding schools (Prasetio, 2019). The abilities of their staff, choose the best applicants, and create efficient succession plans and employee development plans (Wahba,2010).

One of the examples of a method used to assess academicians' competencies is a Competency Mapping for Educational Institutions: Expert System Approach. The development of the expert system is intended to support competence management in the educational environment. An extensive assessment of the literature on competency management practises and interviews with competent deans and managers served as the basis for the knowledge acquisition for this expert system. Analysis of the competency management process is intended to diagnose it. The goal of the research is to develop an expert system for a competence-based management procedure that attempts to solve the majority of the issues with competency management and performance management (Joshi, 2020).

Key Performance Indicators Monitoring Tool (KPI-MT) was developed using Macromedia Dreamweaver. In contrast, PHP Hypertext Pre-processor (PHP) is used as a scripting language and MySQL as the database management system. DSS in the KPIMT system used a weighted sum method (WSM) to calculate the overall score of teachers and to determine whether the performance of teachers in a particular year was very good, good, fair, poor, or weak. With the KPI-MT system, 56 school principals can monitor teachers' performance from the first year of their service at schools (Samuri, 2016). With additional features on the KPI-MT prototype, such as the display of graphs and the ability to monitor the performance of teachers every year, it is seen that the prototype has the potential to replace the KPI system existing at the school to assist the school management, especially the principals, in assessing and monitoring teacher's performance efficiently (Noor, 2019).

Methodology

DSS help users who rely on knowledge to solve problems. DSS is designed to support not replace a decision-maker [33]. The decision support and expert systems have shifted from solely analytical tools for assessing the best decision options (Larsson, 2014). The typical DSS consists of three subsystems which are data management, model management and user interface. DSS is configured with four subsystems as Dialog Generation and Management System (DGMS), Database Management System (DBMS), Model Base Management System (MBMS) and Knowledge Base Management System (KBMS). A significant component of the DSS is the decision-maker, user and task. Thus,it can be concluded that such composition of the DSS is the most rational as shown in Figure 1.

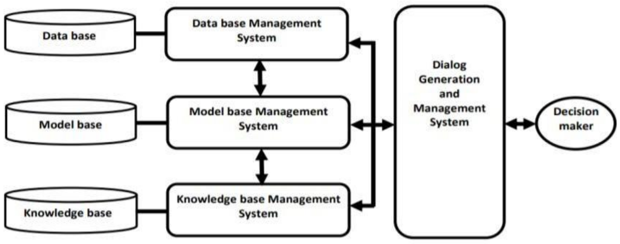

Figure 1. Standard DSS structure [(Noor, 2017), (Larsson, 2014)]

Figure 2 shows the model of the DSS for Evaluating Competencies of Educators in Higher Education (ECOEDSS). It involves four steps which are to determine the educators' competencies, competency testing, usability testing and training need analysis.

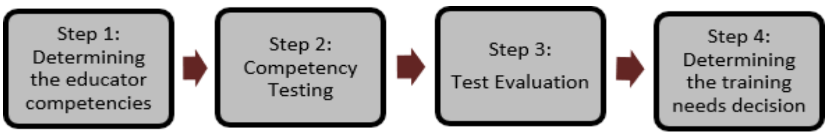

Figure 2. System Model

Step 1 : Determining the educator competencies. The competencies will focus on three components which are personal and social,pedagogy and teaching, and technical skills.

Step 2 : Employing the Likert Scale on CoA self-assessment test and the essential elements was used to implement competency testing.

Step 3 : Testing evaluation utilising the ECOEDSS user interface. The score and competency level will be displayed.

Step 4 : Deciding on the training requirements for educators. The ECOEDSS will activate the proper rules to create recommendations or solutions

The procedure starts when the educator engages with the user interface (UI). The educator is required to fill out information about his skills and activities during the service period based on three factors: personality and social, academic, and technical capabilities. The ECOEDSS User Interface (UI) will determine a ranking, show the competency level, and activate the appropriate standards for categorizing competency solutions or suggestions. The procedure is considered to be complete after the educator has acquired the required ratings, abilities, and recommendations, regardless of whether additional training is required.

Implementation

ECOEDSS interfaces have been developed using the Notepad++ platform, and many aspects need to be highlighted, including the selection of suitable colours and the use of user-friendly icons. The Hypertext Markup Language (HTML), JavaScript (.js), and PHP Hypertext Pre-processor (PHP) languages were used to create this framework. Additionally, the Cascading Style Sheet (CSS) was utilised to increase the interactivity of this tool. The primary interface for ECOEDSS is shown in Figure 4. Only if the data has previously been entered into the database are users able to log in. Users must input their username and password to access the next graphical user interface, which is a self-assessment form. In the event that an unauthorised user tries to log in, a warning box will appear. Only one ID may submit a response to this self-evaluation. A once-per-semester self-evaluation is conducted.

By selecting View Reporting as seen in Figure 3 and Figure 4, both the instructor and the supervisor can see the report. The report will display the Table and Overview (Score). The outcomes of the assessments can also be visualised graphically using Nine-Box and a number of charts. The overall assessments will be displayed in red, the supervisor assessment score in purple, and the educator assessment score in blue. On the y-axis, each assessment is displayed as a percentage. By referring to the competency measured on the x-axis, educators can view their top rating scores in line and bar charts on lines and bars. Educators can view their competency score patterns based on competency ratings in the radar chart. The pattern will let educators assess their degree of competency.

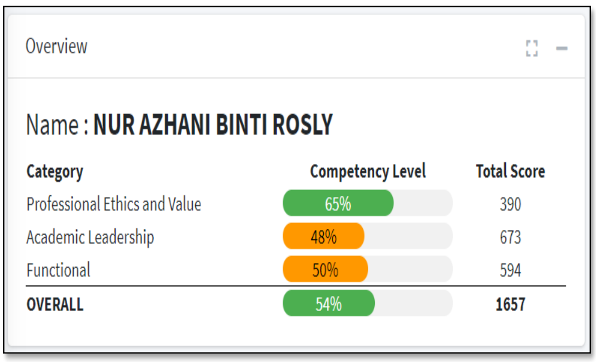

Figure 3. Score Overview

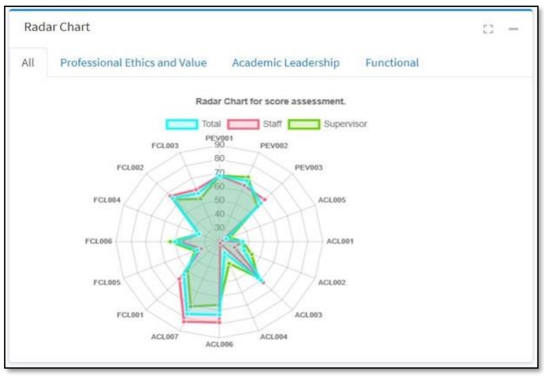

Figure 4. Radar Chart

Figure 5 shows the list of available competencies. The competency has three main categories which are Professional Ethics and Values, Academic Leadership and Functional. Each category, they have its competency. Professional Ethics and Value will measure Integrity (PEV001), Responsibility (PEV002) and University Awareness (PEV003). Academic Leadership will measure seven competencies which are People Development (ACL001), People Management (ACL002), Personal Development (ACL003), Stakeholder Management (ACL004), Community and Industry Relations (ACL005), Student Development (ACL006) and Student Relationship (ACL007). The functional category will measure the competency of Curriculum Development (FCL001), Transformative Assessment (FCL002), Transformative Delivery (FCL003), Teaching and Learning Research and Innovation(FCL004), Cyber Proficiency (FCL005) and Digital Technology (FCL006).

Table

#	Competency	Total Score
Professional Ethics and Value		
1	**PEV001** - Integrity	68%
2	**PEV002** - Responsibility	68%
3	**PEV003** - University Awareness	60%
Academic Leadership		
4	**ACL005** - Community and Industry Relations	25%
5	**ACL001** - People Development	36%
6	**ACL002** - People Management	38%
7	**ACL003** - Personal Development	60%
8	**ACL004** - Stakeholder Management	29%
9	**ACL006** - Student Development	73%
10	**ACL007** - Student Relationship	77%
Functional		
11	**FCL001** - Curriculum Development	54%
12	**FCL005** - Cyber Proficiency	36%
13	**FCL006** - Digital Technology	50%
14	**FCL004** - Teaching and Learning Research and Innovation	35%
15	**FCL002** - Transformative Assessment	65%
16	**FCL003** - Transformative Delivery	58%

NOVICE (0 - 25) QUALIFIED (26 - 50) PROFICIENT (51 - 75) EXPERT (76 - 100)

Figure 5. Total Score Table

The Nine-Box is focused on potential vs performance, and each box has its own scale and indications (Figure 6). The indicators in Nine Box are displayed with a variety of scales on the x-y axis. The scale's range is as follows:

Poor Performance Limited Potential (1-33, 1-34)\
Poor Performance Moderate Potential (1-33, 35-67)
Poor Performance High Potential (1-33, 68 -100)
Good Performance Limited Potential (34-66, 1-34)
Good Performance Moderate Potential (34-66, 35-67)

Good Performance High Potential (34-66, 68 -100)

Outstanding Performance Limited Potential (67-100, 1-34

Outstanding Performance Moderate Potential (67-100, 35-67)

Outstanding Performance High Potential (67- 100, 68-100).

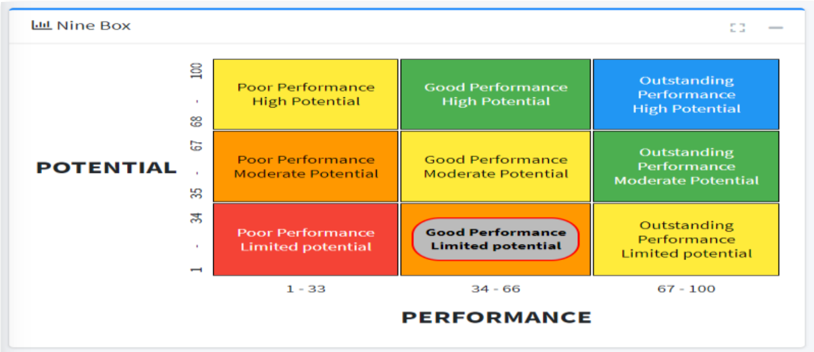

Figure 6. The Nine-Box

As a result, the framework created to gauge the competency level of educators has been successfully implemented. The evaluation of competencies using the CBTM4EDUCATORS can produce various results depending on the conceptual framework used. Based on the competency gap and the results of the system evaluation, management will release training development plans. This enables management to assign educators the proper duties depending on their competencies and training requirements. The first step in establishing the kind of training required is to evaluate an educator's strengths and weaknesses. Competency gaps in competency assessments also give information on development initiatives, which is useful for both businesses and educators.

Conclussion

The discussion led to the development of a framework that satisfies all objectives. The environment of this study is centred on higher-level educators. The section of this study that is mentioned attempts to serve as a blueprint for creating effective educators. The abilities can be applied to hiring staff, creating curriculum for educators' re- and up-skilling programmes, and generating curriculum for educators. To succeed, higher education institutions need hire high-potential individuals. In addition, the framework needs to ensure they undergo training and development needed to identify their potential and suggest improvements. The ECOEDSS was shown to be a more effective method than the conventional one for evaluating the abilities that educators must possess and for developing a training plan to increase those skills.

These abilities will enable educators to adapt and adhere to best practises to suit societal expectations, effectively aiding in the economic development of the nation. It tries to pinpoint the fundamental skills teachers need to possess in order to fully prepare their learners for the transfer to the workplace. Therefore, if effectively implemented, these abilities would guarantee that educators are given the proper training and, as a result, give their learners a smooth transition from the institution to finding employment. There are some restrictions on meeting the predetermined targets. In this system, only self-assessment techniques were employed, and top management was only able to monitor the reported outcome. There are several suggestions that can be made to enhance the usability of the ECOEDSS features, including the user level.

Acknowledgment

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A Review on Teaching and Learning in Decision-Making Post-Pandemic COVID-19

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Abstract: Universities around the globe have begun implementing outcome-based learning (OBE). The curriculum will be revised, evaluated, and the outcomes of the assessments will be reported as part of this OBE implementation. Due to the importance of the evaluation method, several lecturers are searching for innovative approaches for assessing the effectiveness of the Program Learning Outcome (PLO) and Course Learning Outcome (CLO). This study examined outcome-based education for decision-making instruction and learning in the context of the COVID-19 pandemic. This pandemic has effects on the healthcare industry, such as the exhaustion of the healthcare system, disruption of the educational system, and harm to the economy and several other industries. E-learning platforms played a crucial role in helping schools and universities throughout the pandemic by allowing student learning while they were closed. There is a larger need for lifelong learning as a result of the rising need for qualified professionals in education. On the other hand, current trends favour the paradigms of social and practice-based learning. As a result of digitization, our methods of communication and education are changing. The teaching and learning that took place during COVID-19 had a substantial impact on outcome-based learning. We find it fascinating to show how COVID-19 affects outcome-based education (OBE) in a risk decision support system.

Keywords: COVID-19, DSS, Education, OBE, Teaching and Learning

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Introduction

A final demonstration of learning is called an outcome, and it is what a student should be able to do upon completion of a course (Spady, 1994).Outcome-based education is a method of teaching in which curricular decisions are based on the learning goals that students should demonstrate after the course. "Product defines procedure in outcome-based education" (Harden et al., 1999). The opposite of input-based education, where the emphasis is on the educational process and we are willing to accept whatever the outcome is, is outcome-based education, which can be summarized as results-oriented thinking (emphasis original). The gap between outcome-based education and simply providing results for a pre-existing curriculum is enormous. "Outcome-based" does not mean "curriculum-based with outcomes sprinkled on top" (Spady, 1994). It is a revolutionary method of conducting business in the field of education.

As of March 3, 2022, the World Health Organization (WHO) reports that the Corona Virus Disease (COVID-19) has spread to 180 countries, infected 438,968,263 individuals, and killed 5,969,439 people (World Health Organization, 2022). This pandemic has ramifications in the health sector, including depletion of the healthcare system, disruption of education, commercial and economic harm, and a variety of other businesses. Governments around the world have established policies such as lockdowns, social distance, and psychical distancing to ensure that citizens avoid direct physical contact as much as possible to restrict the spread of COVID-19. It is in their best interests for them to continue their activities, such as in the field of education. As a result, demonstrating COVID-19's impact on Outcome-based Education (OBE) in a Risk Decision Support System is exciting to us. This article discussed a review of teaching and learning in Decision Making-Post Pandemic COVID-19

Teaching and Learning

In reaction to the COVID-19 epidemic, the majority of countries have implemented lockdown and social segregation measures, which have resulted in the closure of schools, training centres, and higher education institutions. A paradigm shift has occurred as educators now provide high-quality instruction through a variety of online platforms. Online learning, distance learning, and continuing education have all shown to be effective treatments for this unprecedented global pandemic, despite the challenges that both educators and students encounter. Transitioning from traditional face-to-face learning to online learning can be a completely different experience, which they must adjust to because there are few or no other options. Through numerous internet platforms, the school system and educators have adopted "Education in Emergency," and are obliged to adopt a system for which they are unprepared (Pokhrel & Chhetri, 2021).

During the pandemic, e-learning tools were critical in assisting schools and universities in facilitating student learning during the shutdown of universities and schools (Subedi et al., 2020). Staff and student readiness must be assessed and supported while adapting to the new adjustments. Learners with a fixed mindset have a hard time adapting and adjusting, but learners with a growth mindset adapt easily to new situations. For online learning, there is no one-size-fits-all methodology. There is a range of subjects to choose from, each with its own set of requirements. Various disciplines and age groups necessitate various ways of online learning (Doucet et al., 2022). Physically challenged students can also benefit from online learning because it allows them to participate in learning in a virtual environment with limited movement (Basilaia & Kvavadze, 2020; Pokhrel & Chhetri, 2021).

Students, parents, and educators around the world have felt the unanticipated rippling impact of the COVID-19 epidemic as schools have been closed to deal with the global pandemic. While governments, frontline workers, and health officials do their utmost to contain the spread, educational systems strive to provide high-quality education to all students during these tough times. Many students have experienced psychological and emotional hardship at home/living environments and have been unable to interact successfully. The greatest online home-schooling techniques have yet to be discovered (Pokhrel & Chhetri, 2021).

The skills and exposure to information and communications technology (ICT) for both educators and learners may influence the implementation of appropriate online education. Unified communication and collaboration platforms like Microsoft Teams, Google Classroom, Canvas, and Blackboard have been used thus far to allow teachers to design educational courses, training, and skill development programmes (Bozkurt et al., 2020). They contain features such as workplace chat, video meetings, and file storage, all of which help to keep classes organised and productive. They usually let you share a wide range of files, including Word, PDF, Excel, audio, and video. Quizzes and rubric-based assessments of submitted assignments make it possible to track student learning and assessment. The flipped classroom is a simple approach for presenting learning resources before class, such as articles, pre-recorded films, and YouTube links. The time spent in the online classroom is then used to further comprehension by engaging in discussions with teachers and peers (Doucet et al., 2022). This is an extremely successful technique to promote problem-solving, critical thinking and self-directed learning skills. Videoconferencing (Google Hangouts Meet, Zoom, Slack, Cisco, WebEx) and configurable cloud-based learning management platforms such as Elias, Moodle, BigBlueButton, and Skype are becoming more popular in virtual classrooms (Pokhrel & Chhetri, 2021).

Outcome-Based Learning

Spady proposed Outcome-Based Education (OBE) as a way to ensure excellence in the American education system in the early 1990s (Spady, 1994). OBE was eventually expanded to include higher education as well. 'OBE means centring and arranging an institute's entire programmes and instructional activities around the specified objectives we want all students to achieve when they leave the institute,' according to the system's proponent (Rao, 2020; Spady, 1994). OBE is a method of education that prioritises goals, objectives, successes, and outcomes. It is a practical approach to quality assurance that is used around the world today, in which decisions concerning curriculum and instruction are based on the exit learning outcomes that students should demonstrate at the end of a programme or course (Rao, 2020). Intended Learning Outcomes, Instructional Objectives, Educational Objectives, Behavioural Objectives, Performance Objectives, Terminal Objectives, Subordinate Skills, Subordinate Objectives, General Instructional Objectives, Specific Learning Outcomes, and Competencies are some of the terms used to describe learning outcomes. What a student should be able to do after completing an academic program/course/instructional unit is referred to as an educational outcome. The explicitness in its relevance, the possibility of discourse, intrinsic clarity, accountability, self-directedness, flexibility, and an integrated framework of teaching and learning, as well as assessment, are some of the key advantages of OBE (Davis & Winch, 2015; Rao, 2020). OBE accommodates a variety of learning methods and allows for educational innovation.

Digital Learning

Future manufacturing systems, particularly in the educational sector, will be intelligent, continuously evolving and improving, highly adaptable to shifting environmental conditions, resource-efficient, and creatively combining human and technological systems. Resource efficiency was boosted by adaptability to changing environments, and intelligent human-technology interaction. This progress is aided by recent technology advancements in sensor systems, automation, and manufacturing ICT. This movement is referred to as the fourth industrial revolution, and the term "Industry 4.0" is widely used to characterise it. Flexible Automation, Wireless Sensor Systems, Cyber-Physical Systems, Artificial Intelligence, (Big) Data Analysis, and the Internet of Things form the foundation (Tvenge & Martinsen, 2018). Manufacturing workplaces are shifting toward less manual work and more "brain" work due to Cyber-Physical Manufacturing Systems. Future manufacturing workers will need to be able to analyse, abstract, and invent, and knowledge levels are increasing in general. The growing demand for a skilled workforce has accelerated the need for lifelong learning. Traditional social/practice-based learning paradigms, on the other hand, are being challenged by contemporary trends. The rise of digitalisation will alter the way we communicate and learn (Tvenge & Martinsen, 2018). Individuals work and learn together in teams or Apprentice-Systems in conventional social learning systems in the industry.
Communities of Practice (COP), as articulated by Lave and Wenger (Lave & Wenger, 1991), provide "a sense of belonging, commitment, and shared identity" (Brown & Duguid, 1991; Cataldo, 2009; Wenger et al., 2002) as well as a mechanism for employees to learn from one another. Due to increasingly specialised work and fewer individuals doing the same type of work in Industry 4.0, this manner of learning appears to be challenged. New work structures emerge as a result of fewer individuals and more physical distance between them. This necessitates the development of novel learning methods, such as supervision, guiding, and collaborative learning, which can be synchronous or asynchronous and mediated through ICT tools. ICT tools enable the development of new learning approaches across the spectrum, from lifelong learning to students on campus. From more or less crude e-learning schemes to complex serious games (Pourabdollahian et al., 2012), the utilisation of current ICT opens up new possibilities for on-the-job, personalised workplace learning.

ICT has a natural role in Industry 4.0 education and knowledge development, and there are a variety of expectations for the consequences of ICT-supported lifelong learning (Pouezevara et al., 2014): As a result of having more data and knowledge, there has been an increase in learning, more effective education, learning activities that are centred on the student, innovative learning spaces that foster greater collaboration and cooperation and a greater number of opportunities for critical thinking and analytical methods. However, current implementations of ICT-assisted learning paradigms have not always met the expectations of the participants (Kinchin, 2012). One cause could be the disconnect between formal ICT-supported learning and workplace practice-based learning. Formal learning is currently only a modest part of workplace learning, with informal learning accounting for around 80% of all learning (Cross, 2010). According to research, ICT-assisted learning will not render teachers obsolete. ICT can help to improve the effectiveness and efficiency of learning processes, but only with the right support. Learning activities including social interactions facilitated by a teacher have had the largest influence on learning outcomes, far outnumbering other approaches (Mincu, 2015).

More and more authors are emphasising the fact that ICT-based learning has evolved from being closed off and centred around individuals to being social and requiring sharing: the learner's needs, not the technology itself, are at the centre (Tvenge et al., 2016). However, there is still a need for social and practical training, and technology is just one of many instruments that can help students learn more effectively and expand their learning area (Prinz et al., 2016). Employers value collaboration skills, thus teamwork and communication must be fostered in future workplace learning paradigms. A rising variety of social networks, as well as another web 2.0 and web 3.0 services, can be utilised for flexible and informal learning, as well as providing access to experts and peers. This is also known as the semantic web, and it allows future Industry 4.0 learning to share a limitless number of multi-medial learning resources. Workers can personalise their learning environments (PLEs) based on their interests, learning styles, and goals. For the individual learner, this is both an opportunity and a struggle. SMEs must rely on more or less ready-made solutions (Paulsen, 2009). Large corporations can create internal personal learning environments; SMEs must rely on more or less ready-made solutions to reduce risks. Open educational resources (OER) are papers and media materials that are publicly available for use in teaching, learning, education, evaluation, and research. Implementation risk and impact risk are the two categories of risk we take into consideration when conducting the research. The estimated investment in the digital learning platform may differ from the initial or anticipated requirements, resulting in higher expenses than anticipated. This is the implementation risk. The impact risk, on the other hand, refers to circumstances in which investments in digital learning may fail to meet the commercial or technological requirements of the organisation, leading to a reduction in overall benefits.

Risk Decision Support System Management

A management system is made up of a number of information gathering and decision-making processes, therefore expanding information gathering and enhancing decision-making procedures are both necessary for management to be improved. Prior to deployment in an IT platform, the risk associated with the process should be recognised and identified during analytical workshops. A list of risks, along with their triggers—situations that suggest the risk has already occurred or will do so soon—should be the end result of the identification and categorization process. For example, the risk of changing requirements in a business process might be indicated by information about adjustments to the decisions necessary for later time-consuming procedural steps. Learning about all relationships and mechanisms, as well as making decisions regarding their direction and outcomes, is extremely important for effective management of business processes. It necessitates the use of tools that make it possible to clearly and completely identify all process components as well as the connections that exist between them.

Risk management is identifying any potential threats that may arise during the speculative process and taking all reasonable steps to eliminate or mitigate those concerns (Yuliantini et al., 2019). Risk management is the process of identifying, assessing, and prioritising threats, followed by the efficient and effective use of resources to restrict, screen, and control the likelihood or impact of disastrous events, or to increase the recognition of risks. Every company and organisation is vulnerable to unforeseen, dangerous events that can cost them money or force them to shut down permanently. Risk management enables businesses to prepare for the unexpected by lowering risks and additional costs before they occur. An organisation can save money and protect its future benefits by implementing a risk management plan and considering the various potential threats or events before they occur (Yuliantini et al., 2019). A risk assessment is simply a cautious examination of what, in the workplace, may cause harm to individuals or the organisation when completed to determine whether enough insurance has been taken or whether more should be done to ensure that no one is injured, becomes ill, or the trust is jeopardised. The goal of risk assessment is to provide a precise and systematic tool for identifying a wide range of risks associated with defiance of the law, clinical dangers, key, and budgetary obligations, and evacuating them where possible or receiving all control and precautionary measures that are reasonable and practicable in the circumstances (Yuliantini et al., 2019).

Every decision-making process always includes the risk, which is most frequently related to the issue of task implementation. Business decisions and related processes play a crucial role in how any institution runs. In the context of business operations, they determine the company's competitiveness, set the pace of activity, or rationalise the core function of a particular entity. That comprises risk assessment for delivery activity, resource investigation, risk performance, risk management in part, and evaluation of risk in terms of financial aspect. The DSS system will offer a range of options that will aid in decision-making while preparing risk management in a management environment for higher education institutions. Additionally, this method offers a number of possibilities for any estimation at the level of top management that takes the educators' risk into account. It is anticipated that the opportunity for risk and the impact of risk on the educational system can be reduced by employing this DSS concepts.

Conclusion

The need for lifelong learning has grown in response to the increased need for qualified and quality talents.

Conversely, contemporary trends are putting traditional social/practice-based learning paradigms to the test. Digitalisation is changing how we communicate and learn. Teaching and learning during COVID-19 give a huge impact on outcome-based of learning. In future work, we will propose a new model of risk decision support system which will give impact outcome-based learning which focuses on Program Learning Outcomes and Course Learning Outcomes. Our DSS aims continue providing administrative support towards planning the educational capacity of the university in terms of the number of students each course might accommodate within in the stated resource constraints. By simulating with the input data, decision-makers can evaluate various strategies and generate forecasts. We choose to emphasize on the teaching staff as the primary bottle-neck resource and the online platform of the educational capacity in order to keep the model simple, clear, and avoid functional explosion. Experience has shown that compared to other resources like buildings, budget, appliances, and materials, staff availability and teaching approach are by far the most important resource restriction. It's also the most expensive and least flexible in the near term.

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Using Problem-Based Learning Approach to Facilitate Learning of Science

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Abstract: This paper illustrates the integration of the hybrid Problem-Based Learning (PBL) approach in the development of the prototype C²HADAM, a multimedia courseware that is intended for the teaching and learning of the Science subject for form two students in Malaysian secondary schools. The discussion begins with the Constructivist theory and conceptual frameworks underlying C²HADAM. The learning concepts of inquiry learning, contextual education, simulation, exploratory learning, self-directed learning, and student-centered learning are also incorporated into C²HADAM. Next, this paper details the development of the project using a popular development life cycle namely ADDIE. ADDIE life cycle consists of the analysis, design, development, implementation, and evaluation phases. This paper also highlights some of the screen snapshots taken from C²HADAM prototype. The final part of this paper presents some of the findings from the Effectiveness construct. The results show positive feedback on the use of the courseware, and the courseware proves to enhance learners' performance. The integration of the PBL principles in the development of the courseware, thus, promises more of its application in the teaching and learning of other scientific disciplines.

Keywords: Problem based learning, Science, Constructivism

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Introduction

This paper discusses the design and development of a multimedia courseware package, namely C^2HADAM, for the teaching and learning of the Science subject, particularly on the topic of Nutrition. The whole development of the package is using Problem Based Learning (PBL) approach. The PBL approach, which is gaining popularity nowadays, is viewed as a new paradigm shift in the teaching and learning process. Concurrently, the robust growth of the Internet and multimedia technology has acted as the catalyst for the development of the education system in our country. The use of ICT allows the learners to be exposed to various learning environments and authentic hands-on learning experiences (Zumbach et al. 2006). This paper begins with a discussion of Constructivist learning theory adopted in the development of the C^2HADAM multimedia package. The second section of the paper deals with all five working phases involved in developing the package. Following this is the third section, which presents the module and some screenshots taken from the courseware. The fourth section, also the last section of the paper, discusses the findings from a case study conducted with a number of selected schools.

Theoretical Framework of C^2HADAM

This paper elaborates on the design and structure of C^2HADAM, developed based on the hybrid PBL approach, which evolves from Constructivist learning theory. According to Reigeluth (1999), there have been numerous learning techniques adopting the Constructivism Theory model, such as the project-based approach, situational learning, cooperative learning, and PBL. Nevertheless, Savery and Duffy (1995), and Jonassen (1999), declare that out of all these learning techniques, the PBL approach is regarded as a true manifestation of the Constructivism Learning model. For this reason, the PBL approach has been determined as the learning approach adopted in this attempt of developing multimedia courseware. The constructivist learning approach promotes learning strategies such as exploratory, experiments, and problem-solving, which prove to be effective in the teaching and learning of the science domain (Neale & Smith 1990; Su 2008).

According to Bonk dan Wisher (2000), some learning features of the constructivism model are as follows:

(i) Meaningful learning takes place with regard to learners' past experiences and current knowledge
(ii) Interpretation of meaning is personalized and depends on the learner's background
(iii) Learning is a dynamic process, where experiences are transformed into knowledge and skills.
(iv) Assessments are integrated into every task.

According to Kolmos and Graaff (2007), and Mohd Ali et al. (2007), the PBL methodology is receiving more attention as a teaching and learning strategy, especially for global education. Savery and Duffy (1995), and Gulsecen and Kubat (2006) assert that PBL is defined based on the constructivism principles, which comprise three important aspects:

(i) Learners build up their understanding from their interaction with their surroundings
(ii) Cognitive conflicts serve as a stimulus in a learning process.
(iii) Knowledge is gathered from social interaction and an individual's motivation level.

Barrows and Tamblyn (1980) define PBL as learning activities that take place as a result of working out or solving a problem. In addition, Liu (2005) asserts that PBL is a learning process that presents the learners with sets of problems, which they have to work out critically and creatively. The situations or problems presented should emulate authentic scenarios. This feature makes up the most important component of the PBL approach. The situations are constructed to cater to the intended learning outcomes and required skills (Kearsley & Shneiderman 1999; Tse & Chan 2003). Identifying a problem is the first move in the learning process; thus, learners are introduced to real problems at the early stage of their learning course (Duch et al. 2001; He et al. 2002). The problems, in consequence, will prompt the learners to focus on the application of their problem-solving skills, logical thinking, and knowledge to resolve the problems. These sets of problems also serve as the appetizer to the whole learning topics (Scot et al. 2007).

The C^{2}HADAM Multimedia Prototype

The C^{2}HADAM multimedia prototype is designed based on ADDIE Model stand for analysis, design, development, implementation, and evaluation. This model takes into account various aspects of development: (i) the analysis of PBL teaching and learning methodology; (ii) the design of learning outcomes that suit the ID model and C^{2}HADAM multimedia courseware modules; (iii) the preparation of teaching plan inventory; and (iv) the implementation of assessment and improvement of the system based on the Life Cycle Model of C^{2}HADAM (KH C^{2}HADAM). The C^{2}HADAM multimedia prototype include PBL features, learning activities, ID model construction, courseware modules development, teaching content inventory. There are six (6) modules available as follows:

- The Introduction Module

This module is divided into four submodules - montage, about PBL, about C^{2}HADAM, and users' registration. The Introduction module provides a brief explanation of the C^{2}HADAM courseware, which is developed based on the PBL approach. The montage is created to gauge the attention of its users.

- The Scenario Module

This module consists of several problem-based scenarios on topics related to digestion. It serves as a trigger to the learning and problem-solving process. The module is developed based on the concept of the Contructivist Approach, which reflects real-life scenarios. The scenarios require the learners to take a role of a dietician in a private health center, who is responsible to handle issues of an imbalanced diet. Student need to record the results in the learning journal available in the courseware, to be shared with and viewed by other learners.

- The Teacher Module

This module consists of three submodules: learning outcomes, explanations and examples, and exercises. The contents of this module are derived from a few Science reference books (Choo & Low 2003; Deve et al. 2006; Tee 2006; Yeap & Sopia 2006) and a book titled “Panduan Diet Malaysia” (Jawatankuasa Penyelaras Makanan dan Pemakanan Kebangsaan, Kementerian Kesihatan Malaysia 1999). The submodule Learning Outcomes provides the introduction to all the subtopics with the expected learning outcomes; among the topics are Food Classification, Digestion Process, and Balanced Diet. This is an outstanding feature of PBL because the knowledge gained can be activated before the learning topics are presented. Explanations provided are prepared as scaffolding to facilitate the learners’ understanding of the topics discussed. The use of the 3D animation technique is also integrated into this module, for instance, the use of the animation to describe a normal digestion process versus one with a problem to enhance learners’ comprehension.

- The Test Module

This module includes several sets of sample examinations questions aims to guide the learners with the questions and answers. The questions are constructed with the assistance of teachers who have been teaching the Science topics for Form Two, and also with reference to Science revision books recommended by the school administration (Ooi 2004; Ooi et al. 2004; Hasroni & Daisy 2006). This Test module supplies a few sets of question forms including MCQs, labeling, and fill-in-the-gaps.

- The Problem Solving Module

This module is designed to display explanation and problem-solving exercises aimed to reinforce learning. Several sets of scenarios are prepared for the learners to solve. The learners need to work in groups of 6-7 to finish the tasks. The purpose of this module is to provide drilling practices to boost learners’ competence, as well as their problem-solving skills; thus, aiding them to structure their thoughts systematically.

- The Exploration Module

The learners are given the option to access the websites to search for topics related to nutrition and to use the email facilities and online forums to exchange ideas on the topics. There is also a component named Ask the Experts, which features questions on topics related to nutrition, especially on the process of digestion. Learners may select the ‘expert’ and ask questions.

Method

This section presents the method and results from the evaluation on the effectiveness construct of the courseware application. The results are gathered from a study case with 64 Form Two students from Secondary School Seksyen 24 (2), Shah Alam, Selangor, Malaysia. The evaluation on the effectiveness construct of the C^{2}HADAM courseware application is conducted based on the following research questions:

Q1 Does the use of the C^{2}HADAM multimedia package, with the Hybrid PBL approach, enhance the performance of the Form Two students in comparison with the conventional teaching and learning methodology on the same topic Nutrition?

(a) Pre and Post Tests

This issue was addressed with the quasi-experiment method carried out on two groups of Form Two students: the Experiment Group (X1), who received the treatment by using the C^{2}HADAM multimedia package based on the Hybrid PBL approach, and the Control Group (X2), who received the conventional teaching and learning methodology on the same topic. To measure the performance in terms of the pre and post-tests scores between the two respondent groups, the Experiment Group (X1) and the Control Group (X2), the Dependant T-Test was applied.

Table 1. Demographıc Dıstrıbutıon Of Samples

Group	Girls	Boys	Total
Experiment (X_1)	16	18	34
Controlled (X_2)	16	14	30
Total	**32**	**32**	**64**

The measurement adopted to assess the effectiveness construct of the courseware is from the scores of pre and post-tests taken by both groups on the topic of Nutrition. The students from the Experiment Group (X1) were exposed to teaching using the courseware, and they are labeled with the letter E, followed by the numbers 1 – 34; on the other hand, the Control Group (X2) was taught using the conventional method, and are labeled with the letter K, followed by the numbers 1-30.

Table 2 shows the average scores from the pre and post-tests, together with the improvement scores, for the Experiment Group (X1). Likewise, Table 3 shows the scores for the Control Group (X2). From both tables, there are improvements in the student's performance on the topic of Nutrition for both groups. However, the improvement for the group using the C^{2}HADAM multimedia package is higher than the group using the conventional method. The Experiment Group (X1) had an increase of 28.60%, while the Control Group (X2) 14.75%.

Table 2. Pre And Post Test Scores For Experımental Group (X1)

Students	Pre Test Scores (%)	Post Test Scores (%)	Improvements (%)
E1	27.5	60	32.5
E2	27.5	37.5	10
E3	25	62.5	37.5
E4	35	60	25
E5	55	95	40
E6	35	50	15
E7	30	40	10
E8	32.5	65	32.5
E9	25	52.5	27.5
E10	32.5	55	22.5
E11	30	80	50
E12	30	65	35
E13	20	35	15
E14	35	50	15
E15	30	65	35
E16	15	50	35
E17	20	50	30
E18	25	80	55
E19	35	50	15
E20	25	37.5	12.5
E21	22.5	30	7.5
E22	27.5	50	22.5
E23	37.5	50	12.5
E24	32.5	40	7.5
E25	52.5	70	17.5
E26	30	70	40
E27	30	65	35
E28	30	80	50
E29	22.5	75	52.5
E30	20	45	25
E31	15	55	40
E32	27.5	65	37.5
E33	0	37.5	37.5
E34	0	37.5	37.5
Average	**27.6**	**56.176**	**28.602**

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Table 3. Pre And Post Test Scores For Control Group (X2)

Students	Pre Test Scores (%)	Post Test Scores (%)	Improvements (%)
K1	30	32.5	2.5
K2	32.5	32.5	0
K3	30	35	5
K4	27.5	32.5	5
K5	25	30	5
K6	17.5	17.5	0
K7	27.5	35	7.5
K8	45	67.5	22.5
K9	40	67.5	27.5
K10	37.5	67.5	30
K11	30	62.5	32.5
K12	35	62.5	27.5
K13	37.5	70	32.5
K14	35	70	35

K15	32.5	50	17.5
K16	45	47.5	2.5
K17	27.5	30	2.5
K18	17.5	20	2.5
K19	22.5	30	7.5
K20	15	32.5	17.5
K21	20	27.5	7.5
K22	27.5	45	17.5
K23	30	45	15
K24	22.5	37.5	15
K25	35	40	5
K26	35	60	25
K27	27.5	45	17.5
K28	32.5	50	17.5
K29	20	35	15
K30	35	60	25
Average	**29.8**	**42.6**	**12.8**

Results Discussion

Tables 2 and 3 show that the average score in the pre-test for the Experiment Group (X1) is 27.6%, and the Control Group (X2) is 29.8%. Therefore, the difference in the pre-test scores between both groups is 2.2%. On the same tables, the average score in the post-test for the Experiment Group (X1) is comparatively higher at 56.17%, than the Control Group (X2) at 42.6%. Thus, the difference in the post-test scores between both groups is 13.58%

The analysis from both tables also reveals that there is a difference in the lowest pre-test scores for both groups of respondents. The lowest pre-test score from the Experiment Group (X1) is 0%, while the Control Group (X2) is 15%. Meanwhile, the highest pre-test score from the Experiment Group (X1) is 55%, and from the Control Group (X2) is 45%. Yet, the analysis brings to light another finding that the lowest post-test score for the students of the Experiment Group (X1) is 30%, and for the students of the Control Group (X2) is 17.5%. The highest post-test score for the Experiment Group (X1) is higher, which is 95%, than the highest post-test score for the Control Group (X2), which is 70%.

The passing mark for the tests was set at 40%. The analysis shows that the students from the Experiment Group (X1) have a higher passing rate (85%) than the students from the Control Group (X2) (53.4%). Table 4 displays the distribution of post-test scores for both groups. It reveals that 14 students (46.6%) from the Control Group (X2) failed the test, and only 6 students (17.6%) from the Experiment Group (X1) obtained lower than the passing mark. Another noticeable difference in the student’s performance is that none from the Control Group (X2) obtained excellent scores (80-100%); however, 4 students (11.8%) from the Experiment Group (X1) managed to be in the excellent score range.

Table 2 also shows that students E18 and E29 from the Experiment Group (X1) obtained the highest improvement in scores, which are 55% and 52.5% respectively. On the other hand, students E21 and E24 gained the lowest improvement in scores which is 7.5%. Similarly, Table 3 displays student K14 from the Control Group (X2) had shown the highest improvement in the score with 35%, as students, K2 and K6 attained the lowest improvement which is 0%. Therefore, it can be observed that the Experiment Group (X1) obtains higher scores, in its highest and lowest improvement than its equivalent from the Control Group (X2). The finding reveals that the majority of students from the Control Group (X2) were not able to show a good grasp of the topic (14 out of 30 students obtained scores between 0-34). Conversely, the students from the Experiment Group (X1), who adopted the teaching and learning using the C^2HADAM multimedia courseware, display a rather even distribution of performance.

Table 4. Ranges of Scores in The Post Test

Scores	Experiment Group (X_1)		Control Group (X_2)		Total	
	No.	Percentage	No.	Percentage	No.	Percentage
0-39	6	17.6	14	46.6	20	31.3
40-49	3	8.8	5	16.7	8	12.5
50-59	10	29.4	2	6.7	12	18.7
60-69	8	23.5	7	23.3	15	23.4
70-79	3	8.8	2	6.7	5	7.8
80-100	4	11.8	0	0	4	6.3
Total	**34**	**100.0**	**30**	**100.0**	**64**	**100.0**

Conclusion

This paper discusses selected learning theory, namely constructivist that incorporated into the development of the C^2HADAM multimedia courseware. This courseware focuses on the topic of Nutrition for selected Form Two students, who were tested using the PBL approach for their Science subject. The features of PBL including simulations, problem scenario sets, collaboration, and scaffolding play important roles in aiding the learners to comprehend the scientific concept of the topic of Nutrition. A few series of interviews, checklists, and question sets were administered to evaluate the application of the courseware. In short, respondents provided positive feedback on the use of the courseware, and the courseware proves to enhance learners' performance. The integration of the PBL principles in the development of the courseware, thus, promises more of its application in the teaching and learning of other scientific disciplines.

Recommendations

The current study revealed that Problem Based Learning approach is an important method for enhancing teaching and learning of Science subject. However, the results of this study should be treated with caution due to the small sample size. On this basis, future research should further examine the differences in learning styles among students and personalized learning according to their preferences. It could also contribute to a deeper understanding of the teaching and learning approach suitable for learning Science course.

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Project Development for Blood Bank Application and Convertor for Software Testing

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Abstract: This paper discusses the steps involve in project development for developing the mobile application, namely Blood Bank Application and developing the convertor for software testing. The project development is important for Computer Science students for them to learn the important steps in developing the application and testing the reliability of the application. The first step involved is the development of the mobile application. Then the convertor is developed to convert the mobile application in ".apk" format into Java program in ".java" format. The java program is then tested under Eclipse environment using JUnit. Finally, the Java program is tested for its capability of generating test cases using SenaTLSParser. The comparison of the results of the time taken to produce test cases is presented using Junit and SenaTLSParser. Based on the results, SenaTLSParser is more reliable compared with JUnit since its response time is less than JUnit. The whole steps involved in this project development are discussed in this paper.

Keywords: Project Development, Education Technology, Software Testing, Test Cases, Java Programming

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T. Ozturk, & M. L. Ciddi, *Proceedings of ICEMST 2023-- International Conference on Education in Mathematics, Science and Technology* (pp. 41-52), Cappadocia, Nevsehir. Turkiye. ISTES Organization.

Introduction

Project development is important for students to learn in developing and completing a project within the given time. In this case study, the students are given a project to complete within eight weeks. The project consists of two stages. The first stage is developing the mobile application, namely Blood Bank Application and the second stage is developing the convertor to convert the mobile application in ".apk" format to ".java" format. The purpose of the development of the convertor is to test the practicallity of converting the mobile appplication into Java program. The Java program is then tested under Eclipse environment using Junit. Finally the Java program is tested for its capability of generating test cases using SENATLSParser.

The first step in project development is to gather all the necessary requirements for the project. The second step is to transform the gathered requirements into UML specification. The third step is the development stage. Based on the UML specification, the application is developed. The final step is to test the developed application in order to see the relaibility of the application. Based on the project given, students have to complete these four steps within eight weeks.

Related Work

Nowadays, a software tester has many choices of techniques in order to conduct a software testing. A tester can generate the test cases and testing each module manually but it is time consuming (Afrin and Mohsin, 2017). The implementation of automation tool is necessary in order to reduce cost for testing manually. Example of some of the automation tool for automating the generation of test cases can be found in (Shin and Im, 2017; Du et al., 2019; Elqortobi et al., 2020; Meiliana et al., 2017; Mishra et. Al., 2017; and Ibrahim et al., 2020).

JUnit can be used for repeatable automated software testing within Eclipse (Junit, 2022). It provides a lot of assert functions for testing the share common test data features, expected results, test suites for test organizing and running, and test runner for graphical and textual. An entire or part of object, or interaction between several objects can be implemented also. SENATLSParser can generate test case automatically by examining the source codes line by line. It enables the tester to find the high quality solutions easily (Ibrahim et al., 2022).

In this study, JUnit and SENATLSParser will be used to test a convertor application which can convert the blood bank application with ".apk" format into ".java" source file. The results of the time taken between Junit and SENATLSParser will be compared in order to indicate the performance of Junit and SENATLSParser.

The research of Li et al. (2017) presents DroidBot to support the model-based test input generation with less extra requirements. The main criteria of Droidbot is lightweight UI-guided test input generator for Android apps because it does not need an advanced knowledge on the unexplored code. It gives UI-guided input generation and will generate on-the-fly at runtime. Then, based on the transition model, it will generate the UI-guided test inputs. In order to reach the effectiveness in most cases, we need to generate the input using depth-first strategy.

Next, based on Wang and Liu (2018), software testing is one of the most important criteria in domestic and abroad software researchers to achieve software quality assurance. However, it spends so much time during the software development process. The Particle Swarm Optimization (PSO) can help in optimizing a problem by trying the process iteratively. The approach used based on specific measure of quality. Therefore, the PSO algorithm was introduced to generate the software case and to design novel software test case automatic generation algorithm.

The study by Mao et al. (2016) introduced an Android testing approach called Sapienz. Sapienz performed better compare to the Android Monkey. It is also a practical testing tool. Other than that, even only app's APK file can be accessed, Sapienz still supports in multi-level instrumentation. Besides, Ibrahim et al. (2022) have discussed on generating the test cases with SENATLSParser using Eclipse environment. Based on the research, they found out that SENATLSParser has high reliability and responsed faster than using manual testing. Based on the respective result, it shows that test case optimization is available. The software tester can also discard the source code that redundant. Code smell functionality give results that it is efficient to generate the test cases automatically based on source code (Ibrahim et al., March 2020). Table 1 summarizes the related work for this study.

Table 1. Summary of Related Work

Authors	Technique	Summary
Li et al. (2017)	DroitBot	Support model-based test input generation with less extra requirements
Wang and Liu (2018)	PSO	Results show that it is better than the conventional PSO
Mao et al. (2016)	Android Testing	Perform better compared with Android Monkey
Ibrahim et al. (2022)	SENATLSParser	SENATLSParser has response time faster than manual testing based on the source codes

Project Development

In project development, four main steps are necessary to complete a project within the given time. Figure 1 shows these 4 steps. The project is given to students to be completed within eight weeks. Students must follow the steps given in Figure 1.

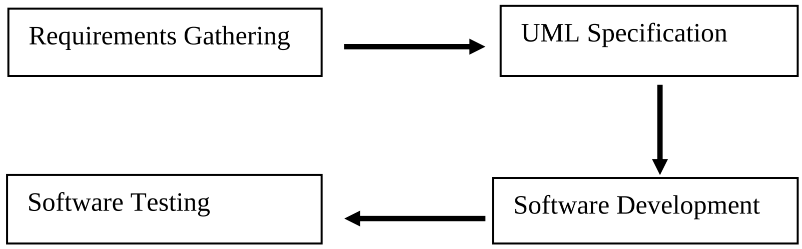

Figure 1. Project Development

Requirements Gathering

Based on Figure 1, the first step is the requirements gathering. Requirements regarding the blood bank mobile application and the convertor must be collected by students. These requirements are then being converted to UML specification. Requirements for blood bank mobile application include the application should be able to have login, register, profile view and make appointment. Meanwhile, requirements for convertor include the capability for the application to read, convert and save.

UML Specification

UML specification consists of few diagrams. Two important diagrams that are needed to develop the application are use case diagram and class diagram. Figure 2 shows an example of the use case diagram for JUnit and Convertor and Figure 3 shows an example of the class diagram for the project.

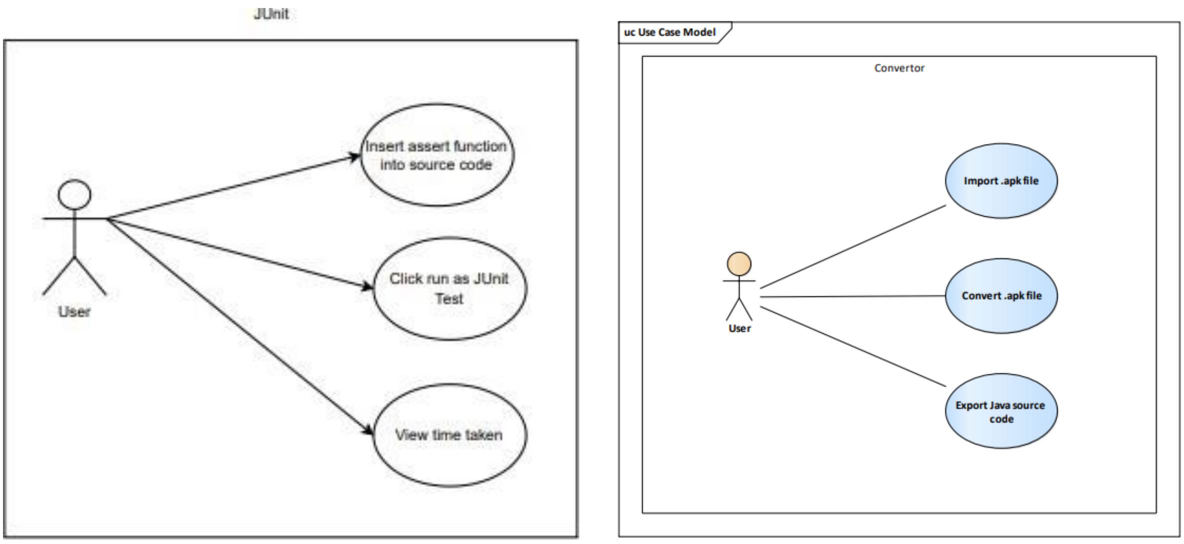

Figure 2. Use Case Diagram for JUnit and Convertor

Based on Figure 2, use case diagram for Convertor, for example, consists of 3 use-cases. They are import, convert and export. Figure 4 shows the example of class diagram for blood bank mobile application.

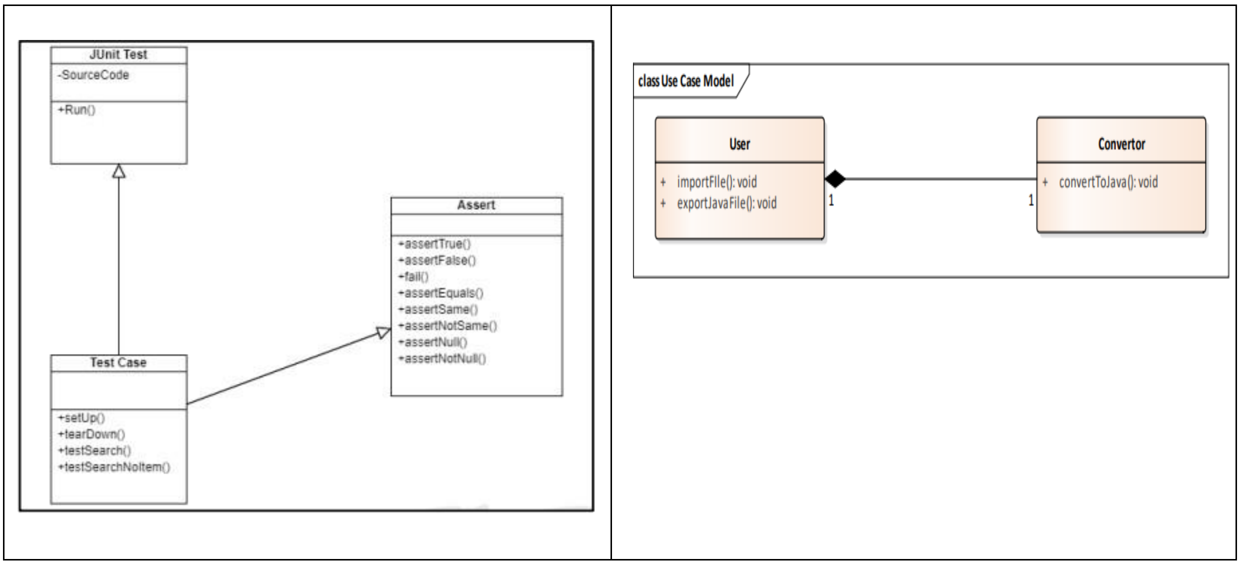

Figure 3. Class Diagram for JUnit and Convertor

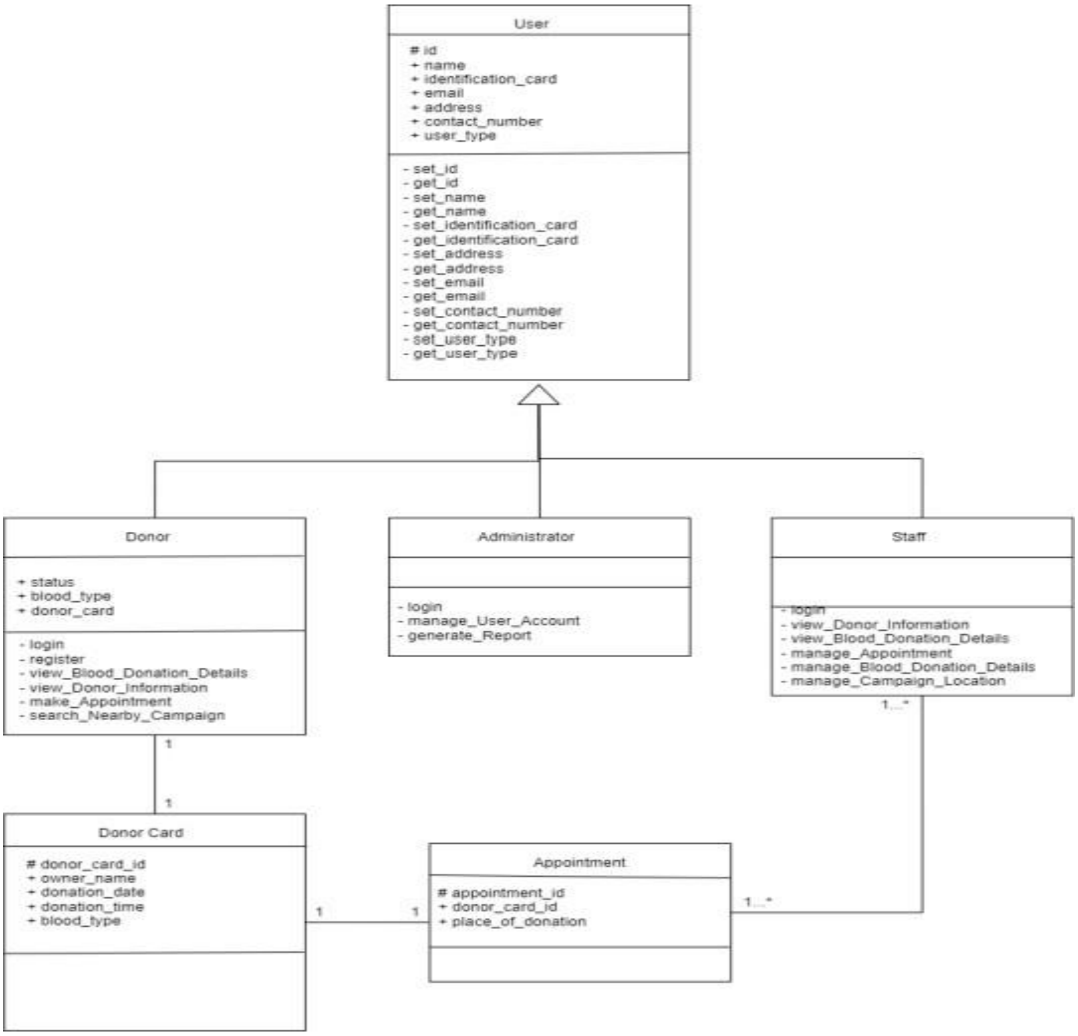

Figure 4. Class Diagram for Blood Bank Mobile Application

Software Development

UML specification have been widely used for software development. Examples of study that used the diagrams in UML specification include (Khuran et al., 2016; Ribeiro et al., 2018; Aman et al., 2014; and Ibrahim et al., 2011). The software can be developed based on the use case diagram in Figure 2 and class diagram in Figure 3. The blood bank mobile application can be developed based on class diagram in Figure 4.

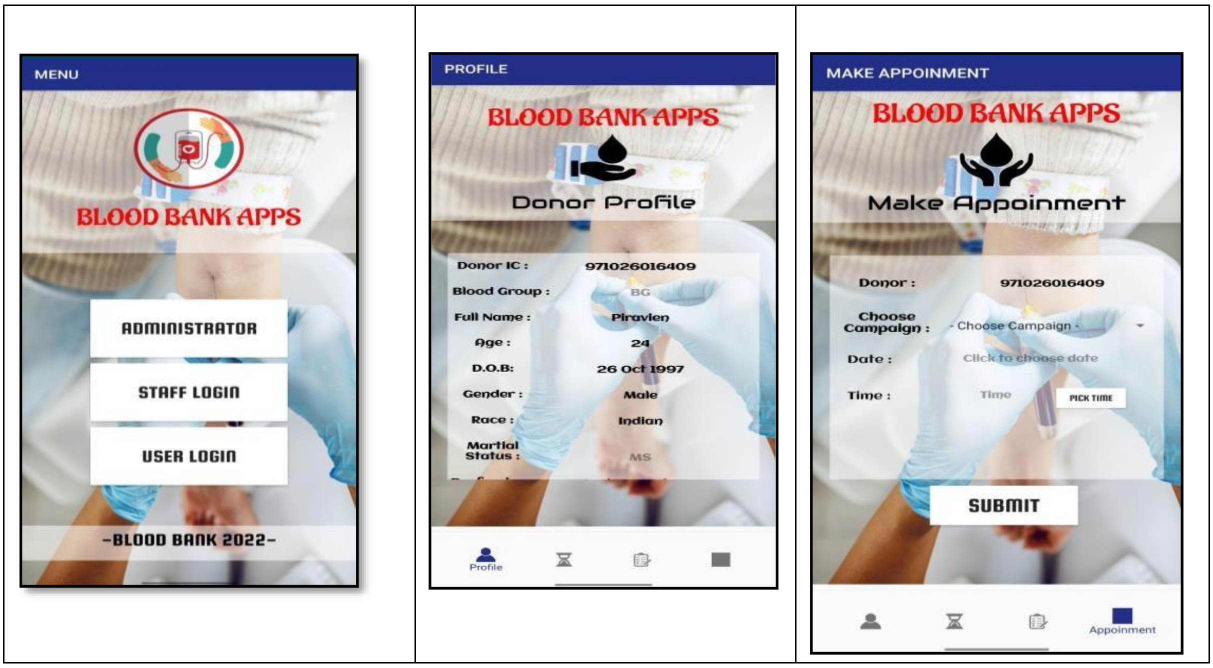

Figure 5. User Interface for Software Development

The blood bank mobile application, for example, have been developed based on the requirements gathering in step 1 of project development. The user interfaces for login, profile view and make appointment are shown in Figure 5. For the convertor, Figure 6 shows the segmentation codes for the development of the convertor. The convertor is developed using Java programming. For the conversion of blood bank mobile application from ".apk" format to ".java" format. Figure 7 shows the user interface for the conversion process.

Software Testing

Software testing is an important stage to test the reliability of the software being developed. Software testing can be done for any software developed (Jamil et al., 2016; Lawana, 2014). For the project, students have been asked to test the software that they developed using the embedded JUnit function inside the Eclipse environment and the SENATLSParser tool that the students need to import and install in Eclipse environment. Figure 8 shows the process for importing the project in Eclipse environment.

```java
        int returnVal;

        if (event.getSource() == chooseAPKButton) {
            returnVal = fc.showOpenDialog(null);
            if (returnVal == JFileChooser.APPROVE_OPTION) {
                selectedSourceFile = fc.getSelectedFile();
                apkPath = selectedSourceFile.toString();
                apkName = selectedSourceFile.getName();
                sourceText.setText(apkName);
            }
        }


        if (event.getSource() == chooseJavaDecompilerButton) {
            returnVal = fc.showSaveDialog(null);
            if (returnVal == JFileChooser.APPROVE_OPTION) {
                jdGuiPath = fc.getSelectedFile().toString();
                sourceText2.setText("Jd-Gui Selected");
                System.out.println("jdGuiPath : " +jdGuiPath);
            }
        }
```

Figure 6. Segmentation of Source Code for Convertor

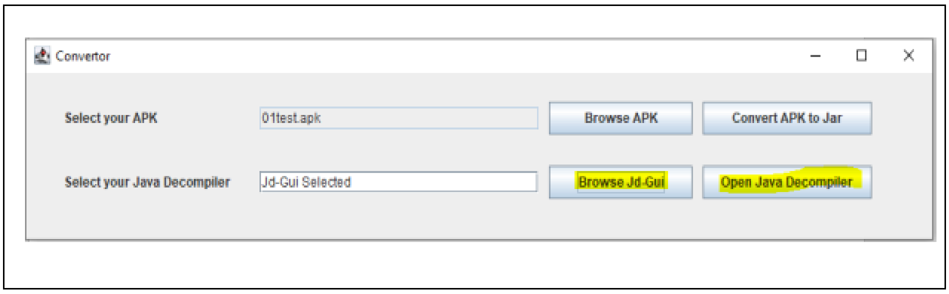

Figure 7. Convertor Interface

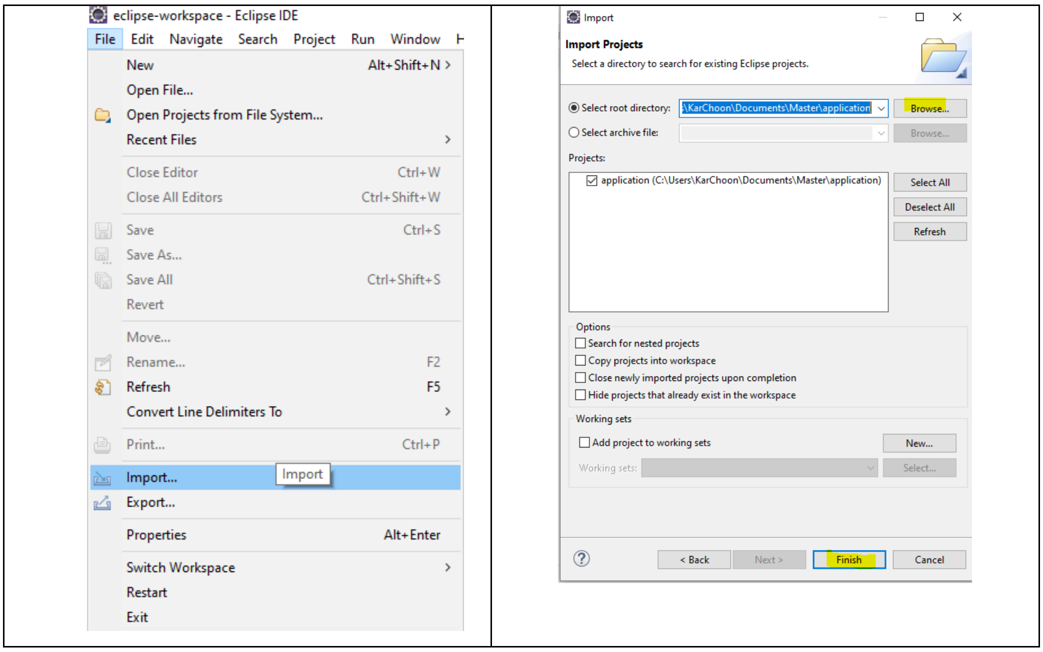

Figure 8. Import Project and Application

Based on Figure 8, by using the convertor and import file, the blood bank mobile application in ".apk" format is able to be converted into Java programming ".java" source codes. Then, SENATLSParser is used for testing the Java source codes. Students are able to learn the whole steps in project development to complete the project within the given period.

Results and Discussion

JUnit has been used to test the blood bank mobile application. The assert function is used for the software testing. Figure 9 shows the assert function is used for the blood bank mobile application. The result for the assert function using JUnit is also shown in Figure 9. The time taken to execute the assert function using JUnit is 0.142s. Meanwhile, SENATLSParser tool is also used for the software testing. The time taken to execute and generate the test cases is 76ms as shown in Figure 10. Based on the execution time using assert function from JUnit and SENATLSParser tool, it has been shown that SENATLSParser is able to execute faster than JUnit. Figure 11 shows the test cases that have been generated aoutomatically from SENATLSParser tool.

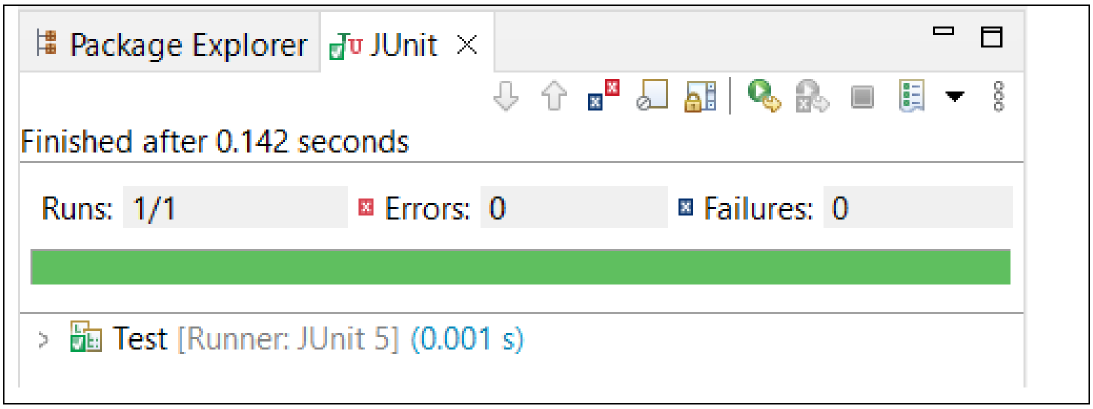

Figure 9. JUnit Testing

Figure 10. SenaTLSParser

The convertor is also tested for software testing using assert function from JUnit and SENATLSParser tool. Three different tests are performed for the convertor. Table 2 shows the results for the test cases generated and the time taken to generate the test cases. Figure 12 shows the graph for the three software testing cases.

```
Console SenaTLSParser
Start Time: 2022/12/08 14:49:14
### Working in project linux-core-service-5 ###

Package

Package CVS

Package com

Package com.CVS

Package com.senatraffic

--------------------------------------------------
Source file Constants.java
Has number of lines: 154

--------------------------------------------------
Source file ItrafficService.java
Has number of lines: 63

Method name :main
Signature :([QString;)V
Return Type :V
Input variable :
args
Generate Test Cases:
Test Case 1 : valid [args]are input with :1
Test Case 2 : invalid [args]are input with :-1
Test Case 3 : null [args]are input with :null

Package com.senatraffic.CVS

Package com.senatraffic.alarm

--------------------------------------------------
```

Figure 11. Console for SenaTLSParser

Table 2. Results of Test Cases

Function Name	***No. of Tests***	***Time Taken (ms)***	
		JUnit (ms)	***SENATLSParser (ms)***
Convertor.java	1	31	1
	2	25	1
	3	27	2
Average Time Taken (ms)		27.67	1.33

Based on Table 2, SENATLSParser tool gives good results as compared with JUnit for the three different tests. The average of 1.33ms has been used to generate the test cases using SENATLSParser tool as compared with 27.67ms using assert function from JUnit. This shows that SENATLSParser tool is capable to generate faster test cases automatically compared with JUnit.

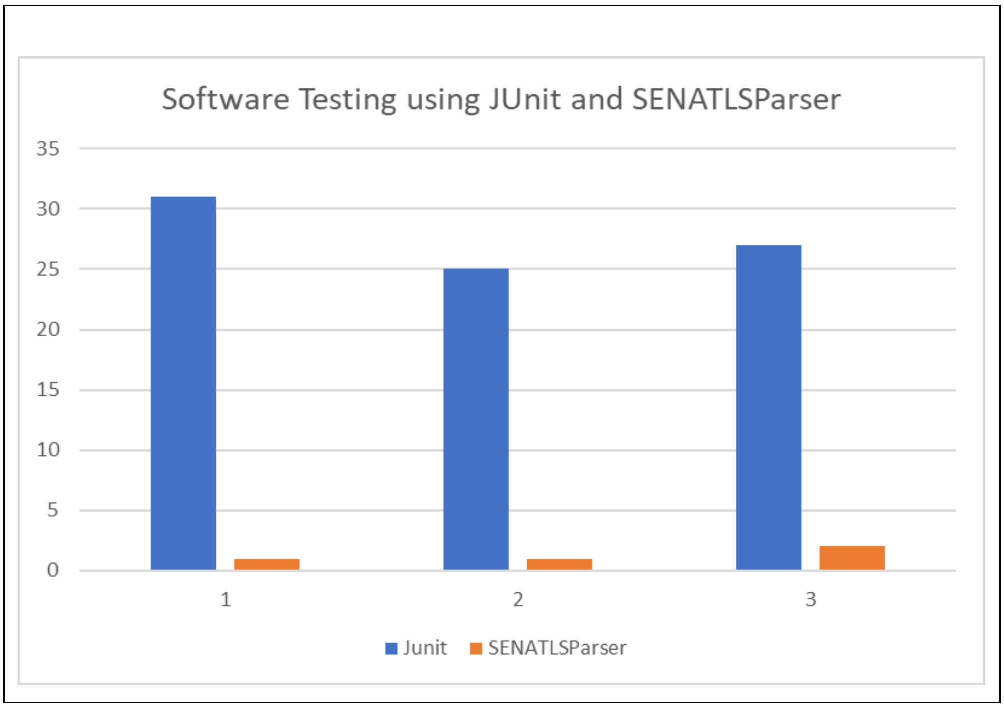

Figure 12. Results for Generating Test Cases using JUnit and SenaTLSParser

Based on Figure 12, SENATLSParser tool is more reliable to be used as a tool for software testing in term of generating the test cases automatically. The three cases have shown that SENATLSParser outperformed the JUnit.

Conclusion

In conclusion, the students have been successfully implemented the project within eight weeks that has been given to them. Project development is important to enable the successful of implementation of a project. The convertor is used to convert the blood bank mobile application from ".apk" format into Java programming ".java" source codes by using the method of executing window batch command (.bat) file and Java Decompiler. After converting, the java source code is testing using JUnit and SENATLSParser. The comparison results of time taken between JUnit and SENATLSParser shows that SENATLSParser uses the least time for software testing. Based on the result, SENATLSParser is more reliable as compared with JUnit since its execution time is less than JUnit.

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Can E-Scaffolding Influence the Shift in the Level of Scientific Reasoning in Physics Learning?

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Abstract: This study observes two groups of high school students who were given different physics learning interventions. The first group (N = 35) learning physics with e-scaffolding in modelling instructions (LPE-MI), while the second group (N = 35) learning physics with modelling instructions (LPMI). This study investigates the influence of e-scaffolding on shifts in the level of scientific reasoning (SR) of students in physics learning by using 15 items modified by Lawson's scientific reasoning test ($\alpha = 0.828$). Our data indicate that the group LPE-MI obtained a G-factor score of 0.53, while the other group achieves G = 0.37. Attention-grabbing results are seen in the shift in levels from transition to formal operations in groups of individuals. For the group LPE-MI it amounts to a significant 43% higher than the group LPMI, which is 9%. The shift in the SR level of students who learning physics with e-scaffolding was more elevated than students who only studied physics with MI, where the comparative analysis test showed an effect of 17.3%. The findings in our study prove that e-scaffolding is not only effective in helping students learn physics independently, but also able to influence students' SR level shifts better.

Keywords: E-scaffolding, Shift in Level, Scientific Reasoning, Physics Learning

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Introduction

Scientific reasoning (SR) is the core of cognitive skills in science education. From a perspective of high-level logical thinking (Kalinowski & Willoughby, 2019; Novia & Riandi, 2017; She & Liao, 2010), SR is a scientific inquiry skill that involves analyzing, hypothesizing, problem-solving, and making appropriate conclusions. Another viewpoint considers SR as a set of basic skills (Fischer et al., 2014; Nurhayati et al., 2016) in thinking and reasoning patterns (Ding et al., 2016). Meanwhile, Zafitri et al. (2019) view SR as a thinking ability that plays a crucial role in solving complex and authentic problems.

Essentially, the important goal of science education is not only to focus on students' understanding of basic concepts, but also to develop their scientific reasoning skills. Various previous studies have found that the development of SR skills has a positive impact on students' conceptual understanding (Muchoyimah et al., 2020; Nieminen et al., 2012; Sriyansyah & Saepuzaman, 2017). Sutopo & Waldrip's (2014) and Meilina et al.'s (2020) analyses found that students with high SR skills are able to understand physics concepts better. When students have high levels of SR, they will be able to optimize their potential, making them more adaptable to complex problems (Zimmerman & Klahr, 2018).

According to Piaget's theory, an individual's cognitive development progresses through stages that correspond to the development of their SR over time. The development of a child's SR is classified into three levels: concrete operational, transitional, and formal operational (Lawson et al., 2000). At the level of concrete operational reasoning (ages 6-11), students are only able to operate simple logical thinking to solve problems. At the transitional level, which is the transition stage between the concrete operational and formal operational stages, students are only able to solve some abstract problems because their cognitive knowledge schema cannot process complex logical reasoning accurately. Meanwhile, at the level of formal operational reasoning (ages over 11), students have been able to solve various abstract problems and can think using more complex logical reasoning, ultimately leading to accurate hypothetico-deductive reasoning (Stammen et al., 2018).

Despite the theory that middle and upper-level students are at the formal operational level, many researchers have shown that most upper-level students have not yet reached that level (Khoirina et al., 2018; Tajudin & Chinnappan, 2015; Widarti & Winarti, 2019). Research by Tajudin & Chinnappan (2015) showed that 9 out of 10 high school students were still at the concrete operational reasoning level, and only a small percentage of students had reached the formal operational reasoning level. Similar results were found in research on the level of SR in physics conducted by Khoirina et al. (2018)), where only 1 out of 10 students in the Indonesian high school population was able to reach the formal operational reasoning level. Meanwhile, research by Widarti & Winarti (2019) found evidence that no students had reached the formal operational reasoning level in physics learning, while 7 out of 10 students were still at the concrete operational reasoning level. These research findings suggest the need for effective learning strategies to train students' SR.

One strategy that can be used to train students' scientific reasoning (SR) skills is the application of Modelling Instruction (MI) in teaching. MI is a learning model that has syntax that is in line with the pattern of scientific reasoning. Several studies (Brewe & Sawtelle, 2018; Jumadin et al., 2017; Stammen et al., 2018; Sujarwanto et al., 2014) on modelling instruction have shown positive results on the development of students' SR in science learning. This is because the steps in MI direct students to construct scientific knowledge and reasoning in a multirepresentational manner (Jumadin et al., 2017; Lestyaningtyas et al., 2017; Ropika et al., 2019) through modeling and investigation activities. However, according to Belland et al. (2015), the low level of SR skills in students is not only caused by learning strategies but also because teachers cannot overcome all the difficulties that students experience during learning.

To overcome the difficulties experienced by students during learning in an effort to improve SR skills, there is a need for cognitive assistance that students can use independently during learning, such as the use of e-scaffolding. E-scaffolding is an online-based scaffolding that is efficient to use in supporting science learning. Various studies have mentioned that e-scaffolding can be used as cognitive assistance that can develop students' thinking processes such as reasoning, problem solving, and finding precise physics concepts (Rashid et al., 2017; Saman & Handayanto, 2017; Saputri & Wilujeng, 2017; Wu et al., 2016). An empirical study by Bell & Pape (2014)) showed that scaffolding can increase students' self-regulated learning. Scaffolding integrated with e-learning (e-scaffolding) utilizes multimedia to be adjusted to the needs of different levels of assistance and cognitive levels of students. E-scaffolding is flexible and built on constructivist principles. Through e-scaffolding, students are involved in making independent decisions (Saputri & Wilujeng, 2017), making it efficient for students who have difficulty understanding problems.

Various studies have shown that the use of scaffolding in online learning plays an important role in increasing the effectiveness of learning. Related literature shows that both teacher e-scaffolding and peer e-scaffolding have the strength to help students achieve learning goals and maximize their learning outcomes. In the subject of physics, online learning with the assistance of e-scaffolding can effectively enhance students' understanding of physics concepts (Rahayu et al., 2022; Santhalia & Sampebatu, 2020). The assistance provided by teachers in the form of e-scaffolding can facilitate students to develop their thinking skills in understanding concepts and make online learning easier. These successes form the basis for improving students' SR skills through the application of e-scaffolding in teaching methods, including the use of modelling instruction. However, the use of e-scaffolding in online learning presents several challenges, including activities for interactive questions, collaborative discussions, and the problem of technology and digital infrastructure availability that need to be considered in order to achieve success in improving students' SR skills (Nurliani et al., 2021).

The implementation of e-scaffolding in physics learning design presents both challenges and great potential for educators and researchers to develop more effective and efficient learning innovations. However, in practice, there are still few educational research studies that utilize e-scaffolding in physics learning with modeling instruction to train students' SR (scientific reasoning) abilities. In addition, most science education research is always fixated on analyzing the overall efforts to improve SR, but there is little scientific literature or empirical studies that specifically present the progress of SR skills through shifts in SR levels. Therefore, this study addresses the main problem, which is to determine whether e-scaffolding in physics learning can shift students' SR levels to a higher level than before.

Method

This research involved 70 high school students aged 16-18 years for half a semester (12 weeks) in one school in East Java, Indonesia in the academic year 2019/2020. The research method used was a quasi-experimental comparative study that observed two groups of students given different physics learning interventions. This study aimed to investigate the effect of e-scaffolding on the shift in scientific reasoning (SR) ability levels between the two groups of students in physics learning. The first group, consisting of 35 students, was the experimental group who learned physics with e-scaffolding in modeling instruction (LPE-MI), while the second group, consisting of 35 students, was the control group who learned physics with modeling instruction (LPMI).

To measure students' SR levels, we used a 15-item modified Lawson scientific reasoning test that has been tested for validity with a reliability of $\alpha = 0.828$. The questions in the test instrument refer to 6 indicators of SR patterns: conservation reasoning, proportional reasoning, probabilistic reasoning, control of variables, correlational reasoning, and deductive hypothesis reasoning. The total score obtained from all indicators is then classified based on the SR level criteria (see table 1).

Table 1. Scientific Reasoning Level Classification

Total score	Level
0% - 33%	Concrete operations
34% - 67%	Transition
68% - 100%	Formal Operations

Adaptation of Babakr et al. (2019)

In this study, the measurement of improvement in SR ability on the post-test in relation to the pretest was evaluated using the G-normalized gain parameter. Meanwhile, the data analysis for the comparison test in this study used the paired t-test with the condition of sig. < 0.05. This test was used to determine the statistical difference in the SR results before and after the intervention, so that we could evaluate how the intervention difference could affect the migration of students' SR levels.

Results

The results indicated that there was no statistically significant difference in the pre-test SR results between the two observed groups (p > .05). The analysis showed that most students in both the LPE-MI and LPMI groups were still at the concrete and transitional reasoning levels. Even in the LPMI group, there were no students who had reached the formal operational level before the course. The comparison between the pre-test and post-test results in SR level between the two groups is presented in table 2. Our data showed that both groups showed improvement, but the students in the experimental group (LPE-MI) were almost three times more successful in reaching the formal operational level compared to the control group (LPMI).

Table 2. Comparison of pretest and posttest scientific reasoning results between LPE-MI and LPMI groups

		Scientific Reasoning level classification (%)		
		Concrete	Transisi	Formal
LPE-MI Group (N=35)	Pretest	37	60	3
	Posttest	0	37	63
	Shift	-37[a]	-23[b]	60[a]
LPMI Group (N=35)	Pretest	43	57	0
	Posttest	0	77	23
	Shift	-43[a]	20[b]	23[b]

[a] Significant shifts, *p<.05*
[b] Non-significant shifts, *p>.05*

For the LPE-MI group, the pretest SR score prior to the course indicated that 37% of students were in the concrete operational thinking level, 60% were in the transitional thinking level, and 3% were in the formal operational thinking level. After the intervention, 0% of students were in the concrete operational thinking level, 37% were in the transitional thinking level, and 63% were in the formal operational thinking level. These results indicate that the SR level of the experimental group increased significantly by 60% in the formal operational level after participating in physics learning with e-scaffolding in modelling instruction.

On the other hand, the pretest SR score for the LPMI group before the intervention indicated that 43% of students were in the concrete operational thinking level, 57% were in the transitional thinking level, and none were in the formal operational thinking level. Whereas, after the course, the posttest SR score for the LPMI group showed that none of the students were in the concrete operational thinking level, 77% of students were in the transitional thinking level, and 23% of students had entered the formal operational thinking level. These results indicate that the LPMI group experienced a substantial increase in the formal operational level but not a significant one.

Overall, both the LPE-MI and LPMI groups experienced an improvement in SR ability in the moderate category as indicated by the normalized gain factor (G-factor). The LPE-MI group obtained a G-factor score of 0.53, while the LPMI group obtained a G-factor score of 0.37 (see figure 1).

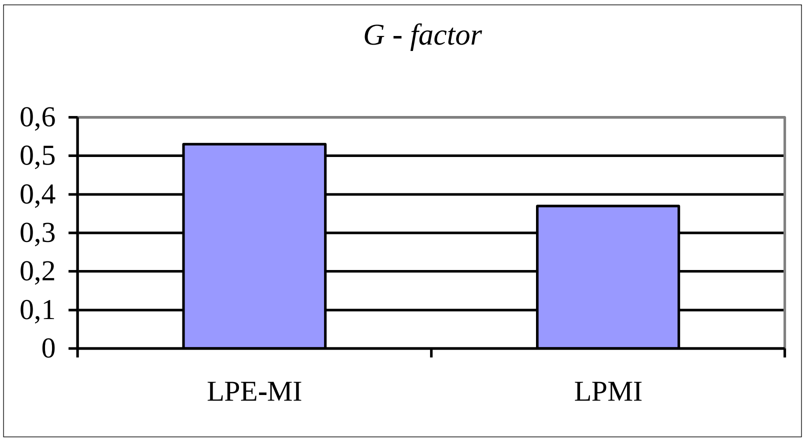

Figure 1. *G-factor* for LPE-MI and LPMI

The improvement of SR ability in both groups as observed in the data analysis indicates a shift in the level of SR. Table 3 shows the results of the analysis of migration between levels of scientific reasoning among students in both physics learning groups.

Table 3. Comparison of Migration of Scientific Reasoning Levels of Students in LPE-MI and LPMI groups

LPE-MI					LPMI				
Pretest		Posttest		(%)	Pretest		Posttest		(%)
Concrete	13	Concrete	0	0	Concrete	15	Concrete	0	0
		Transisional	7	20[a]			Transisional	10	28[a]
		Formal	6	17[a]			Formal	5	14[a]
Transisional	21	Concrete	0	0	Transisional	20	Concrete	0	0
		Transisional	6	17			Transisional	17	49
		Formal	15	43[a]			Formal	3	9[b]
Formal	1	Concrete	0	0	Formal	0	Concrete	0	0
		Transisional	0	0			Transisional	0	0
		Formal	1	3			Formal	0	0

[a] Significant shifts, $p<.05$
[b] Non-significant shifts, $p>.05$

In the LPE-MI group, 20% of students shifted from the concrete to transitional level, 17% of students shifted from the concrete to formal operational level, and 17% of students remained in the transitional level. Meanwhile, in the LPMI group, 28% of students shifted from the concrete to transitional level, 14% of students shifted from the concrete to formal operational level, and 49% remained in the transitional level. Special attention was given to observing the migration of individuals from the transitional to formal operational level in each group. In the LPE-MI group, 43% of students experienced a shift from the transitional to formal operational level, which was much higher than the LPMI group, which only reached 9%. Additionally, a comparative analysis between the two groups also showed that the integration of e-scaffolding effectively influenced the shift in SR level by 17.3%, where the SR level of students who learned physics with E-MI was higher than those who only learned physics with MI.

Discussion

This study investigates the effectiveness of e-scaffolding in modeling instruction to enhance high school students' scientific reasoning (SR). This topic is considered the most important aspect of Modeling Instruction (MI). The study employs an analysis of students' shift in reasoning levels from concrete-transitional-formal in classes using and not using e-scaffolding in modeling instruction. Our research findings confirm Omarchevska et al.'s (2022) study showing that the assistance provided did not affect the modeling learning environment. One possible explanation is that students did not effectively use the provided scaffolding. Another possibility is that the e-scaffolding provided may elicit different responses depending on students' prior knowledge (van Riesen et al., 2018, 2022). Although we did not directly measure prior knowledge in this study, we measured students' scientific reasoning before the intervention. Referring to the strong correlation between knowledge and scientific reasoning (Muchoyimah et al., 2020; Mustika et al., 2019; Purwanti et al., 2016). it is possible that students need sufficient prior knowledge to use scaffolding effectively in their learning or that students with high prior knowledge experience a reverse expertise effect that inhibits their scientific reasoning development (Richter & Scheiter, 2019).

In the scientific reasoning research community, modeling is one of the reasoning styles proposed by (Kind & Osborne, 2017). Therefore, modeling instruction is an effective strategy to enhance students' scientific reasoning skills (Stammen et al., 2018). However, it can be a challenging task for students as it requires strong conceptual understanding and high-level abstract thinking. Consistent with the results of this study, students do not necessarily maximize their learning through modeling instruction. This may be due to some obstacles students face in acquiring knowledge and modeling because of increased cognitive load (Sweller, 1988), resulting in a minimal shift towards formal operational reasoning in LPMI compared to the LPE-MI class. These results confirm Stammen et al. (2018) research on prospective teachers.

While this study highlights the shift in scientific reasoning skills among a group of high school students, further exploration of moderation variables that influence SR in various fields and areas is needed. This study is limited to the participants and region involved in this research. In addition, in terms of educational implications, we suggest that educators provide e-scaffolding that explicitly trains SR to guide students to the formal operational level.

Conclusion

Based on the results and discussion, it can be inferred that learning physics in both groups (LPMI and LPE-MI) can increase students' scientific reasoning. However, it was found that the increase in the SR level of students who learning physics with e-scaffolding in modeling instructions (LPE-MI) was higher compared to the group who only learning physics with modeling instructions (LPMI). Moreover, a significantly higher number of students in the LPE-MI group progressed from the transitional level to formal operations, as opposed to the LPMI group, which only reaches 9%. Overall, the findings in our study prove that e-scaffolding is not only effective in helping students learn physics independently, but also able to influence students' SR level shifts better.

Recommendations

The purpose of this study is to provide some recommendations that may be beneficial for educators and researchers in the future. Firstly, it is important to create a more comprehensive evaluation of scientific skills in physics learning, including scientific reasoning standards and self-efficacy, to minimize bias related to content-based scientific reasoning. Secondly, we encourage future researchers to expand on this study by investigating the impact of incorporating E-scaffolding in learning Physics with Modelling Learning (LPE-MI) on the shift in levels of other scientific skills to provide more diverse learning insights.

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The Development of Learning Tools Based on STEM with PBL model on Bacteria Material to Train Critical Thinking Skills, Creative, and Cognitive Learning Outcomes for 10th Grade Students

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Abstract: 21st-century skills can be applied to STEM education. The Merdeka Curriculum also has a passion to support teachers and schools in exploring and implementing STEM as a learning approach to improve student competence. The study aims to develop learning tools consisting of the syllabus, lesson plans, and student worksheets (SLS) that are valid and practical. This study uses the ADDIE development model. The research involved 43 participants at SMAN 6 Malang. Learning tools are validated by material experts, learning experts, and field practitioners. The research was conducted only as a trial or formative evaluation in the development stage. Formative evaluation includes three stages of testing, namely individual tests of 3 students, small group tests of 10 students, and field tests of 30 students that have passed the material of bacteria. The results of practicality obtained through questionnaires on student responses to worksheets on individual tests, small groups, and field tests showed percentages of 89.85%, 88.14%, and 89.08%. These results indicate that STEM-PBL model on bacterial material is very valid and practiced using and can train critical thinking skills, creativity, and cognitive learning outcomes of 10th-grade students.

Keywords: Critical thinking, creative thinking, cognitive learning outcomes, PBL, STEM.

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Introduction

Education is one of the main foundations for the development of a country. The demand for an increase in human resources globally encourages developments in education. The results of PISA Indonesia in 2018 have decreased in rank compared to 2015. Low scientific ability at 396 or 38% lower than the average percentage can indicate that onlysome students can be critical, analytical, and creative in applying science-related knowledge in various situations.The implementation of the Merdeka Curriculum is expected to prepare students' competencies in accordance with 21st-century skills such as critical thinking skills, creative thinking skills, communication skills, and collaboration (4Cs) (Sudarmin et al., 2023).

The level of complexity of the problems and challenges of global life that are increasingly high encourage 21st-century education to hone intellectual skills, especially high-level skills that include critical and creative thinking skills (Spector & Ma, 2019). Critical thinking skills are needed in various disciplines and life, one of which is when entering the world of work (Mater et al., 2022). The challenges of an increasingly dynamic and uncertain life, creative thinking skills are needed in learning (Hadzigeorgiou et al., 2012). Therefore, creative thinking skills can be said to be the basis of science (Beers Sue Z., 2019).

The 21st-century skills can be further trained with the STEM approach. The Merdeka Curriculum has a passion for supporting teachers and schools in exploring and implementing STEM as a learning approach to improve student competence (Sudarmin et al., 2023). STEM can improve students' ability to learn (Kelley & Knowles, 2016). STEM is expected to be the key and path forthe development of the country, the development of human resources who have 21st-century skills, and the ability to compete globally (Jang, 2016). STEM is an approach that links the fields of Science, Technology, Engineering, and Mathematics.

According to the findings of the interviews and questionnaires, there were no STEM-based teaching materials in the learning process. It was also found that students' critical and creative thinking skills were also low. The average percentage of each aspect of critical thinking skills shows a figure of 49.65% of students who are less skilled in critical thinking. The average percentage for each aspect of creative thinking skills also shows that 51.63% of students still have difficulty in developing ideas and 82% of students need tools that encourage students to find and express ideas. The difficulty experienced by students is that the material in studying bacteria is abstract (observation of bacteria and their characteristics), so it is very difficult to study them.

The difficulties experienced affect the cognitive scores of students when doing tests (Kusmahardhika et al., 2023). One model based on contextual problems that can improve students' thinking skills is Problem Based Learning (PBL). PBL encourages students to think critically, analytically, and discover through various sources (Smith et al., 2022). Thus, the PBL model can encourage students to think critically about a problem and increase students' creativity in finding solutions to a problem (Sudarmin et al., 2023; Sumarni & Kadarwati, 2020). As a result, the purpose of this research is to provide tools for learning, such as a syllabus, lesson plans, and student worksheets (SLS), based on the STEM-PBL model, to train critical thinking, creativity, and cognitive learning outcomes at SMAN 6 Malang.

Method

The conducted research is categorized as Research and Development (R&D) and focuses on the development of SLS. The products developed based on the STEM-PBL model on bacteria material. The development process follows the ADDIE development model, which was adapted from Branch's (2009) framework. This model comprises five stages: Analyze, Design, Develop, Implement, and Evaluate. The subjects of this study consisted of 43 participants at SMAN 6 Malang. The research was conducted only as a trial or formative evaluation in the development stage. Formative evaluation includes three stages of testing, namely the individual tests of 3 students, small group tests of 10 students, and large-scale tests of 30 students that have passed the material of bacteria.

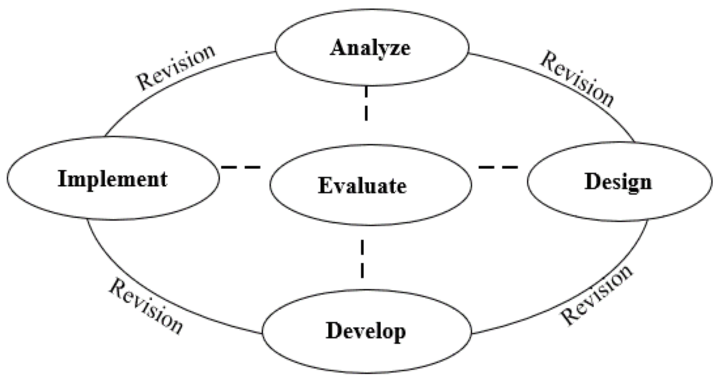


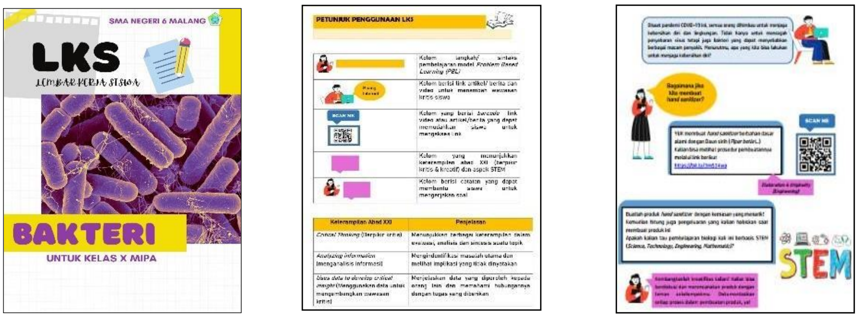
Figure 1. ADDIE model cycle (Branch, 2009)

The data collection process involved gathering both qualitative and quantitative data. Qualitative data were collected through input and suggestions from experts in learning tools, material experts, education practitioners, and 10th-grade science students. On the other hand, quantitative data were obtained from the expert validation results and the practicality response questionnaire for the students' worksheets. The assessment scale on expert validation and student responses uses a score with a scale of 1 to 4 with detailed scores from less (1), enough (2), good (3), and very good (4).

Results

The SLS developed was adapted based on the STEM-PBL model on bacteria material. The worksheets were developed with various student activities that train students' abilities on the material and project activities related to bacteria material (Figure 2). In each activity, there are indicators that show aspects of the skills being trained such as critical thinking aspects which refer to (Greenstein, 2012), and creative aspects which refer to

(Treffinger et al., 2002).



(a) (b) (c)

Figure 2. Student worksheets cover for bacterial material (a) Guidance and instructions (b) STEM-based activities (c)

The results of evaluations by material experts, learning experts, and field practitioners utilizing approval sheets are used to determine the validity of learning tools, which are then computed using percentage analysis by Akbar (2013). The average scores for the syllabus, lesson plans, and student worksheets were 99.58%, 99.75%, and 98.48%, respectively, according to the findings of the product validity test. However, a product redesign is necessary based on the validators' recommendations.

Table 1. The Validity Test Results.

Learning Tools	Material Experts	Learning Experts	Field Practitioner	Average (%)	Criteria
Syllabus	100.0	100.0	98.75	99.58	Very Valid
Lesson plans	100.0	99.25	100.0	99.75	Very Valid
Student worksheets	100.0	100.0	95.45	98.48	Very Valid

The practicality test was conducted through three stages which included individual tests, small group tests, and field tests (Table. 2). Practical results data were obtained from student response questionnaires which included indicators of ease of use, ease of understanding, attractiveness, 21st-century skills (critical and creative thinking), and STEM aspects. The practicality of learning tools in the form of worksheets is measured through a questionnaire response from 10th-grade students. The average score for the three stages of individual, small group, and field tests are 89.85%, 88.14%, and 89.08%, and shows that the worksheets that have been developed are included in the very practical category, meaning that these worksheets can be used.

Table 2. The Practicality Test Results.

Stages	Student Response (%)	Criteria
Individual tests	89.85	Very Valid
Small groups tests	88.14	Very Valid
Field tests	89.08	Very Valid

Discussion

The high value of the validity and practicality test of learning tools proves that the STEM-PBL model is in accordance with the assessment criteria for each validator which refers to Permendikbud No. 22 of 2016 concerning Basic and Secondary Education Standards which contains the systematics of learning tools (Permendikbud, 2016). Each competency achievement indicator is equipped with additional information on related STEM aspects. Competency achievement indicators show the abilities that will be carried out by students and become a reference for the extent to which students have achieved the basic competencies of a material (Sukmagati et al., 2020). Therefore, this syllabus will assist teachers in determining student competency outcomes that are integrated with STEM aspects.

The developed lesson plans are equipped with a description of STEM aspects on each formulated competency achievement indicator. STEM-based learning has many benefits, including enhancing students' skills by presenting them with a task that needs to be solved (Furner & Kumar, 2007; Stohlmann et al., 2012). The learning steps in the lesson plans are adapted to the PBL model and are equipped with information on aspects of critical and creative thinking skills that can be trained through the activities conducted. The Problem Based Learning (PBL) model greatly influences the course of the learning process. Through this model, students are invited to learn through the problems that are around them (Stockwell et al., 2015). The results obtained indicate that the student worksheets developed fulfil various aspects of the assessment. In addition to showing identity and conformity with the selected Basic Competencies (KD), student worksheets are also equipped with several components such as general instructions and instructions for using student worksheets. The general instructions outline how to work on the student worksheets, while the instructions for using the student worksheets present various symbols or icons and explanations of 21st-century skills that special students will encounter in these student sheets. Linguistic and graphic aspects are also considered, such as the use of language that is easy for students to understand, the sentences used are clear and precise, as well as colours and illustrations that attract students' interest (Sukmagati et al., 2020).

Teaching materials that attract students can increase student engagement so that it is easier for students to understand and absorb the material (Kelley & Knowles, 2016). Learning that integrates STEM can improve students' abilities and creativity in coming up with an idea or innovation in facing global challenges (Murnawianto et al., 2017). PBL is the best educational method for teaching actual, real-world problems that require interdisciplinary STEM (Smith et al., 2022). PBL model will encourage student-centred learning so that they are trained to always actively participate in discussion activities and solve problems given (Gordon et al., 2022). PBL requires students to actively participate in using their knowledge and conducting extensive research to learn more about the unstructured problem, then combining and employing metacognitive processes to address the difficulties, encouraging the use of higher-order thinking skills (Capraro et al., 2013; Gomez-del Rio & Rodriguez, 2022). The student worksheets also list learning steps that are in accordance with the PBL model. The problems in the student worksheets are real problems that students can find so that it is easier for students to process information and analyse a problem.

The PBL model, which can improve students' cognitive, is the most effective way to teach STEM subjects (Kusmahardhika et al., 2023). STEM places a strong emphasis on knowledge depth in the areas of linking new ideas to prior understanding, connecting information to practical applications, integrating knowledge in problem-solving, and critically evaluating the benefits and drawbacks of proposed solutions (Capraro et al., 2013). Students will be able to convey their thoughts, combine information from several subjects, and use technology to accelerate their learning by putting this style of learning into reality (Bear & Skorton, 2019; Lee et al., 2020).

Conclusion

STEM-based learning has many benefits, including enhancing students' skills by presenting them with a task that needs to be solved. The practicality of learning tools in the form of worksheets is measured through a questionnaire response from 10th-grade students. The average score for the three stages of individual, small group, and field tests is 89.85%, 88.14%, and 89.08%, respectively. It can be concluded that the development of STEM-PBL model on bacterial material is very valid and practical to train critical thinking skills, creative, and cognitive learning outcomes of 10th-grade students. However, to find out the accuracy of learning tools, further research is needed, especially in the implementation stage.

Recommendations

As for suggestions for further development, it can be implemented, evaluated, and disseminated products to wider targets as well as product development for different topics to decide the exactness of the STEM-PBL model in learning.

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The Development of Games-Based Learning Media in Terms of Students' Mathematical Reasoning

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Abstract: The research aimed to know the result of validity, practicality, and effectiveness of products from the development of games-based learning media in terms of students' mathematical reasoning on three-dimensional shapes. The type of research and development referred to ADDIE model which included five stages, namely analysis, design, development, implementation, and evaluation. The subjects of the research were the 25 VIII grades junior high school students in one of the junior high schools in Indonesia. The research instruments used were the validation questionnaire sheets, teacher responses questionnaire, and student responses questionnaire. The data collection used a Likert scale. Furthermore, the effectiveness data were collected from the post-test that was done by the student through learning media to know their mathematical reasoning abilities. Meanwhile, the data analysis technique used quantitative descriptive analysis. The result showed that media was very valid with an average of 91,86%. Moreover, it was very practical to see from the average of teacher response questionnaire which was 89,58%, and the average of student responses questionnaire which was 85,36%. The value of effectiveness was determined based on students' post-test scores which was 84%. Thus, it can be concluded that this media was effective to be applied as a learning media for junior high school.

Keywords: Blended learning, Learning media, Mathematical reasoning

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Introduction

The development of technology and information, in the 21st century, required the education system to adapt by integrating technology into the learning process. It is useful for improving the education quality under student characteristics in the current era. According to Purmadi et al. (2018), a learning model or media success depended on student characteristics. Today's, students have strong characteristics and interact through social media. They are very fluent in the use of technology, expressive, and always following global trends (Yanasari, 2021).

Learning activity that combines technological development and conventional learning is called blended learning. According to Rusman et al. (2012) blended learning is a combination of blended e-learning aspects in the form of web-based instruction, video streaming, audio, synchronous and asynchronous communication with face-to-face learning including teaching methods, theory, and pedagogic dimensions. This learning design provides the opportunity to learn with various learning sources to create a more effective learning environment for teachers and students. Sutopo (2012) said blended learning is a learning method that combines various methods and learning media.

Sharma (2010) described blended learning in 3 definitions, namely as a combination of face-to-face and online learning, a combination of technology, and a combination of teaching methods. The combination of face-to-face and online learning is a combination of traditional learning with online learning through technology or computer-based learning, such as involving a Virtual Learning Environment (VLE) and using synchronous and asynchronous electronic tools.

Furthermore, a combination of technologies means that the learning activity uses technology to overcome the limitations of space and time, especially in communication between teacher and student. Through blended learning, we can achieve the learning objectives maximally with more interactive, effective, and efficient learning. Sutopo (2012) said blended learning improves the quality and quantity of human interaction in the learning environment. The computer used in learning activities makes students and teachers interact more easily whenever and wherever they are. Then, a combination of methodologies means that the teacher combines several pedagogic approaches, for example involving transmission and constructivist approaches (Sharma, 2010).

Based on the description above, it can be concluded that blended learning is a learning design that combines learning aspects of face-to-face learning and online learning in the form of media, technologies, and learning approaches. Blended learning is structured by paying attention to the advantages of face-to-face learning and e-learning. In addition, according to Rusman et al. (2012), the advantages of blended learning include: (a) increasing the interaction between students, teachers, and instructors in learning activity; (b) enabling learning to occur anywhere and anytime; (c) reaching students in a wider range; (d) easy to refine and keep the learning materials.

Now, mathematics and technology are an inseparable part of our lives. 45% of the world’s population accessed the internet for mobility activity, online courses, and massive open online courses (Borba et al., 2016). There has been a significant increase with a database of statista.com which showed that 64,4% of the world’s population accessed the internet in January 2023. Based on data from Badan Pusat Statistik (BPS) for 2021, there were about 12,07% of Indonesian citizens used computers and 65,87% of Indonesian citizens used smartphones. In addition, based on the result of the Asosiasi Penyelenggara Jasa Internet Indonesia (APJII) survey, in early 2023 the internet user in Indonesia reached 78,19%. These data showed that technology and the internet are a necessity for people to facilitate their work, communicate, have fun, and learn.

Meanwhile, mathematics is a universal science that has an important role in human life, especially in technology development. Mathematics is also a science that provides provisions for humans to be able to face challenges in the era of globalization. Mashuri (2019) said that mathematics is useful for developing someone's intellect and as a fundamental science for the development of modern technological science. Mathematics equips students with logical thinking, analytical, systematic, critical, and creative thinking abilities so that students can solve the problems that they face in daily life.

(Hasanah et al., 2019) said students can develop themselves by practicing their abilities continuously through mathematics. Therefore, mathematics is a compulsory subject from elementary school to high school. It also shows that the integration of technology and mathematics is very influential in daily life. However, many students do not like mathematics because of the difficulty in mathematical reasoning to solve problems. As mentioned by Istikomah & Wahyuni (2018), the students do not like mathematics because they assume mathematics is an unpleasant subject, difficult to understand, and has difficult tasks and problems.

Mathematical understanding and mathematical reasoning are two things that cannot be separated. According to Hasanah et al. (2019) to understand mathematics, students need to reason, while reasoning is understanding and practicing mathematics. Students who have good reasoning skills can understand mathematical concepts more easily.

Mathematical reasoning means that someone carries out a process of logical thinking so that they can understand, think, prove, and evaluate mathematics. Mathematical reasoning is a thinking process that combines two or more thoughts to produce conclusions to create new knowledge (Hasanah et al., 2019). Reasoning ability is needed for solving mathematical problems during the process of understanding, planning the problem solving, solving the problems, and making the conclusion. In line with Bernard & Chotimah (2018) said that solving mathematical problems must involve reasoning. According to Bukhori (2018), the indicators of mathematical reasoning are finding patterns, formulating mathematical conjectures, and drawing conclusions based on valid arguments.

According to Abidin et al. (2020) one of the reasons students have difficulty in reasoning was that students are not given problems to develop their ability to guess, think logically, and draw conclusions from information. The given mathematics learning design presented material from the concepts, not from problems that may be encountered by students in their daily lives. Giving daily problems can develop students' ability to think logically, inductively, and deductively. Therefore, teachers need to make appropriate learning designs to support students' mathematical reasoning abilities. According to Bernard & Chotimah (2018), one of the factors that greatly influences students' mathematical abilities is the quality of learning mathematics.

One of the determining factors for the quality of learning is the selection of learning media. The learning media used must be able to connect the knowledge possessed by students in real situations with learning materials. In addition, the learning media should be adapted to current technological development. According to Abidin et al. (2020), learning media must facilitate students to think critically, creatively, and innovatively.

Based on the result of interviews with one of the mathematics teachers in one of the junior high schools in Indonesia, the teacher had never tried to use learning media that integrated with technology. The teacher conveyed abstract subjects by visualizing them through sketching on the blackboard. However, students still have difficulties in doing mathematical reasoning and lack the motivation in learning mathematics. Students have difficulty to imagining the elements needed to determine the surface area and volume of the 3D shapes. In addition, students also used the memorization method, so they found it difficult to do mathematical reasoning. The learning activity in the classroom also shows a lack of interaction between students and teachers, students and students, as well as students and the learning resources.

Digital games are used as effective media to improve students' mathematical reasoning abilities. Jensen & Skott (2022) said that digital games support the exploration of mathematical relationships, the framework that supports students' conjecturing and justification, as well as comparing and discussing different results from a game with other students. Digital games can support students' mathematical reasoning if the games present tasks that can bring up their discoveries about the mathematical relationships in the game. Moreover, the interaction in learning activities in the classroom must occur properly.

Several studies related to the use of game-based learning media in mathematics learning have been carried out and gave had a positive impact. Kartika et al. (2019), Saputro et al. (2018), and Rofiqoh et al. (2020) developed game-based learning media that can be played on computer devices. These studies show the same results, namely game-based learning media can facilitate students in learning mathematics, provide varied learning so students do not feel bored, and increase student motivation. Furthermore, interaction in learning activity was increased because students interact directly with learning resources and discuss with other students (Jensen & Skott, 2022; Kartika et al., 2019).

Based on the studies above, media development only focuses on evaluating game-based learning and is not equipped with material explanations. However, the games did not use the unlock-level system. The unlock level system can provide challenges to students to complete levels to foster students' competitive spirit. In this study, the games will be equipped with a level-unlock system and the effectiveness of media will assess in terms of mathematical reasoning.

Based on the description above, the title of this research is **The Development of Games-Based Learning Media in Terms of Students' Mathematical Reasoning**. The purpose of this study is to determine the result of validity, practicality, and effectiveness of games-based learning media in terms of students' mathematical reasoning. This media is expected to help students understand the concept of mathematical material so that they can do mathematical reasoning properly and correctly. Furthermore, it is also hoped that his media can increase students' motivation in learning mathematics and make learning activities more interactive.

Method

The Type of Research

The type of this research was Research and Development (R&D) which referred to ADDIE model which contains 5 stages, namely Analyze, Design, Develop, Implement, and Evaluate. ADDIE model is a well-adapted model, flexible, and effective, and also provides a structured general framework (Angko & Mustaji, 2013). Moreover, the ADDIE model has evaluation and revision at each step. The research object was game-based learning media on the flat side 3D shapes subject for VIII grades. The subjects of this research were the 25 VIII grades junior high school students in one of the junior high schools in Indonesia.

The instruments of this research were the questionnaire sheets and the test in learning media. There were three questionnaire sheets, namely the validity questionnaire sheet to measure the validity of media, the student responses, and the teacher response questionnaire sheets to measure the media's practicality. The data of validation and practicality of media were collected by using the Likert scale. Meanwhile, the effectiveness data were collected from the post-test that was done by the students through learning media. Then, the data analysis used a quantitative descriptive analysis technique.

The learning media was validated with 3 assessment aspects, namely media display, contents, and language aspects. The media was validated by 3 validators. According to (Akbar, 2013) the formula for measuring the result of validity is:

$$V = \frac{Tse}{Tsh} \times 100\%$$

Description:

V = The validity score

Tse = The empirical total score

Tsh = The maximum expected total score

Next, the validity score was connected with the validity criteria of learning media. According to Riduwan (Hidayati & Susanti, 2013), the validity criteria of learning media can be seen in Table 1.

Table 1. The Validity Criteria of Learning Media

Validity Score	Validity Criteria
76% - 100%	Very valid

51% - 75%	Valid
26% - 50%	Invalid
0% - 25%	Very invalid

Meanwhile, the practicality test aimed to know that media is practical to use and easy to understand so that students can understand the subjects and help teachers to deliver the subjects easily (Risnawati et al., 2019). According to Akbar (2013), the formula for measuring the result of practicality is:

$$P = \frac{Tse}{Tsh} \times 100\%$$

Description:

P = The practical score

Tse = The empirical total score

Tsh = The maximum expected total score

Then, the percentage of practicality was matched to the practicality criteria of learning media. According to Akbar (2013), the practicality criteria of learning media can be seen in Table 2.

Table 2. Practicality Criteria of Learning Media

Practicality Score	Practicality Criteria
75,01% - 100%	Very practical
50,01% - 75%	Practical
25,01% - 50%	Less practical
00,00% - 25%	Cannot be used

Furthermore, the data from the students' tests were used to measure the effectiveness of learning media. The result of the test that was done by students showed students' mathematical reasoning abilities. The score that showed that students pass the test was 75. So, the learning media was effective if 75% of the total students pass the test. The percentage of effectiveness of learning media can be found by formulas:

$$E = \frac{the\ number\ of\ students\ who\ pass\ the\ test}{the\ number\ of\ students\ who\ join\ the\ test} \times 100\%$$

Results

The product of this research was games-based learning media on the flat side 3D shapes subject for VIII grade students. The media can be run on a computer. The media was an interactive multimedia that provide game-based learning evaluation. Mathematics learning in the media was designed to support students' mathematical reasoning abilities. The development of games-based learning media in this research referred to ADDIE model.

In the first stages, the researcher analyzed the needs of teachers and students. The data were obtained from interviews with one of the mathematics teachers in one of Indonesia's junior high schools. The topics of the interview were about mathematics subjects being studied, the media used, and student characteristics. The result of the analysis stage showed that the 3D shapes were abstract subjects. Students have difficulty understanding the subjects because they have obstacles in reasoning to solve problems in this subject. Then, learning activities also needed media that can increase students' learning motivation to create an interactive learning environment.

In the next stages, the researcher designed the learning media. The necessary research instruments, such as the validity questionnaire, teacher and student response questionnaire, and test, were also made. The initial step taken was to arrange learning material to be presented in the learning media. The subject was 3D shapes which consists of 4 meetings, namely the areas of prism and pyramid as well as the volumes of prism and pyramid. Then, the researcher created the media prototypes. The design of the media display consists of the homepage, instruction page, subjects page, evaluation page, and researcher profile (see Figure 1). The evaluation page is a feature for students who conducted games-based tests independently. The games used a level unlock system where a higher level will be unlocked and can be played if students pass the previous level. If students fail at a level, students need to study again and repeat the evaluation.

Figure 1. The Learning Media Design

After that, the media was produced using Construct 2 software. The media production involved navigation button production and combined some text, images, animation, and audio. Then, the products of learning media were validated by 3 experts. The result of the media validity analysis was very valid with a percentage of 91,86% (see Table 3).

Table 3. The Result of Learning Media Validity

Media	Assessment (%)			Average (%)	Validity Criteria
	V_1	V_2	V_3		
1st meeting	85,23	93,18	98,86	92,42	Very valid
2nd meeting	85,23	90,91	98,86	91,67	Very valid
3rd meeting	85,23	89,77	98,86	91,29	Very valid
4th meeting	85,23	92,05	98,86	92,05	Very valid
Average				91,86	Very valid

Then, valid media can be tested at the implementation stage. Media was tested on 25 students in VIII grades in one of the junior high schools in Indonesia for 4 meetings. Students used the learning media for independent learning. Students played games when they carried out learning evaluations through media. At the last meeting, the students and teacher were given the students and teacher response questionnaires. Then, data from questionnaires were analyzed to determine the practicality of media. Table 4 shows the result of media practicality.

Table 4. The Result of Learning Media Practicality

Respondents	Average (100%)	Practicality Criteria
Teacher	89,58	Very practical
Peserta Didik	85,36	Very practical

Based on Table 4 we know that the average teacher response questionnaire was 89,58% with very practical criteria. In addition, the average of student responses questionnaires was 85,36% with very practical criteria. At this point, students found it difficult to understand the language used in media.

Meanwhile, the result of the student's test was used to determine the effectiveness of games-based learning media. The percentage of effective media was 84% so the games-based learning media was effective. That result also showed that the students' mathematics reasoning abilities were good.

At the evaluation stage, the media was revised based on the advice of experts. On the aspect of the media display, the media was revised in the layout section and color composition. In addition, some of the navigation buttons also need to be repaired because they do not work properly. On the content aspect, the validator suggested writing the units of length at the solution of the example problems so that the units of the area in the conclusion can be identified.

Discussion

The games-based learning media on the flat side 3D shapes for VIII grade students was the product of this research and development. The media was developed using the ADDIE model that consists of 5 stages, namely analyze, design, develop, implement, and evaluate. The result of the analysis stage showed that teachers and students need learning media that can help students understand the subjects easily. This media is expected to create interactive learning and can be used in blended learning.

The learning material was prepared before creating a media prototype. As Herlina et al. (2021) mentioned the material was prepared concerning core competencies, basic competencies, competency achievement indicators, and learning objectives. Thus, the games-based learning media are not only a tool because the media created with reference to learning objectives can be used effectively to improve the quality of learning.

The researcher produced media using Construct 2 software and it was quite easy to do. As Ridoi (2018) mentioned, this software has provided events and actions, behaviors, and various effects that can be used so that the projects can work properly. The user also does not need to know programming languages to create the media.

The result of validity was 91,86% which indicated that the games-based learning media was very valid. Moreover, the percentage of teacher response questionnaires was 89,58% and the percentage of student response questionnaires was 85,36%. It showed that the games-based learning media was very practical. Meanwhile, 80% of students passed the test. It means the games-based learning media was effectively used to help students learn 3D shapes subject. The media also can increase students' enthusiasm and interest.

According to students, learning activity using the media was fun because they played games for doing the test. An interactive learning process also occurred because apart from interacting directly with learning media, students also interacted with each other to get better learning outcomes. Jensen & Skott (2022) also said games can support students to experiment and explore when solving problems. This underlies the interaction and represents students' mathematical reasoning abilities.

Conclusion

Based on the result and discussion of the research, it can be concluded that the development of games-based learning media has tested its validity, practicality, and effectiveness. The learning media can be used to help teachers deliver subjects so that students can understand the subjects easily. The use of learning media allowed students to experiment, explore, and interact. It had an impact on students' mathematical reasoning abilities. So, students can solve problems and achieve good learning outcomes.

Recommendations

The advice for further research is to create an online scoring system so that student scores can be recorded directly into the teacher's database.

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The Importance of Improving Students' Decision-Making on Socio-scientific Issues about Climate Change

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Abstract: Decision-making is one of the important skills that must be possessed by students in the 21st century. One of the topics that require the right decision to be made for each challenge and the impact it will cause is climate change which has already occurred. This study aimed to find out how students' decision-making and the importance of improving these decision-making skills, especially in making decisions on socioscientific issues about climate change. Data collection was carried out for one day through questionnaires that were distributed directly to students. In total, 44 junior high school student respondents filled out the questionnaire in this study. The results showed that students made decisions based on their personal feelings and there were indicators of good decision-making that had not been trained in students. Meanwhile, students' knowledge of issues related to climate change was still in the low category. The findings above have implications for teacher strategies in training students' decision-making skills that must be optimized to forge the next generation who can accomplish the problems and make good decisions, especially on issues related to climate change.

Keywords: Students' decision making, Socio-scientific Issues, Climate Change

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Introduction

In the 21st century, science and technology continue to experience rapid development. Everything that was previously thought to be impossible, can now be realized due to the development of science and technology (Yılmaz, 2021). Current technology makes it possible to obtain information easily and quickly, so this is a challenge in itself to produce individuals who can keep up with the rapid spread of information. To help individuals with various challenges in the 21st century can be done through an educational process.

Various types of competencies must be mastered by individuals to survive during the onslaught of the 21st century. Competencies that are expected to be mastered are in the form of soft skills such as creative thinking, innovation, critical thinking, problem-solving, communication, and collaboration (Tuzel-Iseri, 2018). The future of education in the global context has two main goals (The Organization for Economic Cooperation and Development, 2021). First, education needs to be better prepared for the ongoing transformations in the economic, social, and technological fields. Education must develop to realize its mission of supporting individuals to develop as individuals, citizens, and professionals. A good understanding of how global conditions are today is the key. Second, education must be able to assist individuals in achieving the competencies needed to survive in this global era. Therefore, learning in the 21st century must be able to assist students in achieving the competencies needed to face global challenges, where these abilities are technology-oriented and high-order thinking skills.

Based on several competencies that must be mastered by students in facing the challenges of the 21st century, there are important competencies to be trained in students in the learning process, namely decision-making skills. Information in the digital era, which is very abundant and easily accessible, is a powerful tool for making decisions (The Organization for Economic Cooperation and Development, 2022). However, some problems arise, this fast and abundant access to information is a challenge in itself to be able to sort out correct and appropriate information. Therefore, training students in decision-making activities that involve the ability to filter information is very important.

In this modern and global era, it is very necessary to prepare a future society that cannot only be effective in preventing unwanted situations at the individual level but also be part of a society that can make fair decisions about how to reach an agreement on various issues on a large scale. locally or globally (Fang et al., 2019). Decision-making requires high-level skills and strategies that not everyone can develop naturally (Hsu & Lin, 2017). Therefore, it is very important to train decision-making skills for students because, in the 21st century, many problems require quick decisions and are accompanied by careful consideration. Decision-making ability is a process of identifying problems, integrating various information, and choosing the best option from the existing alternatives (Luan et al., 2022).

This decision-making ability requires higher-order thinking skills (Bayram-Jacobs et al., 2019; Kinslow et al., 2019). The decision-making process requires skills in gathering correct information about issues or phenomena and skills in critical and creative thinking so that they can solve problems with solutions. Thus, it is very important to train decision-making skills from an early age to prepare students to face future challenges that require the ability to be able to make the right decisions when facing a problem.

This decision-making ability is important to master to solve controversial issues which are dilemmas in society. In science learning, there are complex issues related to science that require solutions, often referred to as socio-scientific issues. Socioscientific issues (SSI) are a representation of issues in 4 societies related to natural science in a social aspect (Anagün & Özden, 2010). SSI gives students a role to think like scientists in solving social problems in society. Socioscientific issues (SSI) are complex issues related to science, socially relevant, generally requiring a level of moral reasoning in the process of arriving at a decision and having many solutions (Emery et al., 2017; Garrecht et al., 2020). Socioscientific issues including climate change, food and energy scarcity (Zaikauskaite et al., 2020), as well as decreased biodiversity and sustainable development, are complex issues related to society, science, and technology (Kinslow et al., 2019; Lee, 2007; Sutter et al., 2019).

Climate change is one of the global challenges in the 21st century and will have an even worse impact in the future if efforts are not made to address it (Putri et al., 2022). Climate change is a global challenge that impacts everyone, everywhere (United Nation, 2016). Climate change is a socioscientific issue (Zaikauskaite et al., 2020) that can have an impact on health, life, food security, water availability, and economic growth (Hicks, 2019). Currently, climate change continues to occur, while human attitudes and behavior have not changed much to reduce the impact of climate change (Hicks, 2019). Because in this research a study was conducted on the level of students' decision-making abilities and how important it is to improve these skills to deal with climate change problems that require appropriate solutions and decision-making.

Decision-Making on Socioscientific Issues

To produce the best and accountable decision, there are stages in making a decision. The stages of the decision-making process consist of seven steps, as follows: defining the problem, determining available options, determining criteria, surveying information, conducting analysis, making choices, and conducting reviews (evaluations) (Ratcliffe, 1997). According to Bersch and Herstroh (2005), the stages of decision-making process consist of three stages, as follows: 1) a pre-selectional phase, where students identify problems that require decisions, generate decision-making behavior, and seek information; 2) a selectional phase, where students compare and evaluate various options and reach a decision; and 3) a post-selectional phase, where students underline and defend the chosen decision. Decision-making activities start from defining the problem, making a list of possible solutions to the problem, determining the criteria for the solution to be selected, conducting an informal survey to support available options based on predetermined criteria, analyzing the choice of solutions, making decisions, and evaluating options. taken (Zhang & Hsu, 2019).

There are several examples of socioscientific issues that have been discussed in previous studies. Research conducted by (Gresch et al., 2017) on sustainable development. The first issue discussed was the protection of coral reefs, students were asked to determine steps to protect coral reefs. Then about the coal mining area, and decided on the problem of trout farming location. These topics were chosen because they were considered to be discussed from the point of view of various aspects that met the SSI topic standards. Meanwhile, research conducted by (Lee et al., 2019), raises socio-scientific issues related to shark hunting. This topic was chosen because culturally and economically closer to Hong Kong than the UK, shark fin is a cultural Chinese food consumed at special celebrations such as weddings or birthday parties. So culturally closer to China than

England. Currently, the number of sharks has decreased, so there must be action to reduce shark poaching. This might become a problem and cause different responses between HK and UK students, where HK students have a culture close to shark hunting. In the research, preliminary research was carried out to assess the importance of improving students' decision-making skills on socioscientific issues, especially the topic of climate change which is a dilemma in today's global society.

Method

In this study, data collection was carried out through questionnaires. The questionnaire contains closed-ended questions about how students make decisions and open-ended questions related to students' knowledge of climate change. Questionnaires were given to 44 junior high school students in Bandung City, Indonesia. The data obtained were then analyzed using a descriptive method that aims to describe the extent of students' decision-making abilities so that it will be seen how important it is to improve this ability based on their level of ability when this data is collected.

Results

Students' Decision-Making Skill

Based on the results of the questionnaire data obtained, 75% of students stated that they made decisions based on personal feelings and only 47.7% of students had ever made decisions about environmental issues such as climate change in science learning. The level of student decision-making ability is assessed based on whether or not students carry out the stages of decision-making when deciding something. These stages include defining the problem, seeking information related to the problem, listing possible solutions, seeking supporting information before making a decision, analyzing the advantages and disadvantages of each alternative solution, and evaluating the decisions that have been made. The following graph presents the percentage of students who have done each of these stages.

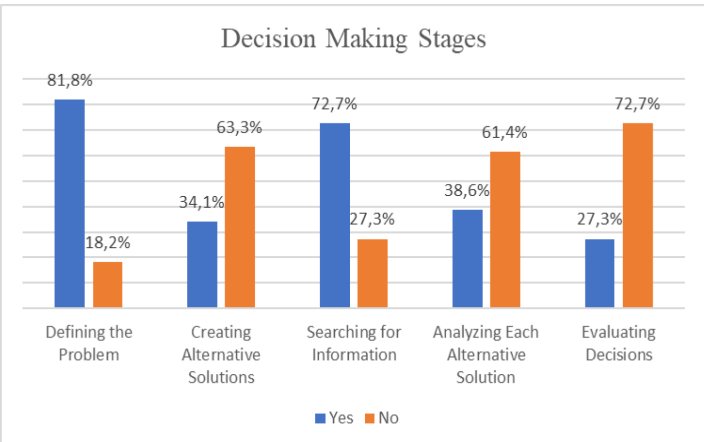

Figure 1. Stages of Student Decision Making

In the graph above, it can be seen that most of the students have done the first step in making decisions, namely as many as 81.2% of respondents, when faced with a dilemma students have already done finding out the essence of the problem and defining the problem. However, only 34.1% of the respondents carried out the second stage of making decisions, namely making alternative solutions to the problems they faced. After carrying out the first stage of making a decision, students immediately searched for information, this stage was carried out by 72.7% of respondents. Then, the stages of making decisions in the form of analyzing each alternative solution and evaluating the decisions that have been taken are also only carried out by 38.6% and 27.3% of respondents.

Student Knowledge of Climate Change

The questionnaire also presented questions to see how far students know about climate change. It was found that most of the students had heard about climate change and global warming, namely 90.9% of the respondents. They hear about climate change from the mass media and from learning at school. In the open-ended questions given to respondents about what is known about climate change, most of the students' answers focused on rising global temperatures and disasters caused by climate change. However, there are still 20.5% of respondents who think climate change is not a global problem and 32% of respondents have never decided on climate issues. In the next open-ended question, students are asked what kind of climate change issues they have ever decided, students explain the actions they are taking to help prevent climate change such as saving electricity and reducing the use of motorized vehicles.

Conclusion

Six stages need to be carried out to produce the best decision, namely defining the problem, determining alternative solutions, seeking information, evaluating each alternative solution, analyzing, making decisions, and evaluating decisions (Ratcliffe, 1997). These stages will be able to help to produce the best and most accountable decisions. Meanwhile, based on the data obtained, it was found that most students had not followed the decision-making stages properly, so the resulting decisions tended to be based solely on personal feelings without any analysis of the advantages and disadvantages of the resulting decisions. Climate change is also a topic that students are familiar with, however, their knowledge of climate change is limited to the increase in the earth's temperature and there is no awareness of the dilemma and worse impacts that can be caused by climate change. Therefore, based on the study results obtained, it appears that student's ability to make decisions has not been well trained, both in general decision-making and decision-making on environmental issues such as climate change. The results of this study indicate that further research is needed which aims to improve the decision-making skills of these students, especially for socioscientific issues regarding climate change.

It is very important to train students' decision-making skills on socioscientific issues about climate change. Climate change is a global issue that requires the best solutions and decisions in the present and the future.

Every individual must be able to work together to overcome this problem, including students. Training students to make decisions about socio-scientific issues of climate change that surround them will help students to be aware and sensitive to what disasters and impacts might have in their lives in the future. In addition, today's fast-paced global world requires individuals who can think quickly and make decisions in a solution, right, and efficiently. This research is expected to provide an overview to educators, that there are still weaknesses in student decision-making, so it is very important to train this ability in students.

Recommendations

Based on the results of this study, the researcher recommends further studies on innovations and the best learning strategies that can train students' decision-making skills, especially using the context of socioscientific issues regarding climate change. So that students can not only practice decision-making skills but at the same time can also build awareness that climate change is taking place and each individual is responsible for stopping it before it gets worse in the future.

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Analysis of The Prospective Chemistry Teacher Student's Competence in Developing Learning Implementation Plan (RPP): Case Study at Tanjungpura University

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Abstract: Learning needs to be well planned so that it can take place in accordance with the objectives to be achieved. This planning can be poured into the learning implementation plan (RPP) prepared by the teacher. Therefore, this study aims to describe the competence of prospective chemistry teacher students to prepare lesson plans using a scientific approach. The research was conducted using a descriptive-qualitative method. The research was conducted at Tanjungpura University with 28 respondents as research subjects. Data collection begins with the collection of the RPP that has been prepared, and then an analysis is carried out regarding the suitability of the RPP components using the RPP assessment sheet. The results of the study showed that the competence of prospective chemistry teacher students to prepare learning implementation plan (RPP) was in the "good" category, with a percentage of 81%. The biggest percentage is obtained in the aspects of determining core competency (KI) and basic competency (KD) and determining the learning medium used. While the lowest percentage is the aspect of compiling an assessment, which is still in the lower category with a percentage of 59%. Even though the competence of prospective chemistry teachers to prepare lesson plans as a whole is good, the suitability of the method with evaluation material for student assessment still needs to be improved so that it has implications for fulfilling the pedagogical competence of prospective chemistry teachers.

Keywords: Prospective Teacher, Competence, Learning Plans

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Introduction

A lesson needs to be planned or developed in order for the learning process to occur frequently and provide the desired outcomes. Every design or plan is always in line with the intended action. Making predictions about the actions to be taken while learning is known as planning. An educator must be familiar with the essential elements of lesson planning. According to Permendikbud (2019), learning planning includes crucial elements including learning objectives, activities, and assessment. Lesson plans, often referred to as RPPs (Learning Implementation Plans), are created by educators with the intention of serving as a roadmap for implementing learning in accordance with the acquisition of fundamental competencies. Teachers are required to create lesson plans (Permendikbud, 2016). Making lesson planning is a component of the Preparation of lesson plans is part of the professional duties of an educator (Ministry of Education and Culture Directorate General of Early Childhood Education, Basic Education, 2020).

This is in line with the concept that lesson planning plays a very important role in ensuring effective and quality teaching in all school subjects (König et al., 2021). It is a very important component in various education programs for prospective teachers around the world, especially in school practice activities (Munthe & Conway, 2017). Numerous factors affect the effectiveness of teaching and learning activities (KBM) in the classroom. The feature of teachers' readiness to carry out learning is one of them (Dewi, 2018). The Law No. 14 of 2005's definition of pedagogical competence for teachers is relevant here. One of the sub-competencies in pedagogic competence that a teacher must learn is the capacity to prepare lessons (Yuswono et al., 2014; Febriana et al., 2016). As a result, managing teaching and learning activities in the classroom requires careful consideration of a teacher's competency profile while creating a Learning Implementation Plan (RPP). The situation in the field demonstrates that many teachers still struggle to prepare teaching materials, such as lessons (Susena et al., 2016; Ernawati, 2017; Nurhaliza, 2020).

Before mentoring, the teacher's capacity for creating lesson plans is still low (Susetya, 2017; Mehram, 2018). There are many challenges involved in selecting the proper method to be used in the design, including deciding the method, describing SK/KI, describing KD, and explaining KD (Anugrahana, 2019). According to Susena et al. (2016), the majority of teachers still have trouble creating lesson plans, both in terms of their capacity to take into account the numerous competences that students must acquire and in terms of meeting various lesson planning principles. The imperfect learning process is influenced by the teacher's incapacity to decide on the many elements. On the basis of this, it is significant to recognize good competency in RPP preparation.

The accessibility of lesson plans created by the teacher is the best possible start to the learning process (Mawardi, 2019). When creating lesson plans, teachers should use their expertise as a guide to ensure that students are learning (Kaimuddin, 2011). The learning process will function more effectively the more teachers there are who are skilled at planning lessons. Being a teacher is one of the career profiles of graduate students at Tanjungpura University's Teaching and Education Faculty (FKIP). In order to prepare to become teachers, students must be able to grasp a number of skills and abilities that can support their professionalism. Therefore, the practice of preparing lesson plans as a performance performance really needs to be implemented for these prospective teachers so that they are skilled and have good competence when they become teachers in the future. Chemistry lessons as one of the subjects programmed at every level of secondary education also really need teachers who are skilled in planning lessons. The initial competencies possessed by prospective chemistry teacher students can be known in advance through a performance analysis study. Based on the explanation above, research was carried out with the aim of analyzing the competence of biology students in preparing lesson plans.

Method

The research was conducted using a descriptive qualitative method. The research was conducted at the Chemistry Education Study Program, Tanjungpura University. The subjects in this study were 28 chemistry teacher candidate students who had taken the Chemistry Teaching Basic Competency course. Data on performance results shown as a form of student competency level is obtained from the value of preparing the lesson plans that have been made previously. RPP documents prepared are assessed using the RPP assessment instrument sheet. Data analysis was carried out in a categorical descriptive manner with reference to the four categories (Table 1).

Table 1. RPP Assessment Criteria

Persentage	Criteria
$80 \leq x \geq 100$	Good (A)
$60 \leq x \geq 79$	Medium (B)
$40 \leq x \geq 59$	Low (C)
< 40	Very Low (D)

Based on the analysis above, students are declared to have good skills if the average score obtained is ≥ 80.

Competence of Prospective Chemistry Teachers in Developing Lesson Plans for Every Aspect

A well-considered lesson plan has the potential to be a factor influencing the improvement of teaching quality (Stein et al., 1996) as well as providing a solid foundation for implementing classroom learning (Li et al., 2009). Student competence in preparing lesson plans in this study was reviewed in 9 aspects, namely 1) Completeness of RPP Identity, 2) Formulation of Core Competency (KI) and Basic Competence (KD); 3) Formulation of Indicators; 4) Formulation of Goals; 5) Selection of Material; 6) Determination of Learning Methods; 7) Selection of Learning Resources; 8) Selection of Learning Media; 9) Learning Steps; and 10) Assessment. This can be seen in Table 2.

Table 2. Competence Of Prospective Chemistry Teachers in Developing Lesson Plans for Every Aspect

No	Aspect of RPP	%Skor	Categori
1	Completeness of RPP Identity	93	Good
2	Formulation of Core Competency (KI) and Basic Competence (KD)	100	Good
3	Formulation of Indicators	85	Good

4	Formulation of Goals	87	Good
5	Selection of Material	80	Good
6	Dete rmination of Learning Methods	84	Good
7	Selection of Learning Resources	100	Good
8	Selection of Learning Media	68	Medium
9	Learning Steps	72	Medium
10	Assessment	59	Low

In table 2, it can be seen that there is one competency aspect that is still classified as a low category, namely the assessment aspect. While the categories that are classified as sufficient are in two aspects, namely aspects of selecting learning resources and learning steps. In general, there are several aspects in the lesson plans that need to be improved, especially in the selection of learning media, learning steps, and assessment. Efforts are needed to further improve the completeness and quality in these aspects to improve the effectiveness and quality of learning.

Discussion

Analysis of The Prospective Chemistry Teacher Student's Competence in Developing Learning Implementation Plan (RPP)

According to Suciati, R., and Astuti, Y. (2016), learning will increase, be effective, smooth, and optimal if there is a lesson plan so that learning objectives can be achieved. RPP is very useful for teachers in teaching students because it reflects the actual conditions in the class to be taught. Develop lesson plans in an effort to realize the comprehensive capabilities of an educator. Because this ability can lead educators to become professionals. A RPP must be made before learning so that the implementation of learning is effective (Ali Arman, 2016).

Check out the most recent 2013 Curriculum Lesson Plan that was adopted from the 2013 Curriculum Technical Guidance Worksheet that the researcher amended. An average score of 81 lesson plans was derived from this study. This finding suggests that chemistry students' ability to create lesson plans is fairly strong. Additionally, Figure 2 illustrates how students aspiring to become chemistry teachers are categorized into two categories based on their ability to create lesson plans, sufficient and good. There were no categories for very little and very little in this study.

Based on this information, it can be seen that chemistry majors who aspire to become teachers generally have a high level of ability when it comes to creating lesson plans, however some students still require more extensive instruction. Additionally, as lesson plans serve as guidelines for instruction, having greater proficiency in this area is an essential pedagogic ability for aspiring instructors. Because the various flaws still exist, research has shown that teachers have difficulty deciding how much time to devote to a lesson, setting indicators, selecting methods, strategies, and media, as well as determining whether learning syntax will be compatible with the model they have chosen and designing the evaluation tools that will be used in their instruction (Kinasih, 2017; Ernawati & Rini, 2017; Kurniawati, 2018; Palobo et al., 2018; Jayanti, 2020). Because the various deficiencies that still exist are in line with the results of research which obtained data that teachers experience problems in terms of determining the time allocation for presenting a material, setting indicators, choosing methods, strategies, media, the suitability of learning syntax with the chosen model and designing instruments evaluation that will be used in teaching and learning activities

Analysis of The Prospective Chemistry Teacher Student's Competence in Developing Learning Implementation Plan (RPP) for Every Aspect

The competence to plan learning is the most crucial aspect of a teacher's job that affects pupils' learning processes (Straessle, 2014). The teacher should be competent in planning every aspect of the teaching and learning process in the classroom in an effort to facilitate the best possible learning process. The teacher is in charge of making sure that the pupils master the competency goals both during and after learning activities. As part of the process to determine how well students comprehend lesson plans, Tadris Biology students—who in this case are prospective teachers—were evaluated on their ability to create lesson plans. Further analysis referring to table 2 can be explained as follows:

Completeness of RPP Identity

Students include the RPP identify accurately and clearly. The RPP identity's inclusion yielded a score of 93. (good). RPP at least includes school information (school name, subject, class or semester, topic, and time allocation) (Bariyah, 2014).

Formulation of Indicators and Formulation of Goals

The score for the inclusion of indicators and learning objectives is 85 (good) and 87 (good). Indicators and learning objectives are made based on basic competence (KD). KD as the achievement of minimum standards by students. KD achievement can be derived through indicators and learning objectives based on educators in building the abilities of their students (Fitriyah & Wardana, 2019). Even though it is classified as a good category, some students still have difficulties when they have to make indicators and learning objectives based on basic competencies (KD). Students still need to understand about indicators and learning objectives. Weaknesses of students in making indicators and learning objectives lie in the elements of behavior (the formulation of student behavior in observing the learning process using verbs) and content (material which includes knowledge, attitudes and skills). Students still need more intensive training in making indicators and learning objectives. Because learning objectives are also an important component in lesson plans. Wikanengsih, Nofiyanti, Ismayani, & Permana (2015), learning objectives are in the form of an overview of the achievement of the process and learning outcomes of students according to basic competencies. A mandatory learning objective for the achievement of an indicator. In determining the goals and indicators students have referred to the ABCD format. In line with the findings of Wulandari (2019), which obtained maximum results, all students were able to determine the formulation of learning objectives following the ABCD format.

Selection of Material and Selection of Learning Resources

The score for the elaboration of subject matter is 80 (good) while the selection of learning resources is 68 (enough). Student teacher candidates are good when describing the scope of material that is in accordance with indicators of achieving competence. Students need more practice when they have to relate material to other knowledge according to the realities of life. Basically, learning materials must contain the relevance of concepts, principles, facts and procedures that are written based on the formulation of competency achievement indicators (Permendikbud Number 22 of 2016). However, in choosing the learning resources used, it is still in the sufficient category. This is because prospective chemistry teacher students in determining learning resources only focus on books (not varied), do not explore materials that are relevant to material such as articles or journals. In addition, students also do not include complete learning resource identities according to the instrument. According to (Kusumah, 2008), the use of various learning resources will provide many opportunities for students to be able to interact actively with these learning resources.

Determination of Learning Methods

The approach that includes the learning model receives a score of 84. (good). The cooperative learning method combined with the inquiry learning model is one example. Students must be able to choose the method to be used in learning from the beginning of creating lesson plans, but it must be in accordance with a scientific approach. Although the methods and models that the students listed are good, the stages of learning that have been prepared show that the methods still do not match the features of learning. The appropriateness of methods and models with indicators, objectives, and learning materials must be taken into consideration while establishing learning techniques and models, claim Natalina, Darmawati, and Yarini (2016).

Selection of Learning Media

Media selection receives a score of 100. (good). The learning media that students included into the lesson plans they created were still deemed to be of high quality. Students are able to choose the right learning tools, like simple practical exercises and the usage of technology, like powerpoint (PPT). The media must be chosen in a way that is appropriate for the students' characteristics, learning objectives, and competencies (Wikanengsih et al., 2015). The utilization of educational media will increase students' interest, optimism, and readiness to learn

(Bariyah, 2014). The main principle that must be considered in the use of media is that the media is used and directed to make it easier for students to learn in an effort to understand the subject matter. Thus, the use of media must be viewed from the point of view of student needs (Suyanti, 2010).

Learning Steps

The score for the elaboration of learning activities is 72 (enough). In general, students are good enough when describing learning activities which consist of the initial stage (delivering apperceptions and objectives to be learned), the core and closing stages. Learning activities include an introduction that must have motivation, core activities and closing activities (Natalina et al., 2016). Preliminary activities are the beginning of opening learning by motivating, creating readiness and creating fun learning, linking the material to learning materials, explaining learning objectives, explaining learning activities (Sukirman, D., & Kasmad, 2006). Several students just included greetings and student attendance in the RPP, while others included introduction activities without giving thought to the content that will be presented. There were other students who merely incorporated the delivery of learning objectives in the preliminary activities. According to Mulyasa (2004), relating course material to prior knowledge and experience can foster active and student-centered learning environments. Additionally, Rusman (2011) argued that instructional materials should be connected to students' lived experiences because knowledge cannot simply be imparted by teachers; rather, students must interpret it for themselves. When providing lessons, some of the main activities that students included were effective when using the media. However, creating learning processes that are in line with a scientific method is something that future chemistry teachers' pupils still need to work on. The selection of learning activities that are packed in a pleasant way to accommodate 4C abilities, character education, and more optimal optimization in the use of prepared media is frequently not in agreement with the nature of the scientific method. The main activities of the lesson should be able to condition enjoyable, engaging, and inspirational learning in order to inspire students to be independent and creative, according to Sukirman, D., & Kasmad (2006).

The closing activities have also been nicely planned. Some have incorporated reflections and drawn a conclusion to the topic, while others have just provided homework for the following meeting without drawing any substantive conclusions. According to Sukirman, D., & Kasmad (2006), closing activities give an overview of the learning activities based on how well students did in the cognitive, affective, and psychomotor areas that they had learnt. By calling the meeting to a close and assigning exams or assignments for the next meeting, closing activities can be completed.

Assessment

The score for determining the assessment is 59 (less). The assessment listed in the student lesson plan is the least important aspect. This is due to students' failure to fully compile the assessment needs as a barometer of learning achievement as chemistry teacher candidates. The components that many students forget when developing assessments in lesson plans are the test questions, clear and systematic key answer instruments, and remedial guidelines. The answer key instruments or assessment rubrics prepared by students are still incomplete because they are only described briefly and do not accommodate all of the predictions of the answers that will be given by students. However, there were also students who completely included their assessment rubric but did not prepare remedial and enrichment guidelines. Both of these things are very important. Included in the RPP is an assessment that must pay attention to the assessment technique, as well as an assessment rubric and indicators (Natalina et al., 2016). In addition, in the aspect of student assessment, they are still unable to create tests that are in accordance with the objectives and indicators that have been formulated previously, which can be seen in the nature of the High Order Thinking Skills (HOTS) questions, which do not accommodate taxonomic bloom levels, especially at the analyzing level (C4). evaluate (C5), and create (C6).

The absence of a comprehensive understanding of the various components of lesson plans is a problem faced by teachers (Mawardi, 2019). This is relevant to the findings in this study, where there are various obstacles found by prospective chemistry teachers who are still categorized as having poor competence. In the end, various errors were found when the RPP document was reviewed. As a result, prospective chemistry teachers' abilities must be developed beginning in college, particularly in terms of their pedagogical abilities as a future provision when becoming a teacher. One of the most important is developing a learning implementation plan (RPP), which is a guide for teaching. According to Anggraeni & Akbar (2018), a teacher is required to have teaching guidelines contained in lesson plans so that learning objectives are achieved and directed. Lesson plans assist teachers in delving deeper into learning materials, how to convey material, and how to assess student learning success based on predetermined goals (Shen, 2007). The ability to create lesson plans is one of the indicators of a teacher's professionalism in the classroom (Kartawagiran, 2011). The better the teacher's competency in compiling the lesson plan document, the more proven the professionalism of the teacher is. It is also assumed that learning will take place better because maximum preparation has been made.

Conclusion

Based on the research results, it can be concluded that the competence of students as chemistry teacher candidates in developing lesson plans (RPP) is quite good, with the scope that there are two categories in it, namely the sufficient category and the good category. The first category is those who have good competence, namely 60%. The second category is classified as having sufficient competence (40%). However, while prospective chemistry teachers' ability to prepare lesson plans in general is good, students' understanding and mastery must be constantly improved and prepared, particularly in terms of the suitability of methods with student evaluation materials. This is shown because it can have implications for fulfilling the pedagogic abilities of prospective chemistry teachers in the future. One way to deal with students who are still categorized as lacking competence in compiling lesson plans is that lecturers can provide further guidance or direct peer tutors to assist those concerned so that they are more skilled and can improve their competence in preparing lesson plans.

Recommendations

Based on the results of the research and conclusions, several things can be recommended so that chemistry education students at FKIP Tanjungpura University have the ability both in terms of knowledge and skills in preparing lesson plans, namely, the provision of knowledge and understanding of lesson plans that are in line with government policies regarding the applied curriculum. This is because the curriculum in Indonesia changes frequently, so student teacher candidates must be prepared for the circumstances and educational situation.

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Arabic Language Learning Video Media Model for Speaking Skills for Eight Grade Students at MTS Negeri 39 Jakarta

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Abstract: Innovative learning media are very important in supporting the learning process, including learning Arabic. Therefore, this study aims to develop video media for learning speaking skills as a medium for learning speaking skills for seventh grade students at MTs Negeri 39 Jakarta. The research was conducted using the Research and Development (R&D) method with the ADDIE model (Analyze, Design, Development, Implementation, and Evaluate). The stages carried out in the research were: (1) analyzing the needs of seventh grade students for Arabic learning video media; (2) designing products; (3) developing products through assessments from material experts and media experts; (4) implementing products directly to students; and (5) evaluating products through a questionnaire given to 30 students in seventh grade. The results of the study showed that: 1) Based on the needs analysis of 30 students, it was found that 93% of students expressed interest in and needed Arabic learning video media. 2) Based on the results of the questionnaire distributed to experts, the average score for the material category was 80%, which was included in the "very eligible" category. The media category received 96%, which also included the categories "very feasible" and 3). Based on the evaluation given by the students, an average score of 85% was obtained, which was included in the "very eligible" group. Thus, this Arabic language learning video medium is feasible to be used as an Arabic learning medium, especially in distance learning, so that it can have implications for supporting the student learning process.

Keywords: Learning Media, Video, Arabic, Speaking Skills

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Introduction

Education disruption is a social phenomenon in the modern era. As Yoga (2017, 2018) showed, social phenomena related to disruptions in education still occur in the 21st century. There are four aspects of education disruption. Among them are students, parents, technology, and skills. The focus today is technology, especially during a pandemic like today. Teachers are required to be able to do online learning, which really requires the use of technology. Learning on the Internet is something new in the process of teaching and learning, especially in Indonesia since the era of the pandemic caused by the Corona virus (19). Learning on the Internet means the process of teaching and learning that uses information technology, and in this case, the Internet is used as a means of communication, interaction, and facilitation. In the educational process of the Arabic language, there are four skills that must be mastered: the listening skill, the speaking skill, the reading skill, and the writing skill. These four skills are linked together. To master the Arabic language, students must master all skills.

Nour Hadi recognized that speech is one of the most important forms of linguistic activity for children and adults. People used to use speech more than writing, that is, they spoke more than they wrote, and we could then consider speech to be the primary form of communication for humans. The areas of life in which a person practices speech or oral expression have multiplied. We speak with friends, sell, and buy, and ask about events, times, places, and so on, all by means of speech. According to this definition, speech is a means of communication between an individual and others for the speaker's spoken message to be understood.

The complex problems in the process of teaching the Arabic language were fundamental. The many influences were either internal elements derived from the students, who do not motivate and do not like to study the Arabic language, or external elements derived from the cases, including the teacher, who is an important element as the primary player in the process of teaching the Arabic language. Other than that, the material and the means of illustration contribute to determining the success of the educational process.

Clarification aids of various types, including audio and visual, are presented to facilitate the process of education because they can motivate students and challenge their absorption and reservations, helping the teacher communicate the tangible lesson to students and achieving the goals of teaching the Arabic language comprehensively.

As mentioned earlier, the educational medium has different forms. Among them is audiovisual. Febliza and Afdal (2015: 50) state that audio-visual media is a means of learning using the medium that contains sounds and images, where the process of absorbing materials involves the senses of sight and hearing. One of them is video. Now, video is an accessible educational method. There is no need to use VCD or DVD anymore. Just by using the YouTube platform, the videos can be easily accessed. As a result of the accessibility of this video, it is undeniable that the most effective teaching medium used today is video. Besides the current pandemic situation, students are required to be able to access their learning materials and are often required to study them on their own at home. Therefore, students need learning materials included in the learning medium that are accessible and interactive to increase their interest in learning.

The development is done to make the educational medium attractive. An engaging learning medium and methods will facilitate teachers' efforts to increase students' motivation and comprehension of the learning material. The lack of developing a video-based Arabic teaching aid that is engaging, interactive, and easy to understand, as well as the need for a learning medium during online learning, especially for Arabic speaking skills in State High School 39 Jakarta, is the criterion used by the authors to develop instructional videos for students.

Based on the practical teaching experience at Government High School 39 in Jakarta, it is easy for class 8 students to understand the illustrated material, especially for Arabic speaking skills, through the medium of video learning. Therefore, the researcher is interested in developing a video learning aid that students can use independently so that students can easily understand the subject of the Arabic language, especially for speaking skills. The media is a video-based educational tool that helps students understand the subject of the Arabic language, especially for the skill of speaking the Arabic language in the eighth grade.

Method

Development Research Method

Research is an activity of collecting, processing, analyzing, and presenting data that is carried out systematically and objectively to solve a problem or test a hypothesis to develop general principles, while development is a process or method used to develop something to be good or perfect. If the meaning of research and the meaning of development are linked in one word, which is research and development, then it can be interpreted as "the collection, processing, analysis, and presentation of data activities carried out systematically and objectively accompanied by activities to develop a product to solve a problem you encounter."

The definition of the term "developmental research" is difficult to distinguish from "research and development" because these two terms refer to the same thing, that is, the results of conducting research under these two terms can contribute to science (theoretical contributions) that are equally important. by being able to also contribute to product improvement (practical contributions). For example, according to the Puslitjaknov team (2008), the idea of development research in the field of education (in research on developing learning innovation) is a research method with three main components, namely: (1) a development model; (2) a development procedure; and (3) prototype testing or product development. Meanwhile, Borg and Gall (1983) state: "Educational research and development, R & D, is a process used to develop and validate educational products" (the process used to develop and validate educational products); Jay Mills & Erasian (2009) stated: "...the process of researching consumer needs and then developing products to fulfill those needs. The purpose of R&D efforts in education is not to formulate or test theory but to develop effective products for use in schools (the process of researching customer needs and then developing products to meet those needs). The aim of research and development in education is not to formulate or test theory but to develop effective products for use in schools).

Research Aims

The purpose of this study is to create an educational method, the Arabic language video, to improve the speaking skills of students in the eighth grade at Jakarta's government secondary school 39, and to obtain:

1. Analyzing the needs of students in the eighth grade at Jakarta's government secondary school 39 in terms of the Arabic language video educational method for speaking skills.
2. The creation of an educational tool, an Arabic language video, to improve the speaking skills of students in the eighth grade at Jakarta's government secondary school 39.
3. Creating an educational method, an Arabic language video, for students in the eighth grade at Government Secondary School 39 in Jakarta.
4. Experimenting with an educational method—an Arabic language video—to improve the speaking skills of eighth-grade students at Government Secondary School 39 Jakarta.
5. Evaluation of the production of the educational method, the Arabic language video, for the eighth grade students of the government secondary school 39 Jakarta's speaking skills.

Research Method

In this study, the researchers used a research model adapted from the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) research development model. This ADDIE model started in the 1990s and was developed by Dick and Carrie. The researcher chose to use the ADDIE research model as a guide for developing effective learning media. In addition, the ADDIE research model has clear research stages so that it is easy to understand and apply. The ADDIE research model is often used by other researchers until its efficacy has been demonstrated.

An example of a systematic, effective, and efficient development model is "ADDIE." The word "ADDIE" is an abbreviation from the English language for the steps that take place in the field of development; (evaluation). Here are the steps to using the ADDIE development model:

1. The analysis stage: the researcher analyzes needs, analyzes tasks, and identifies learning problems.
2. In the design phase, researchers develop learning plans, formulate learning objectives, and need to consider relevant learning resources.
3. The development stage, in this stage, the researcher develops the educational media that were designed in the design stage.
4. The implementation stage, in which the researcher implements the learning system that was created.
5. At the evaluation stage, the researcher performs an evaluation to see if the learning system or the product made is successful or not.

Results

Data Description

The focus of this research is on how to use educational videos in Arabic to develop speaking skills among eighth grade students at the Islamic State Middle School 39 in Jakarta. And the subject of it consists of an expert in educational materials (the teacher of the Arabic language lesson in the Islamic State Middle School 39 in Jakarta) and an expert in the method (the lecture of the Department of Arabic Language Education at Jakarta State University) and 30 students from the eighth grade in the Government Islamic Intermediate School 39 in Jakarta. The collected data provided a description, and the description of the data from this research consists of the result table and Histkrem, which the researcher will discuss in this section.

The data on the educational method for the skill of speaking Arabic in the educational video for the students of the eighth grade in the public Islamic middle school in Jakarta consists of 13 statements on the aspect of education (questionnaire of the materials expert) and 21 statements on the aspect of the method (questionnaire of the expert of the method). There are two forms of estimation, with five answers, the highest is 5 and the lowest is 1, and with four alternative answers, the highest is 4 and the lowest is 1.

Data Analysis

The development of the language educational video teaching aid followed the ADDIE development model, which consists of five stages: analysis of needs, production design, production development, production experience, and production evaluation. The residence information is as follows:

Need Analysis

At this stage, the researcher analyzes the learning objectives that will be achieved through the learning implementation plan created before the learning process. Then the researcher conducted an unstructured interview with the Arabic language teacher about how the teaching process is for the Arabic language lesson at the Government Islamic Intermediate School 39 in Jakarta, the students' responses during the education process, and the problems that occur during the learning process, whether in terms of teachers, students, or the means, especially in distance learning.

The researcher found specific problems in the educational process for the Arabic language lesson. Teachers face difficulty in making the educational method exciting, attractive, and appropriate for the distance learning system, given the limited skills in mastering today's technology and the limited free time because they must divide the time between preparing the educational method and taking care of the home. Therefore, many teachers use PowerPoint slides equipped with sound recording because it is an easy educational tool to use and create. Then the researcher distributed the questionnaire to the students. And the distribution of a questionnaire to thirty Islamic governmental middle school students in the eighth semester to determine their need to develop an educational method, the Arabic language video. The researcher got the result as follows:

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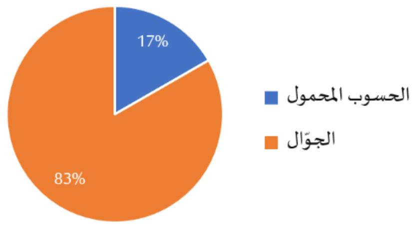
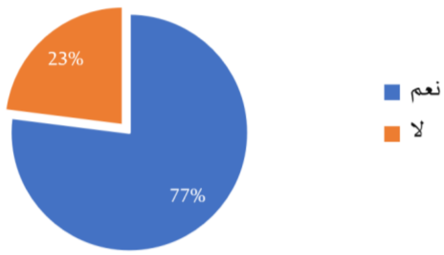
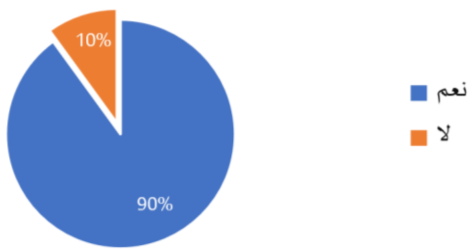
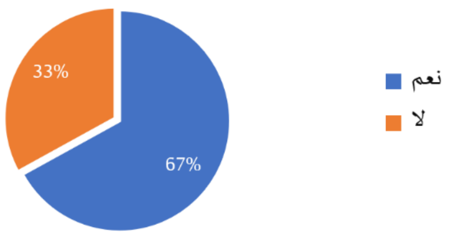
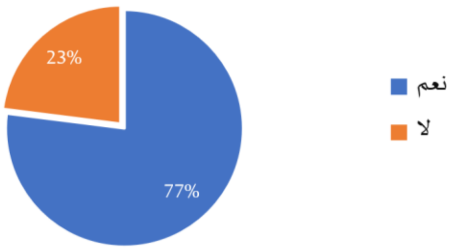
Table 1. Result of the questionnaire

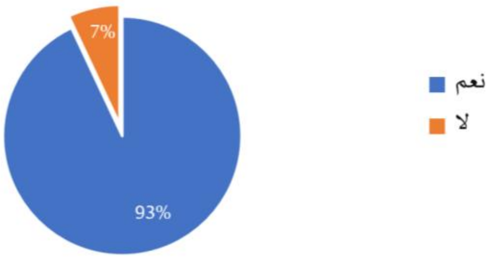
Question	Graph	Graph Description
What devices do you use for distance learning?		Based on the chart above, most of them answered the laptop with a score of 17%, and most of them answered the mobile with a score of 83%.
Did the teaching aids used in your school make the Arabic lessons easier to understand?		Based on the chart above, most of them answered yes with a score of 77%, and most of them answered no with a score of 23%.
Do you feel happy if you use a variety of educational tools to learn Arabic?		Based on the chart above, most of them answered yes with a score of 90%, and most of them answered no with a score of 10%.
Do you need another educational tool to learn Arabic?		Based on the chart above, most of them answered yes with a score of 67%, and most of them answered no with a score of 33%.

Have teachers in the school ever used the medium when learning the Arabic language?



Based on the chart above, most of them answered yes with a score of 77%, and most of them answered no with a score of 23%.

Are you interested in learning Arabic through media such as interactive educational videos?



Based on the chart above, most of them answered yes with a score of 93%, and most of them answered no with a score of 7%.

Product Design

At this stage, the researcher conducted an analysis of the educational materials used during two semesters of Arabic language lessons at the 39th Government Middle School Jakarta in the latest book published by the Director of Curriculum, Facilities, Institutions, and Student Affairs (KSKK Madrasah), Ministry of Religious Affairs.

The physical chapters in this book, which are included in the video, consist of four topics: the clock, our diaries, hobbies, and sports. This video's product content contains a brief explanation of vocabulary material and conversational dialogue. At this point, the researcher prepares to craft content material prior to the video creation process, as shown below:

Figure 1. Project Teaching Materials

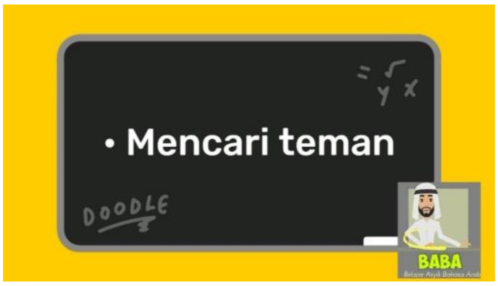
Then the next stage is the process of creating a storyboard. Here is the illustrated story from one of the topics in the Arabic book chapter eight, which is "Sports".

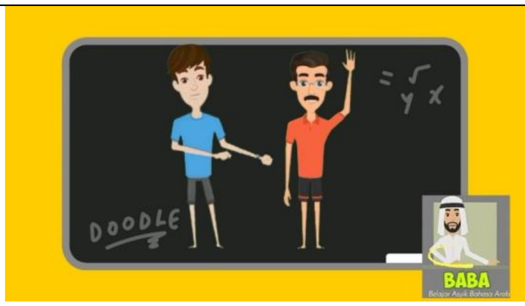
Table 2. Illustrated step development

Statement	Picture	Sounds
An overview instructional video	 	Back sound and audio explanation for the beginning of the video.
The narrator opens the video tutorial by saying "Sports".	   	Backsound and phonetic pronunciation of "Sports" and explain it.

The narrator introduces the material from the dialogue.		Background sound.
Shows the animated characters who will play a role in the dialogue.		Background sound.
Displays a conversational dialogue between the animated characters.		Back audio and dialogue pronunciation
The narrator introduces the material with the word "training"		Background sound.
The narrator introduces the material with the words "Exercise 1"		Background sound.

The narrator explains the directions for the first exercise.		Background audio and audio caption material.
Displays a conversational dialogue between the animated characters.		Back audio as well as audio pronunciation of dialogue.
The narrator introduces the material with the words "Training 2".		Back sound
The narrator explains the directions for the second exercise.		Background audio and audio caption material.
Displays an animated character chat dialog with the text of one of the committed characters.	 	Back audio as well as audio pronunciation of dialogue.

The narrator introduces the material with the words "Exercise 2".		Background sound.
The narrator asks about the students' abilities and explains the directions for the third exercise.	   	Background audio and audio caption material

		
End of the video tutorial	   	Background audio and audio caption material

Production Development

The next step was for the researcher to conduct an educational video production activity in which the creation of the medium was adapted to the scenario that was designed and evaluated by the experts. This activity is carried out using tools in the form of questionnaires aimed at obtaining advice and responses on the feasibility of the video before testing it in the field. The method has been developed with the instructional video according to the development procedures that have been validated by the materials experts and the method experts. The process of producing a video teaching aid consists of three stages: the pre-production stage, the production stage, and the post-production stage. The pre-production stage begins by preparing all the tools needed to create the educational tool, whether hardware or software. The physical components consist of a mobile device, a computer, and a mouse, while the software consists of many programs that support the medium to be packaged as needed, namely Animaker, Kinemaster, Adobe Premiere Pro, and Filmora.

Then the production phase is the video creation phase, as already envisioned on the storyboard in the design phase, where there is video production design from start to finish. The next step is to create animations in Animaker online.

Starting from the characters to the animated background. After completing the animation, the researcher downloaded the video. I kept adding video sections like "Exercise 1" etc. into Kinemaster. It is the process of inputting a narrator's voice as well as animation, video background audio, and inputting subtitles using Adobe Premiere Pro. In the final stage, the researcher edited the video in the Filmora application to add dialogue text.

The final stage of this development is post-production where the activity is to review and evaluate the means that have been produced, the main activity in post-production is the validation of video tutorials. The source consists of the educational materials expert and the method expert. The educational method must pass the validation stage because the method at this stage is reviewed by the validity checker and corrected by the researcher so that it is considered possible for use in learning.

Correction from a material expert

At this stage, the material correction involves Mrs. Dewi Yuliana MA, an expert in educational materials, who teaches Arabic at the Government Intermediate School 39 Jakarta. The material in this study was validated twice, with one evaluation conducted through a Google form dated June 23, 2021.

Based on the summarization of the results of the material validation, the results of the assessment of the teaching materials from material side 4 and learning side 4 are included with a very good statement. According to the data, the language instructional video teaching aid for class VIII students at Public Middle School 39 Jakarta is rated "very decent" (80%) on both the material and learning sides. The researcher also received some criticism and suggestions from the materials expert for refining the educational method through the production of an educational video in Arabic.

Correction from a media education expert

Correcting the media at this stage involves Prof. Dr. Raden Ahmad Barnabas Masters, a wasila expert from the Department of Arabic Language Education, Faculty of Languages and Arts at Jakarta State University. The method in this study was validated with one assessment through a Google Form dated June 23, 2021. Based on the summarization of the results of the validation of the method, the results of the evaluation of the educational method from the visual side were 4.85, the acoustic side was 4.5, and the engineering-media side was 4.875, where both aspects received an excellent score. The data show that the educational video teaching aid for the Arabic language for eighth-grade students at the Government Intermediate School 39 Jakarta belongs to a very decent category (96%) from the visual aspect, the acoustic aspect, and the media engineering aspect. The researcher also received criticism and suggestions from method experts for refining the educational method through the production of an Arabic language educational video.

Production Experience

The researcher tested the products that were manufactured, developed, and validated by material experts and method experts. This experiment involves the students of the eighth grade at Middle School 39 in Jakarta using this method of educational video for the Arabic language during the distance learning process from September to October. This stage aims to determine the clarity of the content of the product, the attractiveness of the product, the ability to motivate students and their activity, as well as the ease of use of the video in the teaching process.

Production Evaluation

In the final step, the researcher measured or evaluated the products of the video educational aid that were developed and tested for the eighth grade students in middle school at 39 Jakarta in the teaching process. This step is carried out to find out the students' response and determine the level of feasibility of the product that has been developed. At this stage, the researcher used a questionnaire evaluation tool containing 13 questions that were shared through a Google Form at the end of the lesson.

This questionnaire is for evaluating the responses of 30 students in the eighth grade at Middle School 39 in Jakarta to find out the students' interest in the educational method in the educational video of the Arabic language used during the distance learning process. The following are the results of measuring students' responses.

Based on the results of the students' questionnaire after experimenting with the Arabic language video educational method, the researcher summarized that the average value is 3.4 with a more positive estimate. The data show that the Arabic language educational video teaching aid for the eighth grade students in Government Intermediate School 39 Jakarta belongs to the very decent category (85%).

Discussion

In facing the challenges of learning Arabic, the use of video tutorials as a media presentation has become the main focus for supporting the student's learning process. Data from a survey of respondents shows that video tutorials in Arabic managed to attract the attention of the majority of respondents, with a significant percentage. This can be seen from the positive response to the use of images, colors, sounds, text, and the contents of the material in the video tutorial. Furthermore, this video tutorial is considered to be very helpful for students in learning and mastering Arabic, especially in understanding vocabulary and fluent pronunciation.

In addition, in the context of distance learning, which is needed during a pandemic, the use of video tutorials is an effective solution. Under these conditions, video tutorials can be accessed by students without time and place restrictions, thereby facilitating independent learning. The Arabic tutorial video learning media model is the result of the development of learning media that assists teachers in presenting material that is interesting to students so that students become more motivated and understand Arabic lessons more easily.

By utilizing video tutorials as a tool for learning Arabic, teachers can strengthen students' interactions with learning materials, increase their understanding, and improve their speaking skills in Arabic. Therefore, the use of video tutorials in learning Arabic is an interesting topic that needs to be explored further to discuss its effectiveness and benefits.

Based on the statement above, the use of video tutorials as a medium for learning Arabic has proven successful in attracting students' interest, facilitating understanding of the material, and improving their speaking skills. Especially in the era of distance learning, video tutorials are a practical solution to overcome learning barriers. Therefore, it is suggested that teachers adopt video tutorials as an effective tool for teaching Arabic.

Conclusion

Based on the results of the search for a model of a video method for teaching Arabic language to students of the eighth grade in the public middle school 39 Jakarta, the researcher presented the conclusion as follows:

1. Analyzing the material to be included in the Arabic language teaching video through educational books used in schools and consulting with Arabic language teachers. After that, the researcher analyzed the students' needs for the Arabic language teaching video, using a questionnaire. The results of the needs survey show that students, in general, need an interactive video medium to teach Arabic.

2. Designing the production based on the previous needs and problems The researcher designed the preparation of educational materials from the book used, and the preparation of topics using the video.
3. Develop productions by making themes and checking out experts. The method, an advanced video, obtained 80% of the subjects' expert knowledge on subject and educational aspects. The result of the investigation will remain at 76%–100% until it reaches the level of "very decent." Then the advanced video method obtained 95% of the method's expertise on the audio aspects.
4. The visual aspects and the engineering aspects of the method and the result of the verification are separated by 76%–100% until it reaches a "very decent" level.
5. Experimenting with a field event, a video method for teaching Arabic to eighth-grade students at Jakarta's Government Intermediate School 39.
6. Production evaluation by assessing the educational method, a video, and a questionnaire of responses from eighth-grade students at Government Intermediate School 39, Jakarta. I got 85% of the students' evaluation and the result of the investigation in the range of 76%–100% until it reaches the level of "very decent.".

Recommendations

After conducting this research, the researcher provides the following recommendations:
1. Teachers in schools should support each other in learning development, especially in the field of technology.
2. Teachers need to master technology in order to create fun, creative, and innovative learning media.
3. Teachers can develop learning media using video tutorials for other topics.
4. Students can use video tutorials as a means of independent learning and as material for monitoring.

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Analysis of the Natural and Social Science Curriculum at the Elementary School Level in Indonesia

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Abstract: The independent curriculum is designed to be a better future solution for education in Indonesia. This curriculum is expected to reduce the learning losses that occurred after the COVID-19 pandemic. In the independent curriculum at the elementary school level, natural science subjects are changed to natural and social science subjects. Natural sciences and social sciences are combined into one subject at the elementary level. This is due to the fact that children in elementary school tend to see everything as a whole and integrated. In addition, they are still in the concrete and simple, holistic, and comprehensive thinking stage, but not in detail. The combination of these subjects is expected to trigger children's ability to manage the natural and social environments in one unit. The aim of this research is to describe the curriculum of natural and social sciences in elementary schools including goals, content, processes, and evaluations that apply in Indonesia. This study uses the method of a literature review. Researchers collect data sourced from books, government regulations, journals, and previous research. The results of the research show that learning natural and social sciences in elementary schools focuses on the study of knowledge about living and inanimate things in the universe and their interactions, and examines human life as an individual as well as social beings who interact with their environment. The natural and social science curriculum in elementary schools includes material understanding and process skills. The learning process takes 180 hours of lessons per year. Evaluation of learning is carried out through daily assessments, midterm assessments, end of semester assessments, and end of year assessments.

Keywords: Curriculum, Natural and Social Science Subjects, Elementary School

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Introduction

Curriculum changes are necessary because the times are constantly developing and changing, so education must also be adjusted so that it can prepare the next generation to compete and adapt in an era full of progress. The Merdeka Curriculum was initially launched in the form of an emergency curriculum as the first step in implementing the curriculum during the COVID-19 pandemic. The Merdeka Curriculum is a much more concise, simpler, and more flexible curriculum to be able to support learning loss recovery due to the COVID-

19 pandemic, as stated in Kepmendikbudristek No. 56 of 2022 concerning Guidelines for Implementing Curriculum in the Framework of Learning Recovery.

In line with this, the independent curriculum within the scope of elementary schools is also echoed as a solution and design for a better future in the world of education. According to the 1945 Constitution, elementary school education refers to efforts to educate and create the life of a nation that fears, loves, and is proud of the nation and state. In addition, it also fosters a skilled, creative, virtuous, polite attitude and the ability to solve problems in their environment. Indonesian students are also required to have the competence to become democratic citizens and to become superior and productive human beings in the 21st century. In line with this, especially in the elementary school curriculum, there are several developments from various fields, one of which is the integration of natural science and social science subjects into the natural and social sciences. Natural and Social Sciences (IPAS) is a science that examines living and inanimate things in the universe and their interactions, as well as human life as individuals and social beings who interact with their environment.

In general, knowledge is defined as "a combination of various knowledge that is organized logically and systematically by taking into account causes and effects" (Big Indonesian Dictionary, 2016). This knowledge includes natural knowledge and social knowledge. Science education has a role to play in realizing the Pancasila Student Profile as an ideal picture of the profile of Indonesian students. Science Science helps students grow their curiosity about the phenomena that occur around them. The basic principles of scientific methodology in science learning will train scientific attitudes (high curiosity, critical thinking skills, analysis, and the ability to draw the right conclusions) that give birth to wisdom in students. As a country that is rich in culture and local wisdom, it is hoped that through IPAS, students will explore the wealth of local wisdom related to IPAS, including using it to solve problems. As a result, the primary goal of learning natural sciences at the elementary level is not how much material content students can absorb, but how much competence they have in applying what they know.

Given that elementary school-aged children still see everything as a whole and integrated whole, science and social studies learning are combined into one subject, namely natural sciences. This is also done with the consideration that elementary school-age children are still in the stage of thinking simply, holistically, and comprehensively, not in detail. Learning in elementary school needs to give students the opportunity to explore, investigate, and develop an understanding of the environment around them. So studying natural phenomena and human interaction with nature and between humans is very important at this stage. The purpose of this research is to describe the curriculum of natural and social sciences in elementary schools, including the goals, content, process, and evaluation that apply in Indonesia.

Method

This study used qualitative research methods. This study uses the method of literature review. Researchers collect data sourced from books, government regulations, journals and previous research. The process of collecting research data is a documentation study, interviews and field observations or surveys. The data source used in this research comes from qualitative data. According to Sugiyono (2017) there are 2 types of data, namely qualitative and quantitative data. Qualitative data is data in the form of words, sentences or pictures. In this study, the data sources used came from interviews with students, teachers and school principals. In addition, qualitative data was obtained from the results of a documentation study of curriculum documents and government regulations, as well as other supporting documents. There is also data taken from direct observation. The data collection techniques used by researchers are interviews, documentation, and observation. Interviews were addressed to teachers as project facilitators to strengthen the profile of Pancasila students, school principals, and students. When conducting research data analysis, researchers used documentation techniques as material for consideration as well as evidence showing the relevance of the results obtained when conducting research.

Results

Reporting from the official website of the Directorate of Elementary Schools of the Ministry of Education and Culture, the essential thing from the Merdeka Curriculum at the elementary level is the Science subject, which emphasizes strengthening basic competencies and understanding logistics, to understand the surrounding environment, Science and Social Studies subjects are combined as Natural and Social Sciences subjects. (IPAS) and integrate computational thinking in Indonesian, Mathematics and Natural Sciences subjects.

The results of the research show that learning natural and social sciences in elementary schools focuses on the study of knowledge about living and inanimate things in the universe and their interactions, and examines human life as an individual as well as social beings who interact with their environment. The science and social curriculum in elementary schools includes material understanding and process skills. The learning process takes 180 hours of lessons per year. Evaluation of learning is carried out through daily assessments, midterm assessments, end of semester assessments, and end of year assessments.

Discussion

Goals

Science learning goals are regulated in BSKAP decision No. 033/H/KR/2022 concerning learning outcomes in early childhood education, primary education, and secondary education.

Preface

The challenges in the world of education are increasing. Science is developed to solve these challenges. IPAS is a science that examines living and inanimate things in the universe and examines human life as an individual and social being who interacts with their environment. Science education has a role to play in realizing the profile of Pancasila students as an ideal picture of the profile of Indonesian students.

Aims

Develop interest and curiosity so that students are triggered to study phenomena that exist around humans and understand the universe and its relation to human life; play an active role in maintaining, protecting, and preserving the natural environment and managing natural resources and the environment wisely; develop inquiry skills to identify, formulate, and solve problems through real action; understand who he is, understand how the social environment he is in, and interpret how human life and society change from time to time; understand the requirements needed by students to become members of a community and nation group and the meaning of being a member of the nation and world community, so that they can contribute to solving problems related to themselves and the environment around them; and develop knowledge and understanding of concepts in science and technology and apply them in everyday life.

Characteristic IPAS

Along with the times, science is also constantly developing. What we have known as scientific truth in the past may experience a shift in the present and the future. That is why science is dynamic and is a continuous effort made by humans to uncover the truth and use it for life (Sammel, 2014). The carrying capacity of nature to meet human needs from time to time is also decreasing. The exponential increase in the human population also triggers the many problems it faces.

Many problems cannot be solved by looking at them solely through the lens of natural science or social science. Instead, a more holistic approach is needed that includes a variety of cross-disciplines (Yanitsky, 2017). Students should learn the natural sciences and social sciences to gain this understanding. need to be combined into one unit, which we then call the IPAS. Understanding science and social sciences, as well as developing process skills, are the two main components of science learning.

Content

Preface

The material in the independent curriculum is regulated in Permendikbudristek No. 7 of 2022 concerning content standards in early childhood education, basic education, and secondary education. In this regulation, IPAS is a compulsory subject at the elementary school level. In general, the development of content standards refers to the development of graduate competency standards in educational units at the basic education level, which are focused on: 1) Preparation of students to become members of a religious community; 2) Cultivating characters according to Pancasila values; 3) Development of literacy and numeracy competencies.

Scope of material

In general, the science subject matter in elementary schools is as follows: Investigations related to self-knowledge and the surrounding environment, including objects and living things, Data and Information Analysis, the life cycle and reproduction of living things; the interactions of living things; and their relation to efforts to preserve living things, substances and their uses, Sources and forms of energy, including benefits and how to save them, Waves and their uses, Magnets and electricity, Natural disasters, The solar system and the influence of the earth's rotation and revolution, Socialization and interaction to recognize values and norms in society, Geographical environmental conditions that affect biodiversity and its use in everyday life, Human behavior to meet the needs of life also The history and struggle of the nation's heroes

The learning process

The learning process applied in Indonesia is regulated in Permendikbudristek No. 16 of 2022 concerning educational process standards in early childhood education, primary education, and secondary education.

Learning planning

Learning planning is an activity to formulate learning objectives, ways to achieve learning objectives, and ways to assess the achievement of learning objectives carried out by the teacher. Lesson plans are prepared in the form of clear, simple, and flexible lesson planning documents. Lesson planning at least contains learning objectives, learning activities, and assessments in accordance with the elementary school curriculum.

Formulate learning objectives, Learning objectives are a set of competencies and the scope of learning materials. Learning objectives are formulated by considering the characteristics of students and educational unit resources. Determine learning activities, Learning activities are carried out using learning strategies that are designed to deliver high-quality learning experiences.Learning strategies are designed to provide a quality learning experience in a way that; 1) Allows for the application of material to real-world problems or contexts; 2) Encourage participation and optimize resources, and 3) Using ICT tools. Learning activities are designed to provide learning experiences by taking into account the characteristics of students, including age, level of development, level of previous abilities, physical and psychological conditions, and family background. In addition, learning activities can be carried out across subjects or across class levels according to achievements in certain phases.

Assess the achievement of learning goals, How to assess learning objectives achievement can use a variety of assessment techniques and instruments that are appropriate to the learning objectives and refer to assessment standards. Implementation of learning, The implementation of learning is carried out in an interactive, inspiring, fun, and challenging atmosphere, motivating and providing sufficient space for student creativity as well as active participation. In this case, the teacher acts as a role model, companion, and facilitator.In the implementation of learning at the elementary school level, the learning load is arranged in the form of lesson hours.

Assessment of the learning process, Learning assessment is an evaluation of the teacher's planning and implementation of learning.The assessment is carried out by reflecting on the planning and learning processes and the results of the assessment. Assessment of the learning process can be carried out by fellow educators, heads of education units, and educators with students.

Assessment

The assessment in learning is based on Permendikbudristek number 21 of 2022.In this ministerial regulation, education assessment standards are defined as minimum criteria regarding the mechanism for evaluating student learning outcomes. Assessment is the process of collecting and processing information to determine learning needs and developmental achievements, or student learning outcomes. 1) The assessment of learning outcomes is carried out in accordance with fair, objective, and educational goals; 2) Procedures for assessing student learning outcomes include formulation of assessment objectives, development of assessment instruments, implementation, processing of assessment results, and reporting of assessment results.

There are at least two types of assessment of learning outcomes, namely formative and summative assessments; 1) Formative assessment aims to monitor and improve the learning process, evaluate the achievement of learning objectives, and collect information related to learning difficulties and student learning development; 2) Summative assessment aims to assess the achievement of student learning outcomes as a basis for determining grade promotion and graduation. Assessment of the achievement of learning outcomes compared with the criteria for achieving learning objectives.

Conclusion

Based on the explanation above, it can be concluded that the elementary school curriculum in Indonesia combines science and social studies, with the consideration that elementary school-age children still see everything as it is, intact and integrated, so learning science and social studies is simplified into one subject, namely natural sciences. This is done while keeping in mind that elementary school-aged children are still in the stage of thinking simply and concretely, holistically, and comprehensively, but not in detail.The objectives of learning science are to: 1) develop curiosity to study phenomena that exist around humans; play an active role in preserving the natural environment; and manage natural resources and the environment wisely. 2) develop inquiry skills to understand who one is, the social environment one is in, and how human life and society change from time to time; 3) solve problems related to himself and the environment around him; and 4) develop knowledge and understanding of concepts in science and technology and apply them in everyday life.

The material developed contains process skills and an understanding of science. The learning process is carried out by designing learning plans in advance, learning steps, and assessments. IPAS subjects in the independent curriculum are carried out for 180 hours of lessons per year. Science learning evaluation is carried out with various forms of assessment, which are carried out at least once in one semester. The assessment is divided into two parts: formative and summative. This assessment can be carried out during daily assessments, midterm assessments, end-of-semester assessments, and year-end assessments.

Recommendations

Based on the results of the research described above, the authors can provide recommendations to always study and understand the curriculum implemented in schools. This is not specific to teachers, principals, or school staff, but the whole community. Education is our collective task, and by understanding a curriculum, it will be easier for us to guide our children. By understanding the curriculum, we can also determine learning strategies that can highlight students' interests, talents, and achievements. In addition to studying the curriculum, we are also required to understand the stages of student development. so that all forms of activity are in accordance with the ability and age of students.

Acknowledgements

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Profile of Students' Critical Thinking Ability with Citatah Karst Damage as a Learning Source

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Abstract: Previous research found that critical thinking skills of students need to be trained more intensively using authentic problems in daily life. Critical thinking can be developed through problem-based learning as a pedagogical approach in an aligned learning and teaching context. This research aims to obtain the profile of students' critical thinking skills through authentic problems, the damage to the Citatah karst environment. Learning activities are carried out using a Problem Based Learning (PBL) model. The sample used was 25 people of 7th grade students of SMP Krida Utama Padalarang. This type of research is descriptive qualitative research. The indicators of critical thinking skills measured in this study are: formulating problems, asking HOTS questions, arguing, observing and choosing sources of information, determining actions and communicating. Based on data analysis and discussion, it can be concluded that on all indicators of critical thinking skills, most students are in the moderate category or need assist to stimulate their critical thinking skills.

Keywords: Critical thinking, Problem based learning, Karst Citatah

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Introduction

Critical Thinking Ability

In an effort to prepare future generations to navigate their lives with resilience, education plays a crucial role in shaping students' character and mindset. The development of 21st-century skills is essential in the learning process. Trilling and Fadel (2009) identified three key aspects of 21st-century skills: critical thinking and problem-solving (expert thinking), communication and collaboration (complex communicating), and creativity and innovation (applied imagination and invention).

These three skills redefine the traditional perspective on future work skill demands. The increasing need for individuals who can think critically, solve problems, communicate effectively, collaborate efficiently, and demonstrate creativity and continuous innovation presents a significant challenge for the current education system. Trilling and Fadel (2009) assert that critical thinking skills are closely intertwined with problem-solving skills. By cultivating critical thinking and problem-solving abilities, students can reason effectively, employ systemic thinking, make informed judgments and decisions, and tackle complex problems. Problem-based learning, which utilizes real-world facts and authentic issues relevant to students, can effectively foster critical thinking and problem-solving skills within the educational process.

Previous research highlights the importance of intensively training students' critical thinking skills using authentic problems from daily life. Consequently, this study aims to assess students' profile of critical thinking abilities by examining the impacts of karst damage on the Citatah region as a learning resource.

Critical thinking skills are crucial for effective problem-solving, decision-making, and reasoning (Ennis, 1985). Authentic problems, which are real-world, relevant, and meaningful challenges, play a vital role in assessing and developing these skills (Dori & Belcher, 2005). By engaging students in authentic problems, educators provide context and relevance to the learning process, promoting active learning and higher levels of student motivation (Lombardi, 2007). Authentic assessments, such as performance tasks, case studies, and simulations, accurately capture the depth of critical thinking skills and students' abilities to transfer knowledge to practical situations (Pellegrino et al., 2001). Moreover, authentic problems encourage collaboration, communication, and teamwork, fostering students' interpersonal skills (Prince & Felder, 2007). The integration of authentic problems across disciplines prepares students for real-world challenges and workplace requirements (Perkins, 1992). Teachers play a vital role in designing and facilitating authentic problem-based learning experiences, providing students with feedback and opportunities for reflection to enhance their critical thinking development (Hmelo-Silver et al., 2007). Ongoing reflection and evaluation of the effectiveness of using authentic problems in teaching and assessment practices are essential for continuous improvement (Gijbels et al., 2005).

Citatah Karst Damage as Learning source

The West Bandung Regency, particularly Padalarang, is home to a vast karst area encompassing at least eleven karst hills. Unfortunately, most of these karst hills have been severely damaged due to limestone and marble mining activities. Large-scale mining operations by certain companies have resulted in escalating ecological degradation.

The Citatah karst complex holds significant importance as a learning resource and is closely linked to the development of critical thinking skills. As a school located in Padalarang, where the karst area is abundant, it is essential for students to explore and understand the natural resources in their. By incorporating the Citatah karst complex into science learning activities, students have the opportunity to engage in real-world problem-solving and critical thinking processes.

As a school located in Padalarang, it is crucial for students to identify the natural resources in their area and comprehend the associated risks. To address this, SMP Krida Utama Padalarang implements a regular program that involves visits to the Citatah karst complex as part of science education. This program aims to enhance students' critical thinking skills, particularly regarding contextual issues in their surroundings. Normally, students would visit the Citatah karst complex in person; however, due to the pandemic, a combination of online and limited face-to-face learning is currently implemented. The problem-based learning (PBL) model is utilized, with contextual topics centered around the karst citatah complex. During online learning, activities are conducted virtually through the use of pictures, articles, and videos. Additionally, when limited face-to-face learning is possible, students engage in group presentations to explore alternative solutions. This topic aligns with the Basic Competencies of environmental pollution and the interaction of living things for grade 7, as outlined in the Indonesian science national curriculum.

To reiterate, the focus of this research is to assess students' profile of critical thinking abilities in relation to the impact of karst damage on the Citatah region as a learning resource. The critical thinking aspects investigated in this study include problem formulation, posing high-order thinking questions, argumentation, observation, source selection, decision-making, and communication.

Method

This research adopts a descriptive study design with a qualitative approach. Qualitative research involves gathering descriptive data, whether through oral or written sources, focusing on the treatment given or observed phenomena as the research focus (Bogdan & Taylor, 1975 as cited in Lexy J, 2007). The population and sample for this study were purposively selected. The research sample consists of 25 students from grade 7 at SMP Krida Utama Padalarang. Data collection methods included observation, interviews, and questionnaires. The observation data were then categorized, analyzed, and compared based on specific criteria. These criteria were selected purposively, taking into account their relevance and the researcher's ability to observe them at the time. The criteria used in this study were derived from Ennis (1985), as follow.

Table 1. Critical Thinking Criteria

Aspects of critical thinking	Criteria		
	high	Moderate	poor
Formulate problems	Students are able to formulate problems from shows/ data/ phenomena that are presented correctly	Students are able to formulate problems from shows/ data/ phenomena that are presented correctly with assistance	Students are not able to formulate problems from shows/ data/ phenomenapresented Asking HOTS questions

Asking HOTS questions	Students asking HOTS questions	Students asking questions	Students don't ask questions
Finding and selecting learning sources	Students are able to find sources of relevant information that are correct and credible	Students are able to find sources of relevant information that are not yet Credible	Students are not able to find sources of relevant information
Arguing	Students are able to argue with the right reasons	Students are able to argue with inaccurate reasons	Students are not able to argue
Determining Actions and Communicating	Students are able to determine the right actions and communicate them well	Students are able to determine the right actions but do not communicate them properly	Students are not able to determine the right actions and communicate them properly

Ennis,1985

Overall, this research aims to explore the critical thinking skills of the selected sample of grade 7 students by analyzing and interpreting the collected data in relation to the established criteria. By employing a qualitative approach and purposive sampling, the study seeks to gain insights into how these students demonstrate critical thinking abilities in the context of the Citatah karst complex. Through careful analysis and interpretation of the data, the researcher aims to provide valuable information about the students' critical thinking skills and their application in addressing authentic problems related to the karst complex.

Leave one blank line (1.5 times spaced) before and after each heading. (Exception: no blank line between consecutive headings.) Please margin all headings to the left. Leave one blank line (1.5 times spaced) before and after each heading. (Exception: no blank line between consecutive headings.) Please margin all headings to the left.

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Results

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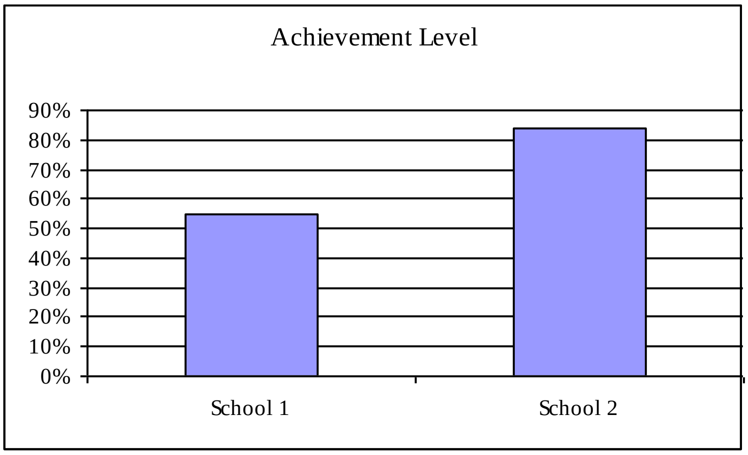

Figure 1. Centre the Caption below the Figure

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Conclusion

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Evaluation of Beginning Teacher Induction Program in Elementary Schools

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Abstract: One effort to improve teacher quality is the beginning teacher induction program or Program Induksi Guru Pemula (PIGP). PIGP is an orientation activity, on-the-job training, development, and practice of solving various problems in the learning process for beginning teachers at their workplace. PIGP aims for beginning teachers to adapt and become professional teachers. The aims of this study were to evaluate the beginning teacher induction program or PIGP at Harapan 1 Public Elementary School, Cimahi City, Indonesia. The method used is evaluation research with the Responsive Evaluation Model. This evaluation model emphasizes the response of program stakeholders which includes antecedents, transactions, and outcomes. The research sample was one of the teachers at Harapan 1 Public Elementary School, Cimahi City, Indonesia. The results of the study indicated that the antecedent aspects consisting of planning and preparation for PIGP had been sufficiently implemented. In the transaction aspect, overall the PIGP implementation activities were not implemented properly. Finally, on the aspect of outcomes, namely the performance of beginning teachers in learning, it can be concluded that the competence of beginning teachers is good at planning lessons. However, beginning teachers' competence in carrying out learning and evaluating is in the sufficient category. It can be concluded that the PIGP evaluation at Harapan 1 Public Elementary School was in the sufficient category. Therefore, improvements to PIGP are needed, one of which is to improve the quality of school principals in designing PIGP because school principals are the key to the success of PIGP.

Keywords: Teacher Induction Program, Beginning Teacher, Elementary School

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Introduction

Quality education is born from a good planning system, with good material and management systems, and delivered by good teachers with quality education components, especially teachers (Mulyasana, 2011, p. 120).

Teachers according to Law No. 14 of 2005 paragraph 1 professional educators with the main task of educating, teaching, guiding, directing, training, assessing, and evaluating students in early childhood education through formal education, basic education, and secondary education. The teacher plays an important role in the education process because the teacher is the implementer of the curriculum. Furthermore, teachers are directly involved in interacting with students, so their role will be very fundamental in the context of building a national civilization by improving the quality of education. It's vital and fundamental role makes this profession very noble. Krishna (2007) says that there are three noble professions, the first is teacher, the second is doctor, and the third is lawyer or prosecutor. If you have to choose, the teaching profession is the noblest.

The noble of this profession needs to be accompanied by continuous quality improvement. Law no. 14 of 2005 concerning teachers and lecturers states that four competencies must be mastered by teachers, namely: personal competence, pedagogical competence, professional competence, and social competence. Each competency has components that must be mastered by the teacher. For example, in pedagogic competence, several components must be mastered by the teacher, namely: 1) mastering the characteristics of students from the physical, moral, spiritual, social, cultural, emotional, and intellectual aspects. 2) mastering learning theory and educational learning principles. 3) develop a curriculum related to the subjects taught. 4) organizing educational learning. 5) utilizing information and communication technology for the benefit of learning. 6) facilitate the development of the potential of students to actualize their various potentials. 7) communicate effectively, empathetically, and politely with students. 8) Carry out assessments and evaluations of learning processes and outcomes. 9) utilizing the results of the assessment for the benefit of learning, and 10) taking reflective action to improve the quality of learning (Suhana, 2004).

The fact that the quality of education in Indonesia is low has been reported by various institutions such as those reported by PISA and TIMSS. In the PISA report, Indonesia was ranked 64th out of 65 countries in 2012 (OECD, 2013) and ranked 64th out of 72 countries in 2015 (OECD, 2017). Even though it has increased, Indonesia is still at a low level. Indonesia is still at a low ability level when viewed from a cognitive aspect (knowing, applying, reasoning) (Kusuma, et al., 2017). In line with PISA, the results of the TIMSS study of Indonesian students in 2011 were ranked 40 out of 42 countries and in 2015 they were ranked 45 out of 48 countries (TIMSS, in Nugroho, 2018). Furthermore, based on the results of the Teacher Competency Test conducted in 2015 the following national results were obtained, the maximum score was 100, the minimum score was 10, the average was 53.05 with a standard deviation of 12.56 from a total sample of 2,430,427 teachers. Of the 34 provinces in Indonesia, only seven provinces achieved scores above the average score, namely West Java, Central Java, Yogyakarta, Jakarta, Bali, East Java, and Bangka Belitung (Kemdikbud.go.id., 2015). The average score is of course still far from the government's target, which expects all teachers to achieve a score of 80. The results of these studies are enough to prove that the quality of education in Indonesia is not doing well.

The quality of Indonesian education is correlated with teacher competency. Leonard (2015) reported that almost

75 percent of teachers did not prepare for the learning process properly and taught conventionally (monotonously). Seftiawan (2019) explains that Indonesia still has low-quality teacher competence. Saido, et al. (2015) showed that teachers tend to teach students to memorize concepts, while problem-based, collaborative, and investigative learning is still not implemented by teachers. These results are in line with the research of Sopandi, et al. (2019) in an innovative learning model workshop, teachers tend not to understand the syntax of innovative learning models that are already known so far that conventional models remain the mainstay of teachers in teaching students. Activities in the class that are dominated by assignments and memorization show the low involvement of students' thinking skills in learning (Tembang, 2017). There is still a lot of rote material contained in short-term memory, so students' thinking skills in Indonesia are only at the level of remembering, restating, or referring without processing (reciting) (Nugroho, 2018, p. 12). This will have implications for ratings that are also unsatisfactory or have not touched HOTS (Abdullah, et al., 2017). This is what causes Indonesian students to be at the LOTS level and has a direct impact on the low quality of Indonesian education.

Various efforts have been made to improve teacher competence, both through workshops, seminars, and training. But in fact, these activities have not had a positive impact. One thing that is often forgotten is that a teacher must be well prepared, this preparation must be continuous starting from pre-service and Teacher Professional Education to becoming a beginning teacher in the Education unit. One form of developing and improving the quality of teachers, especially beginning teachers, is an induction program for beginning teachers. An induction program is a system-wide, consistent, and comprehensive process of training and support that continues for two or three years and then smoothly becomes part of a lifelong professional development program to keep new teachers teaching and increase their effectiveness (Alberta, 2013). The induction program aims to improve the performance and retention of new teachers and improve skills to prevent the loss of new teachers to enhance student growth and learning (Ingersoll, 2012). In the Indonesian context, this induction program is called the Program Induksi Guru Pemula (PIGP).

Beginning Teacher Induction Program or PIGP (Kemdikbud, 2010) is an orientation activity, on-the-job training, development, and practice of solving various problems in the learning process and counseling guidance for beginning teachers in their workplace. Beginning teachers are teachers who are assigned to carry out the learning process and counseling guidance for the first time in an education unit organized by the government, local government, or community. The aims of implementing the Induction Program focused to guide beginning teachers so they can: 1) adapt to the work climate and school culture and 2) carry out their work as professional teachers in schools. PIGP is regulated in the ministerial Regulation for Administrative Reform and Bureaucratic Reform No. 16 of 2009 concerning Functional Positions of Teachers and regulation of the Minister of Education and Culture No. 27 of 2010 concerning Beginning Teacher Induction Programs.

From the description above, the researcher is interested in conducting a further evaluation to provide an overview of the beginning teacher induction program in Cimahi City, especially at Harapan 1 Public Elementary School as well as evaluate the implementation and success of the program. Because it aims to provide an overview of the conditions for program preparation, the involvement of school supervisors, the implementation of the beginning teacher induction program, and the achievement of the program's objectives, the researcher uses the "responsive" evaluation model from Stake. The Stake evaluation model seeks to describe the events, activities, and conditions that existed before, during, and after the implementation of a program by taking into account the responses of the stakeholders involved in the program. The researcher took the title "Evaluation of the Beginning Teacher Induction Program at Elementary School ".

Method

This research is evaluation research that uses the Responsive Evaluation Model which was developed in 1975 by Robert E. Stake. This evaluation model emphasizes the response of program stakeholders which includes antecedents, transactions, and outcomes. The evaluation criteria used in this study refer to the criteria set by the Ministry of Education and Culture (2010) in the PIGP implementation guidelines, namely: 1) Antecedent aspects are focused on two components which include planning for the implementation of the beginning teacher induction program and preparation for PIGP implementation; 2) The transaction aspect focuses on PIGP implementation starting from PIGP guidance, assessment and reporting activities; and 3) The outcomes aspect in this study consisted of three components, namely the teacher's ability to plan to learn, the teacher's ability to carry out learning and the teacher's ability to evaluate student learning outcomes.

This study uses qualitative and quantitative methods to describe the results of the PIGP evaluation at Harapan 1 public elementary school. The data in this study were collected in three ways, namely by using interviews, documentation studies, and observation. The informants involved were Elementary School Superintendents, Principals, Supervisors, and Beginning Teachers. While observation is used to obtain data regarding the competence of beginning teachers who have participated in PIGP. The range of values to see teacher performance is as follows (Kemdikbud, 2010)

Table 1. Beginning Teacher Performance Score Criteria

Criteria Value Range	Criteria
91-100	Very Good
76-90	Good
61-75	Enough
51-60	Less
< 50	Very Less

To support and strengthen the accuracy of the data that has been collected through interviews and observations, a review of several documents related to the beginning teacher induction program at Harapan 1 public elementary school was carried out.

Results

This research is evaluation research using the Responsive from Stake model (antecedent, transaction, and outcomes) or often also referred to as the input, process, and results of the beginning teacher induction program at Harapan 1 public elementary school. The data generated in this study will be discussed based on the three evaluation dimensions.

1. Planning and preparation for PIGP at Harapan 1 Public Elementary School

The input (antecedent) aspect is focused on two components which include planning for the implementation of the beginning teacher induction program and preparation for implementing PIGP. In the PIGP planning the supervisor makes the plan by including the program in the supervision program related to the implementation of PIGP and the supervisor records the newly appointed teachers. The supervisor then held a coordination meeting with the education office regarding the mechanism for implementing outreach to beginning teachers. The school principal follows up on the guidance supervisor's submission by calling beginning teachers and appointing supervisors who will assist beginning teachers in implementing PIGP. Planning was not carried out properly because the schedule clashed with the basic training program for civil servants. Furthermore, beginning teacher mentors were taken from senior teachers from other elementary schools due to the absence of senior teachers who were ready to become mentors. This resulted in the PIGP planning meeting not being held with the school principal.

Figure 1. Interview Activities with School Supervisors and Principals

In the preparatory stage, the supervisor socializes the induction program and trains the parties involved in the program, namely principals, counselors, and beginning teachers. The school principal coordinates with supervisors in conveying information about PIGP to supervisors and beginning teachers and various things that must be prepared, then determining the time for implementing PIGP and facilitating the needs of these beginning teachers. However, supervisors are less involved in helping beginning teachers prepare their learning administration. As a result, beginning teachers prepare learning tools that will be used when they start teaching independently in implementing PIGP.

2. Implementation of PIGP at Harapan 1 public elementary school Cimahi City

The process (transaction) aspect, namely the implementation of PIGP at Harapan 1 public elementary school includes three components, namely mentoring the implementation of PIGP, evaluating the implementation of PIGP, and reporting on the implementation of PIGP. Based on the guidance guide carried out by the supervisor only for the mentor and further guidance it is the mentor who guides the beginning teacher during the mentoring stage for 1 year, however, the supervisor does not carry out the guidance for the mentor. Supervisors carry out guidance to beginning teachers once. While the principal is only limited to coaching and mentoring beginning teachers, they are handed over to the supervisor's responsibility. At the guidance stage, the mentor has an important role.

Figure 2. Interview Activities with Mentor

The researcher's meeting with the mentor who had been appointed by the principal to be the supervisor provided information that was not very detailed about the stages of the guidance that had been carried out, the mentor only revealed an outline of the guidance that they carried out. Mentoring activities are not optimal, not only because of clashes with civil servant basic training schedules and the condition of Covid-19 which forced the disruption of PIGP activities, the factor of differences in work units between beginning teachers and mentor causes the intensity of mentoring to be very low. Based on the PIGP guidelines, mentoring activities are carried out during the 2nd to 9th month, where mentoring activities are carried out at least once a month. Mentoring activities were only carried out 3 times at quite a distance apart. This has an impact on the process of preparing the annual program, semester program, syllabus, and lesson plans conducted by beginning teachers that are not running optimally. Beginning teachers arrange learning administration independently. However, the mentor still provides positive feedback.

The assessment of the implementation of PIGP at Harapan 1 public elementary school carried out by the supervisor is a recapitulation of the assessment that has been obtained by the beginning teacher from the mentor and principal. The principal is responsible for evaluating the results of beginning teachers and the assessment by the principal is carried out in the second phase of the assessment together with the school supervisor which aims to determine the performance value of beginning teachers. The assessment of the PIGP beginning teacher at Harapan 1 public elementary school is the teacher competency possessed by the beginning teacher which is assessed from the second to the ninth month by the mentor and the tenth month is the final assessment by the school principal and school supervisor.

Reporting on the implementation of PIGP at Harapan 1 public elementary school, the supervisor only reports which is an accumulation of assessments from supervisors and school principals. The preparation of the PIGP report is carried out by the school principal based on evidence in the form of documents or other evidence collected during the one-year induction period through learning observation activities, and general observations about the performance of beginning teachers in learning. The reporting carried out by the principal during the implementation of the beginning teacher induction program at Harapan 1 public elementary school is to report the accumulated scores obtained by beginning teachers from mentor, school supervisors, and the principal himself during the PIGP implementation. Meanwhile, the reporting on the implementation of PIGP at Harapan 1 public elementary school which was carried out by mentor was limited to reporting the results of the assessment of beginning teachers while implementing PIGP. In reporting activities, the school principal did not propose to issue a certificate to the Education Office.

3. The performance of teachers who have participated in PIGP at Harapan 1 public elementary school Cimahi City

The outcome aspects in this study consisted of three components, namely the teacher's ability to plan learning, the teacher's ability to carry out learning, and the teacher's ability to assess student learning outcomes. These three abilities were analyzed descriptively quantitatively, then the scores obtained were interpreted using the value range table (criteria) which has been described in the methods section.

The ability to plan lessons can be seen in the lesson plan documents prepared by beginning teachers. the learning implementation plan is taken from the learning implementation plan used in the PIGP assessment in the 10th month. The following table shows the teacher's ability to plan learning.

Table 5. Results of Analysis of Documentation Study Instruments Concerning Teachers' Ability to Plan Lessons

No	Observed Things	Score
1	Load lesson plan components according to Permendikbud no 22 of 2016/SE No 14 of 2019	4

2	Conformity between Basic Competencies-Indicators-Objectives-Assessments	4
3	There is a student-centered learning step	4
4	There are innovative learning resources and media	2
5	There are elements of renewable learning (literacy, character, 4Cs, ICT) in the learning steps	3
6	there is a HOTS-oriented assessment	3
	total	20

Based on the table above regarding the criteria for the dimensions of outcomes in the aspect of the teacher's ability to plan to learn, a score of 20 is obtained and converted to a scale of 100, and a score of 83.3 is obtained. So it can be concluded that the ability of teachers to plan lessons that have participated in PIGP at Harapan 1 public elementary school is in a good category.

Figure 3. Observation of Learning Implementation Activities

Furthermore, on the outcomes dimension, the aspect of the teacher's ability to carry out learning is assessed through observation of the implementation of learning for beginning teachers during the PIGP assessment. The following scores obtained are presented in the table below.

Table 6. Results of the Observation Instrument Analysis Regarding the Teacher's Ability to Implement Learning

	OBSERVED ASPECT	SCORING SCALE
A	INTRODUCTION / INITIAL ACTIVITIES (KW)	
1.	Orientation/Creation of Initial Conditions	5
2.	Attract attention/motivate	4
3.	Provide reference	4
4.	Making connections/apperceptions	3
	$Total = 16$	
B	PRESENTATION / CORE ACTIVITIES (KI)	
1.	Explanation of concepts / data / facts / principles with examples / illustrations / demonstrations	5

2.	Questions and answers / giving reinforcement	4
3.	Providing learning activities/assignments	4
4.	Use of learning media	2
	$Total = 15$	
C	CLOSING / FINAL ACTIVITY (KK)	
	Draw conclusions together	3
	Reflection	4
	Evaluation	1
	Follow-up	4
	$Total = 12$	
	Total Score = KW + KI + KK = 16 +15+12 = 43	

Based on the table above and the criteria for the dimensions of outcomes in the aspect of the teacher's ability to carry out learning, a total score of 43 is obtained and converted to a scale of 100 with a score of 71.6. So it can be concluded that the ability of teachers to carry out learning that has participated in PIGP at Harapan 1 public elementary school is in the sufficient category.

Furthermore, the dimensions of outcomes in the aspect of the teacher's ability to assess learning, it is assessed through a documentation study of lesson plans and assessment instruments. The following table presents the results of the assessment.

Table 7 Results of Analysis of Documentation Study Instruments Concerning Teachers' Ability to Assess Student Learning Outcomes

No	Observed Things Teacher	Score
1	Contains affective, cognitive, and psychomotor assessments	4
2	Using a variety of alternative assessments	4
3	There are questions and grids	2
4	There are scoring guidelines	1
5	HOTS oriented assessment	4
	Total score	14

Based on the table above and the criteria for the dimensions of outcomes in the aspect of the teacher's ability to assess student learning outcomes, a score of 14 was obtained and converted to a scale of 100 to 70. It can be concluded that the teacher's ability to assess student learning outcomes who have participated in PIGP at Harapan 1 public elementary school is enough category.

Discussion

Based on the results of the PIGP evaluation described above, information can be obtained that the implementation of PIGP at Harapan 1 public elementary school has not been implemented properly. This can be seen from the input aspect (antecedent) which includes two components, namely planning for PIGP implementation and preparation for PIGP implementation, both of which have not been implemented optimally. Not including PIGP in school activity plans has resulted in PIGP not being seen as a school program that has a high level of urgency. As a result, the implementation of PIGP has become less than optimal. This illustrates that the ability of school principals to plan PIGP is still low, this is consistent with the results of Pakaya's research (2019) which states that the ability of school principals to plan PIGP is still low.

In addition to this input aspect, there was an inconsistency in the PIGP schedule which clashed with the basic training for prospective civil servants base schedule. Furthermore, there is no reduction in teaching hours for beginning teachers so beginning teachers find it difficult to arrange time for guidance. Another problem is the appointment of mentors who do not use specific criteria resulting in less optimal involvement of supervisors, even though according to Niam (2021) the process of appointing PIGP supervisors needs to be carried out with a certain mechanism so that the quality of supervisors is maintained. This happens because there is no proper planning between the principal and supervisor, even though the principal and supervisor must plan and prepare for PIGP together to obtain maximum results (Sugiyarti & Sumardjoko, 2017). These obstacles explain that several aspects of PIGP planning and preparation are not by the PIGP guidelines.

Because the PIGP planning and preparation process encountered many obstacles, this had an impact on the PIGP implementation. Mentor don't guide beginning teachers, this can be seen from the low intensity of mentoring carried out. Instructors only carry out 3 mentorships while in the PIGP guidelines at least once a month which means a minimum of nine mentorships. This also happens to school principals and supervisors whose number of mentoring is below the standard for the amount of mentoring in the guidelines. The reason stated was the condition of the Covid-19 Pandemic which reduced mobility. However, Milaini (2021) in his research suggested that when conducting guidance during the Covid-19 Pandemic, you could use E-Mentoring which was proven to improve the performance of beginning teachers. This emphasizes that stakeholders do not understand that the use of technology to support work is mandatory (Murti, 2015).

Furthermore, the PIGP assessment did not encounter significant obstacles. This is because school principals and supervisors are accustomed to giving an assessment of teacher performance in teaching.Various obstacles experienced in the implementation of PIGP, directly and indirectly, had an impact on the teaching performance of beginning teachers. The results of the analysis show that the beginning teacher's ability to design learning is in a good category. This is because, according to interviews, beginning teachers previously knew how to prepare lesson plans in lectures. However, in the aspect of carrying out learning and evaluating the performance of beginning teachers, it is in the sufficient category. This indicates that PIGP has not been implemented properly. Whereas induction of beginning teachers is an important process in enculturating teachers for their new careers and helping them overcome obstacles in the early years of teaching (Kearney, 2021).

The induction program has been proven to support improving the welfare of beginning teachers. (Helsel DeWert, Babinski, & Jones, 2003; Kessel, 2010). In a review of the literature on research on Beginning teacher learning and professional development, Avalos (2016) emphasizes the benefits of having a support system (eg, mentoring), as early career phases must be strengthened and beginning teachers must be supported in a context shaped by a learning culture (Sunde & Ulvike , 2014).

What is more important is that the success of PIGP depends on the quality of school principals (Costa et al. 2019). Therefore, to improve the quality of PIGP, training for school principals is needed. Managerial individual guidance strategies can be an option for improving the quality of school principals in implementing PIGP (Pakaya, 2019).

Conclusion

Based on the results of the study it can be concluded that the antecedent aspect which consists of PIGP planning and preparation, has been implemented quite well because the principal, supervisor, mentor, and beginning teacher have studied the PIGP documents. However, there are drawbacks, namely the school implementing the program does not include this induction program in the school program. Apart from that, the Covid-19 condition, the appointment of supervisors who did not meet the criteria, and inconsistent schedules (schedule clashes with basic training for prospective civil servants) made PIGP preparation and planning activities not carried out properly.

In the transaction aspect, overall the PIGP implementation activities were not implemented properly. Even though the introduction to the school environment was carried out well, the mentoring activities of supervisors, principals, and mentor were not optimal as evidenced by the lack of mentoring as stated in the guidelines. Mentor from different schools lead to a lack of assistance for beginning teachers. The absence of a reduction in teaching hours and clashes with prospective civil servants during PIGP made it difficult for beginning teachers to focus on completing PIGP.

Finally, on the aspect of outcomes, namely the performance of beginning teachers in learning, it can be concluded that beginning teacher competence is good at planning lessons. However, beginning teachers' competence in carrying out learning and evaluating is in the sufficient category. Therefore it is necessary to improve PIGP, one of which is to improve the quality of school principals in designing PIGP because school principals are the key to the success of PIGP. Efforts to increase this can be done using individual managerial training or guidance to school principals.

Recommendations

This study concluded that the implementation of the beginning teacher induction program had not gone well.

Therefore, further research is needed regarding the more effective and efficient design of beginning teacher induction program training for school principals so they can understand the program well. Furthermore, interventions are needed using both learning models and learning methods so that the implementation of the beginning teacher induction program can be better.

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Bridging between Real World & Mathematics Ideas through Modelling Task

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Abstract: In this paper duality between real world phenomenon and mathematics will be discussed. This duality exists for many years which considerably remarked in the history of mathematics curriculum. One of the good potential for filling the gap between real world phenomenon and mathematical ideas would be modelling tasks which require performing the modelling cycle. In this paper after discussion about modelling in more details, two modelling cycles will be elaborated in the context of mathematical tasks that are related to everyday life. Main ideas behind different modelling cycles is starting point that would be from real world situation. Then gradually mathematical elements of real world phenomenon identified and mathematics problem will have shaped in a form that could be solved through mathematical problem solving techniques. Furthermore, it would be important phase that call interpretation of mathematics answer and check it in front of real world situation. This paper will be followed by discussion about learning theories that support the idea of modelling. Finally, two educational challenges (Design good modelling tasks and assessing of students performance) in mathematical modelling activity will be discussed.

Keywords: Real world, Mathematics, Modelling Task, Modelling Cycle, Word Problems.

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Introduction

> Ultimately, only life educates, and the deeper that life, the real world, burrows into the school, the more dynamic and the more robust will be the educational process. That the school has been locked away and walled in as if by a tall fence from life itself has been its greatest failing. Education is just as meaningless outside the real world as is a fire without oxygen, or as is breathing in a vacuum (Vygotsky, 1997).

Mathematics exist everywhere around us. We can see mathematics in everyday phenomenon, in high-tech instruments like mobile phone and satellite. It is true that mathematical ideas start from human being real life and real world phenomenon but mathematics can quickly lose its connection with reality because of its nature and essence. But, sometimes students feel that the mathematical concepts which they learnt at school are useless and meaningless. They couldn't understand the situation of mathematics problems and they couldn't solve it, so they start to complain about that and some of them experience math as boring and stressful subject. What we can do in this regards as teachers and educators of mathematics at school and university level? Is there any excellent way for making connection between mathematics ideas and students real life? How we can organize mathematical lessons around that excellent way?

Upon my 20 years of experiences in teaching mathematics at school level and based on my teaching and research experiences in different universities around the world, I could recommend to use modelling approach as an excellent way for overcoming this challenge. In many mathematics curriculum documents at many countries we can find some sort of modelling approach as their learning outcomes. At the university level, also we can find or define connection between real life experience and mathematics (which explicitly refer to modelling approach) as learning outcome.

It is seems to be an easy task for implementing modeling approach as learning outcome at actual mathematics classroom setting, but there are many details which reveals the complexity and difficulties of implementing this approach at the mathematics classroom. In the next section, brief history related to using application of mathematics in curriculum will be discussed and then modelling process will be define through modelling cycle and modelling approach will explain with more details.

Literature Review

> How we can maximize learning of students in mathematics? This is an old question! But, is there a new answers for that old question?

Mathematics curriculum change during last centuries for many time to prepare good response for above question. Niss, Blum and Galbraith (2007) discuss about the swing of the curriculum pendulum between pure and applied mathematics during the last two centuries. For example in early 1800, mathematics curriculum focused on applied mathematics while in late 1900 mathematics curriculum focused on pure mathematics. Upon Niss, Bloom and Galbraith (2007), in the past, mathematics as a field of human knowledge included its adjacent fields such as physics, astronomy and engineering and as a result, until the beginning of the 19th century, mathematics was a part of natural sciences and was included other practical activities. From the beginning of the 19th century, much attention was paid to purely mathematical education in order to strengthen intellectual powers (Nice, 1996). Since the late 19th century, most post-primary curricula have emphasized both pure and applied mathematics components. But during the 20th century, the school mathematics curriculum has always fluctuated between these two divisions - applied mathematics and pure mathematics.

Over time, the balance has sometimes been in favor of teaching pure mathematics and sometimes in favor of teaching applied mathematics. These successive changes have been based on social tendencies and various changes in the educational and learning needs of students; For example, in England, industrialists claimed that school graduates are unable to use their mathematical knowledge in real world situations (Pollack, 1979). The protest of the industries was actually because the students were only able to use their knowledge to solve familiar problems and they weren't able to use their mathematical knowledge for solving unfamiliar and non-routine problems. This protest of the industrial owners led to the introduction of some applications in the school mathematics curriculum. As a result, to enable students to solve real world problems. Therefore, mathematical modeling and application appear in school mathematics curriculum. Although according to Nice, Bloom and Galbraith (2007), attention to the modeling and application in mathematics education has a long history and rooted in cultural activities of Islamic, Indian, Chinese, and Egyptian group. For example finding the direction of Qibla or calendar setting in Islamic cities during Islamic golden age were a modelling problems.

Mathematical modelling is a round-trip process that connects the real world and the mathematical world (Steelman, 2010). There have been several interpretations for mathematical modelling cycles. The four steps modelling cycle (see picture 1) is one of the well-known (Vershafel, 2002, Kaiser and Schwartz, 2006, Rafiepour, Stacey and Gooya, 2012) one which the modeling process starts with a problem from the real world and then it is formulated and becomes a mathematical problem; then the mathematical problem is solved by mathematical problem solving techniques and the mathematical answer is interpreted in the real world to measure its compatibility with the real world. Finally the answer should be checked in front of real situation to control sensemaking of the final answer.

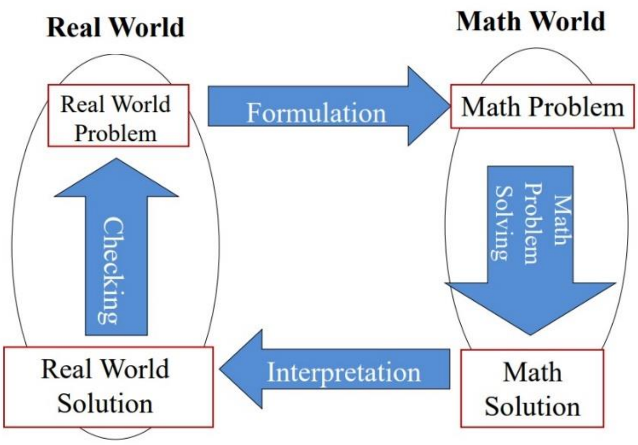

Figure 1. Four steps modelling cycle

As an example for modelling task, you can consider travelling from one city to another one for the purpose of participating in a workshop which there are different possible ways for traveling contain using personal car, train and flight. If you asked to find best way in terms of time consuming, or in terms of economical point of view or regard to environmental concerns and air pollution, what would be your choose? You have to choose one of these ways upon your situation, so this problem start from real world and you have to make mathematical problem based on given information through process of formulation (see Figure 1). Then in mathematical world, you have to use your mathematical knowledge and mathematical problem solving techniques. Then after finding the answer in math world, you have to do interpretation and checking phase of modelling cycle (see Figure 1). There is another well-known and well defined modelling cycle (see Picture 2) which has seven steps and it will be more suitable for explaining formulation part of modelling cycle which mathematical elements of real situation realized with more detailed steps. Specifically the terms of situation model refer to mental representation of the situation.

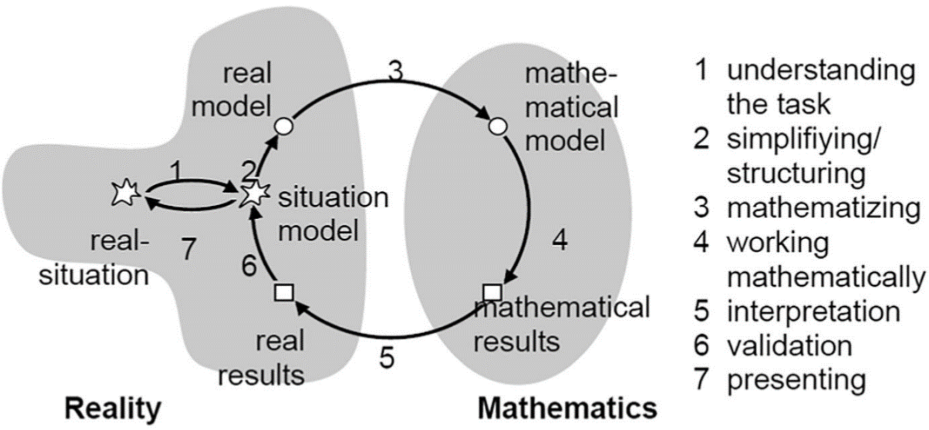

Figure 2. Seven steps modelling cycle (Blum and LeiB, 2007)

Learning theories which support the idea of modelling and application

No single logic is strong enough to support the total construction of human knowledge. (Jean Piaget, 1970)

Like as Piaget, Rienecker, Jørgensen, Dolin, and Ingerslev, (2015) believe that there is no “correct” learning theory that explains the learning of everything in all situations. Even in teaching and learning of a single subject like mathematics, it should be more effective to use different theories of learning. In this paper, modelling and application introduced as a mean for filling the gap between real life experiments and mathematical ideas. Several learning theories support the idea of using mathematical modelling and application in the process of teaching and learning mathematics. For example, in the modelling cycle learners start from real world situation which is familiar for them and this component alien with constructivism point of view that discuss for starting teaching activities from students experiences and try to build knowledge up on these experiences. Rienecker, Jørgensen, Dolin, & Ingerslev, (2015) believe that the key to constructivism as a learning theory is that each individual person constructs his or her knowledge through interaction with his or her surroundings.

Essence and identity of modelling tasks put based on learners group working and discussion about every component of modeling cycle. So, this element of mathematical modelling alien with social cultural theory of Vygotsky. In the line with Rienecker, Jørgensen, Dolin, & Ingerslev, (2015) which discuss about consequences of applied social constructivism theory of learning for teaching practice, it would be consider that in modelling tasks students would be able to work into the social situations where they can apply and reflect on the application of the culture’s artefacts. In this situation, they have many dialogues to exchange views and understandings.

Another theory of learning that support modelling point of view will be critical reflection that introduced by Paulo Freire (1987, 2005). Students who start to work in the modelling tasks, have to formulate real world problem to math world problem and after solving this problem, they have to interpret and check the solution in front of real world situation. In this phase of modeling cycle, they have to use their critical reflection skills to make final answer.

Designing a good modelling activity

One of the most important and challenging part of using modelling activities in the mathematics classroom would be finding or designing a good modelling activity that is suitable, believable and authentic. Mathematical modelling task should be suitable for the students and that means the task must related to level of students mathematical knowledge. Mathematical modelling task should be believable by students and that means the task must choose or designed based on students real life experiences. Finally, the mathematical modelling task must be authentic for the students and that means whether modelling task make sense for students or not?

Mathematical modelling tasks could be taken from literature or designed by mathematics teachers or instructor. Mathematical modelling tasks could be designed by teachers or instructors in advanced, or develop by teacher and with corporation of students based on their common experiences, or developed based on students experiences and support with teachers feedback. Noticed that the last method for designing modelling task will be suitable just for experienced classroom that complete several modelling activities. One of the useful researches which help beginner and give them some ideas for designing mathematical modeling task is Bonotto paper (2007) which discuss how we can replace ordinary word problems in the textbooks by realistic mathematical modelling activities.

As an example for mathematical modelling activities consider below modeling activity which related to students everyday life who live in society based on agriculture and horticulture. Teacher can bring different type of apples (size, shape and weight and color) in the mathematics classroom and ask students to help apple farmers in order to classified these apples for different market. Mathematical modelling task related to classification of apple presented in Figure 3.

You are apple farmers and must classify the apples in your basket for several buyers:

- high quality gift basket distributors (the “best” apples);
- supermarkets (“apples which can be sold”);
- school districts (“smaller apples for lunch”);
- and the least attractive apples which can be used for making purees and juices.

Each group of students has tools for measuring, weighing…and a blank piece of paper for writing the results. You must classify your apples for the different buyers and then explain how you have decided to classify the apples and why. In order to do this, each group has to prepare a presentation for the other apple farmers in order to help them understand how to classify their apples for potential buyers. In the end, we will bring together all of your explanations.

Figure 3. apple classification modelling task (Alsina and Salgado, 2022)

As we can see working on mathematical modelling activities like apple classification modelling task (see figure 3) can activated the high level (Relational level and Extended abstract level) of SOLO taxonomy as well as medium levels (Uni-structural level and Multi-structural level). Action like calculate, identify variable, collect data (related to level 2 of SOLO taxonomy), describe, formulate, solve, express, display, report, simulate (related level 3 of SOLO taxonomy), analyze, explain, compare, summarize, design, optimize, construct (related to level 4 of SOLO taxonomy), and discuss, estimate, evaluate, interpret, predict, criticize, reflect (related to level 5 of SOLO taxonomy), to be done during apples classification modelling activities.

Mathematics teachers or educators also can choose mathematical modeling task from literature and modified it based on students cultural and social context. For example consider below task from Jensen (2009).

- How does the tax you pay depend on the income tax percentage and the VAT percentage?

Different societies and countries have different rules and regulation for tax, and this problem can be modified based on contextual information and used in different societies and countries.

Assessment and supervision in modelling activities

One of the important part of implementing mathematical modelling activities in mathematics classrooms is related to supervision of students and give them continuous feedback. It is not easy and straightforward task for teachers to provide constructive feedback to students, but it is challenging and enjoyable task for them. Usually students specially novice one in mathematical modelling have difficulties in building situation model (see figure 2), to formulate (mathematizing) mathematics model from reality (see step 3 in Figure 2) and in completion of mathematical modelling cycle. For troubleshooting, teachers have to provide different feedback for the students. For example, when the students didn't complete covering of mathematical modelling cycle, teacher can notify them about that. In many cases, students forget to do final steps of modelling cycle (step 6 and 7 in figure 2). In this cases teacher just remind them for do these steps. Sometime students couldn't formulate (mathematizing) mathematics model from reality. In this case teacher can help them to define and consider variable that is important in the situation without reveal direct reference to solution of the problem.

In supervision of students when they are working on mathematical modelling activities, it is very important to provide them useful feedback. Hattie and Timperley (2007) believe that an ideal learning environment occurs when both teachers and students seek answers to three below questions related to feedback.

- Where am I going? (feed up dimension)
- How am I going? (feed back dimension)
- and Where to next? (feed forward dimension)

In feed up dimension, teacher have to ask students to read carefully mathematical modelling activities and understand the context and focus on demand of question. In this way, students can understand all components of mathematical modelling activities and will be able to formulate problem. This understanding help students to develop shared commitment which is necessary for feed up dimension. In feed back dimension, teachers provide information relative to the mathematical modelling activity or students' performance and their success or failure on solving that problem. In feed forward dimension, teachers encourage students to generalized the problem that they solved during their engagement in mathematical modelling activity through changing the assumption.

In last section one of the most important and challenging part of using mathematical modelling activities in the mathematics classroom was discussed. Another challenge of implementation of mathematical modelling activities in the mathematics classroom is related to assessment of students activities when they engage into the modelling activities. Although there are several rubrics for assessing students' performance in modelling activity (e.g. Ludwig and Xu, 2010), but, as Galbraith (2007) mentioned that mathematical modelling community of research need to do more research in this area to find most effective ways for assessing students work when they engaged in solving mathematical modeling tasks. Ludwig and Xu (2010, p. 80) framework for assessing mathematical modelling have six different consecutively levels (see Figure 4).

- Level 0: The student has not understood the situation and is not able to sketch or write anything concrete about the problem.
- Level 1: The student only understands the given real situation, but is not able to structure and simplify the situation or cannot find connections to any mathematical ideas.
- Level 2: After investigating the given real situation, the student finds a real model through structuring and simplifying, but does not know how to transfer this into a mathematical problem (the student creates a kind of word problem about the real situation).
- Level 3: The student is able to find not only a real model, but also translates it into a proper mathematical problem, but cannot work with it clearly in the mathematical world.
- Level 4: The student is able to pick up a mathematical problem from the real situation, work with this mathematical problem in the mathematical world, and have mathematical results.
- Level 5: The student is able to experience the mathematical modelling process and validate the solution of a mathematical problem in relation to the given situation.

Figure 4. six level for assessing mathematical modelling competency (Ludwig and Xu, 2010, p. 80)

Concluding Comment

Many students and teachers who participated in one of my previous mathematical modelling workshops acknowledged that they enjoyed from participation on the workshop and they learnt mathematics in meaningful way. But, there are still two challenges for implementing mathematical modelling activities in mathematics classrooms. One of them related to design suitable and meaningful mathematical modelling activities based on students everyday life. Another one related to assessing students during engagement and solving mathematical modelling activities.

I believe that, one of my challenges as mathematics educator who interested to expand mathematical modelling at the mathematics classroom is that supporting prospective mathematics teachers (teachers students at pre-service university education) through designing many mathematical modelling activities in several social-cultural context related to the students and teachers everyday life. Another challenges of mine is that to encourage prospective mathematics teachers to design mathematical modelling activities based on real life phenomenon around them through careful observation of surrounding phenomenon and eliciting mathematical ideas from that phenomenon. In this way they need more and more mentoring through expert (mathematics educators who work in this domain of research) supervision to find their own motivation, courage and self-confidence.

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Geometry–Do, White Belt Chapter

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Abstract: *Geometry–Do* is a textbook about plane geometry. It will be divided into two volumes, *Geometry without Multiplication: White through Red Belt*, and *Geometry with Multiplication: Blue through Black Belt*. The white- and yellow-belt chapters are neutral geometry; the remainder of *Volume One* and all of *Volume Two* is Euclidean geometry. It is primarily intended to teach geometry from the ground up, starting with the postulates and citing only already-proven theorems. It trains mathletes for competition, but it is not the usual grab-bag of unproven theorems chosen haphazardly and solely because they appeared in past exams. The early chapters prepare students for jobs in construction, architecture, surveying, graphic arts, and military defense. The later chapters teach geometry needed by engineers and military officers. In this lecture, the White Belt chapter is presented. I will address these people:

Pure Mathematicians	Moise derides the "lighthearted use of the word *let*." I prove the crossbar theorem and other foundations not usually taught in high school, and I discuss Hilbert's *Foundations of Geometry*.
High-School Teachers	Randomly assigning letters to points is what makes geometry confusing. I have special symbols for midpoints, perpendicular feet, and infeet (where the angle bisector cuts the opposite side of a triangle) and exfeet.
Administrators	I present clear distinctions between *Geometry–Do* and *Common Core* with examples that concerned parents can understand.
Construction Workers	I invent the Aguilar A-Frame, give detailed instructions on squaring a basement foundation wider than a tape measure without exiting the rectangle, and discuss how building with wood differs from steel construction.
Military Officers	I discuss troop positioning along a frontier that is plagued with cross-border raids, which assumes that friendly and enemy troops move at the same speed, and a parabola is the set of points equidistant from the focus and the directrix.

Keywords: Geometry Applications, Common Core Math, Neutral Geometry, STEM, David Hilbert

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Introduction

This article is divided into two parts. The first part is the introduction to *Geometry–Do*, which discusses the foundations of geometry. The second part is the White Belt chapter, which proves some basic theorems. Every chapter, including White Belt, has appendices that discuss applications. The main text of each chapter strictly follows the axiomatic method with each theorem being proven citing only the postulates and previously proven theorems. But the chapter appendices sometimes call on information that students are expected to know from their previous studies; *e.g.* the appendix about defense positioning assumes prior knowledge of the equation for a parabola. Parabolas are taught in Algebra I, which precedes Geometry in most high schools.

The main text of *Geometry–Do* does not have any prerequisites – we are doing *Volume One* without multiplication – though the extended chains of reasoning will be best met by students with some prior study of mathematics. But White Belt is basic, so any high-school student should be able to read this article. If readers wish to continue, the rest is here:
www.researchgate.net/publication/291333791_Volume_One_Geometry_without_Multiplication

Euclid's Postulates Plus One More

Segment	Two points fully define the **segment** between them.
Line	By **extending** it, a segment fully defines a **line**.
Triangle	Three **noncollinear** points fully define a **triangle**.
Circle	The center and the **radius** fully define a **circle**.
Right Angle	All **right angles** are equal; equivalently, all **straight angles** are equal.
Parallel	A line and a point not on it fully define the **parallel** through that point.

Segments are denoted with a bar, $\overline{EF}$; **rays** with an arrow, $\overrightarrow{EF}$, which have endpoint E and are extended on the F side infinitely; lines with a double arrow, $\overleftrightarrow{EF}$, which are extended infinitely both ways; and **angles** as $\angle EFG$ or $\angle F$ if there is only one angle at F. Triangles and quadrilaterals are also denoted with bars, as $\overline{EFG}$ and $\overline{EFGH}$. The **postulates** are in terms of **fully defined**, which means that a **figure** with the given characteristics exists, and it is unique. **Under defined** means figures with the given characteristics are legion. John Playfair stated the parallel postulate as I and David Hilbert do, which is **equivalent** to Euclid's Fifth Postulate (Euclid, 2013, p. 2).

If a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles.

While Hilbert and I both found Euclid's postulate to be convoluted and chose Playfair's version, and we both reject real numbers as unsupported by our postulates, we otherwise are different.

Euclid also had five "common notions," which vaguely describe what modern mathematicians call equivalence relations, total orderings, and additive groups.

Equivalence Relations and Total Orderings

A **relation** is an operator, $\mathcal{R}$, that returns either a "true" or a "false" when applied to an ordered pair of elements from a nonempty set. (We only use binary relations, so we can omit "binary.") Relations must be applied to objects from the same set. For instance, $\overline{EF} = \angle G$ is neither true nor false; it is incoherent. There are four ways that relations may be characterized. For one to hold, it must apply to all possible choices x, y, z from the given set, not just some of them.

Reflexive	$x \mathcal{R} x$
Symmetric	$x \mathcal{R} y$ implies $y \mathcal{R} x$
Anti-Symmetric	$x \mathcal{R} y$ and $y \mathcal{R} x$ implies $x = y$
Transitive	$x \mathcal{R} y$ and $y \mathcal{R} z$ implies $x \mathcal{R} z$

A reflexive, symmetric, and transitive relation is called an **equivalence relation**. The principal equivalence relations considered in geometry are **equality**, $=$, which applies to segments, angles, or areas; **congruence**, $\cong$, which applies to triangles; **similarity**, $\sim$, which applies to triangles; and **parallelism**, $\parallel$, which applies to lines. $\overleftrightarrow{EF} \parallel \overleftrightarrow{GH}$ means that $\overleftrightarrow{EF}$ and $\overleftrightarrow{GH}$ do not intersect. There are an infinity of points in the plane; strange and useless results can be made of small finite sets.

Since segments are known only by their **length**, $\overline{EF} = \overline{GH}$ means that $\overline{EF}$ and $\overline{GH}$ are the same length. Since length is the same regardless of direction, it is always true that $\overline{EF} = \overline{FE}$. But triangles are known, not by just one magnitude, but by six. The vertices are ordered to show which ones are equal. $\overline{EFG} \cong \overline{JKL}$ implies $\overline{EF} = \overline{JK}$, $\overline{FG} = \overline{KL}$, $\overline{GE} = \overline{LJ}$, $\angle E = \angle J$, $\angle F = \angle K$ and $\angle G = \angle L$; and these equalities imply congruence. Beware! Writing the vertices of a triangle out of order is one of the most common mistakes made by beginning geometers.

A **quadrilateral** is a union of two triangles adjacent on a side such that it is **convex**; congruence or similarity holds if and only if both pairs of triangles are congruent or similar. If $\overline{EFG} \cong \overline{JKL}$ and $\overline{EHG} \cong \overline{JML}$, then, $\overline{EFGH} \cong \overline{JKLM}$. Analogously, if $\overline{EFG} \sim \overline{JKL}$ and $\overline{EHG} \sim \overline{JML}$, then, $\overline{EFGH} \sim \overline{JKLM}$. Similarity is defined as two triangles with all corresponding angles equal, so $\overline{EFG} \sim \overline{JKL}$ and $\overline{EHG} \sim \overline{JML}$ means that six pairs of corresponding angles are equal. This is more than just saying that the four corresponding **interior** angles of $\overline{EFGH}$ and $\overline{JKLM}$ are equal; thus, it is not true that proving these four angles equal is sufficient to prove $\overline{EFGH} \sim \overline{JKLM}$. A counter-example is a right square and rectangle; they have all right angles, but they are not similar. "Four-sided figure" is a vacuous quadrilateral definition that leads beginners to err by claiming that right squares and rectangles are similar. We make quadrilaterals a logical extension of triangles.

Relations that are anti-symmetric can only be defined if we have already defined equality, because equality is referenced in its definition. (Equality is the only relation that is both symmetric and anti-symmetric.) A relation that is not symmetric but has the other three characteristics is called a **total ordering**. The adjective total is redundant because we said relations must hold for every pair of elements. (Partial orderings, such as subset, exist in other branches of mathematics.) Geometers only use less than or equal to, $\leq$. ($\geq$ could be, though we usually order from small to large; $<$ and $>$ are irreflexive and so are not orderings.) A nonempty set with both an equivalence relation, $=$, and a total ordering, $\leq$, is called a **magnitude**. Geometers consider three magnitudes: lengths, angles, and areas.

Note that our definition of magnitude does not imply that real numbers can be associated with lengths, angles, or areas; only that the relations $=$ and $\leq$ exist and have the required properties. (In real-life applications I use integer lengths, denoted by absolute value, *e.g.*, $|\overline{EF}| = 5$ m.) It does imply that magnitudes are unique, which is what the replication **axiom** below is stating.

Equal magnitudes are an equivalence relation and can be reproduced wherever needed; that is, compasses do not collapse when lifted from the paper but are like holding a chain at a length. Compasses that collapse would be like surveyors who can walk a chain around an **arc** but, the moment the center guy moves, their chain turns to smoke. This is a parlor game, not a science!

An **equivalence class** is defined as a subset of all the elements that have an equivalence relation with each other. It can be shown that any two equivalence classes either coincide or are disjoint, hence the collection of equivalence classes form a partition of the set. For example, if the set is all the lines in the plane, it is partitioned by parallelism; each equivalence class is composed of lines stacked on top of each other (parallel) but tilted relative to the lines in the other classes. Equivalence classes can be defined in reference to an existing equivalence class. For instance, if an equivalence class is defined as all the angles equal to a given angle, then all the angles **complementary** to any member of that class are equal to each other; that is, they form their own equivalence class. All the angles **supplementary** to any member of that class are also equal to each other. If an equivalence class is defined as all the lines parallel to a given line, then all the lines **perpendicular** to any member of that class are parallel to each other. All the circles with radii equal to any member of an equivalence class of equal segments are an equivalence class.

Equivalence also refers to statements that can be proven if the other one is assumed, and in either order. For instance, Euclid's fifth postulate and Playfair's postulate are equivalent because, assuming either to be true, it is possible to prove that the other is true. The equivalence of **theorems** can be expressed by separating them with the phrase "if and only if," which can be abbreviated "iff." Proof in the other direction is called the **converse**; that is, if p implies q, then the converse is that q implies p. If p and q are equivalent, then both implications are true.

Proof by contradiction when there is only one alternative that must be proven impossible is called a **dichotomy**. A **trichotomy** (*e.g.* ASA congruence) has three alternatives. A magnitude can either be less than, equal to or greater than another, and only one of these three is desired; thus, by proving the other two to be impossible, we know that it is the one that makes the theorem true.

Additive Groups

We define an additive group as a nonempty set that is closed under an operation that we will denote $+$ and which has these properties for all x, y, z that are members of that set:

Associative property	$(x+y)+z = x+(y+z)$
Commutative property	$x+y = y+x$
Existence and uniqueness of an identity	$x+0 = x = 0+x$
Existence of unique inverses (identity is its own)	$x+(-x) = 0 = (-x)+x$

There exist magnitudes that are not additive groups, such as economic value. Given a choice between x or y, it is always possible for a person to choose one. But, because x may substitute for or be a complement to y, they are not independent the way geometric magnitudes are. There are also additive groups that cannot be ordered, such as matrices. Matrices of the same dimension are an additive group, but we cannot say $\boldsymbol{X} \leq \boldsymbol{Y}$ for any two distinct matrices.

On the first day of class I ask the students to look back to a time eight or ten years prior, when they were little kids and knew only how to add and subtract; multiplication and division was still scary for them. I assure them that geometry will be like going back to 1st grade. Sticking segments together end to end or angles together side by side is no more difficult than 1st grade problems about adding chocolates to or subtracting chocolates from a bowl of candies. How easy is that?

Replication Axiom

Given $\overline{EF}$ and $\overrightarrow{JK}$, there exists a unique point L on $\overrightarrow{JK}$ such that $\overline{EF} = \overline{JL}$.

Given $\angle EFG$ and $\overrightarrow{KJ}$, there exist rays $\overrightarrow{KL}$ and $\overrightarrow{KL''}$ such that $\angle EFG = \angle JKL = \angle JKL''$.

The symbol $<$ is defined by the terms "between" and "inside," as stated in the two axioms below. But this symbol can also be applied to magnitudes. $|\overline{EF}| < |\overline{JK}|$ means that the number of units that can be laid off inside $\overline{EF}$ is less than the number that can be laid off inside $\overline{JK}$. The absolute value signs denote these numbers, so we use $+$ when combining them; $|\overline{EF}| + |\overline{JK}|$ is the sum of these lengths. Degrees or radians measure angles and can be added, but that is undefined in this book; it is trigonometry. We measure area though; $|\overline{EFG}| + |\overline{JKL}|$ is their combined area.

Interior Segment Axiom

*If M is **between** E and F, then $\overline{EM} < \overline{EF}$ and $\overline{MF} < \overline{EF}$ and $\overline{EM} \cup \overline{MF} = \overline{EF}$.* ($\cup$ *means union.*)

Interior Angle Axiom

*If P is **inside** $\angle EFG$, then $\angle EFP < \angle EFG$ and $\angle PFG < \angle EFG$ and $\angle EFP \cup \angle PFG = \angle EFG$.*

Axioms and Foundational Theorems

For a point to be between E and F means to be on the segment they define, $\overline{EF}$, but at neither **endpoint**. To be inside $\angle EFG$ (not straight) means to be between points on $\overrightarrow{FE}$ and on $\overrightarrow{FG}$, with neither point being F. It is instinctive that all humans know what it means for a point to be between two points and – in the case of Pasch's axiom – also what it means for a segment to be continuous; that is, with no gaps where another segment might slip through. Triangles and quadrilaterals are defined to be convex; this means that they are not allowed to be concave or **degenerate**. Interior angles are greater than zero and less than straight (indeed, all angles are because of "between" in the definition), so triangles are never segments, and quadrilaterals are never triangles or darts.

Pasch's Axiom

If a line passes between two vertices of a triangle and does not go through the other vertex, then it passes between it and one of the two vertices.

In *Geometry–Do*, plane, point, shortest path and straight are **undefined terms**. These are concepts that a parent does not have to explain to a child; they are just giving names to what is already in the child's mind. Specifically, a plane is undefined because rigorously defining uncountably infinite, flat, and of exactly two dimensions is beyond the scope of this book. Euclidean **area** is defined as the measure of the size of a triangle or a union of **disjoint** triangles. Like the ancients, we do not have a rigorous definition of limits but just rely on intuition; wheat plants are infinitesimal compared to fields, so weighing the wheat is almost like calculating a limit. Thus, area too is something that small children can understand without explanation. Defining area as the product of a right rectangle's sides waits for *Volume Two: Geometry with Multiplication*. This definition of area is not intuitive to small children, who know nothing of multiplication. For now, just know that area is a magnitude.

Degrees of angle or radians will not be defined in either volume because doing so is trigonometry.

Triangle Inequality Theorem ***(Euclid, Book I, Prop. 20, 22)***

Three lengths can be of triangle sides if and only if the sum of the lengths of any two sides is greater than the length of the third side.

In ancient Greece, Epicurus scoffed at Euclid for proving a theorem that is evident even to an ass (donkey), who knows what the shortest path to a pile of hay is. Some textbooks call it an axiom, and some prove only one direction – they start with the existence of the triangle and prove the inequalities – but that is not the direction needed for SSS, which cites it. Beginners here should just take it as an axiom; also, they should take the continuity theorem (below) as an axiom. Its proof requires the Cantor axiom, which assumes a knowledge of set theory that is not expected of beginning geometers. Experts can find detailed proofs in an appendix at the end of this book.

Continuity Theorem

1. *A line that passes through a point inside a circle intersects the circle exactly twice.*
2. *A circle that passes through points inside and outside a circle intersects it exactly twice.*

The foundations explained above are sufficient through red-belt study. In these early chapters, students will learn to bisect, trisect and quadrisect a segment, and to multiply it by small natural numbers by using repeated addition. No more of these repeated additions are needed than four, for construction of the Egyptian or $3:4:5$ right triangle, except that we mention in passing the $5:12:13$ right triangle, which is used by plumbers when installing $22.5°$ elbows. Elementary school teachers are wrong when they define multiplication as repeated addition; this is why so many students are later confounded by real numbers like $\sqrt{2}$ or π. The repeated addition used in $3:4:5$ right triangles has nothing to do with multiplying lengths as defined in *Volume Two*.

Blue belts will learn of similarity and prove the triangle similarity theorem. They will go beyond bisecting and trisecting segments to constructing segments whose length relative to a given unit is any rational number. Another axiom is needed for this. A nonempty set with both an equivalence relation, $=$, and a total ordering, $\leq$, is called a magnitude. But to construct segments whose length relative to a given unit is any rational number, length must also be Archimedean.

Archimedes' Axiom

Given any two segments $\overline{EF} < \overline{GH}$, there exists a natural number, n, such that $n|\overline{EF}| > |\overline{GH}|$.

This may seem trivially true, but Galois (finite) fields are not Archimedean. Every schoolboy is taught that Archimedes claimed that, given a long enough lever and a fulcrum to rest it on, he could move the world. They typically receive no clear answer from their teacher on why it matters, since no such fulcrum exists, and Archimedes seems to ignore that gravity is attractive. The point that Archimedes is making is that, if there were such a fulcrum and much gravity under it, he would need a lever 6×10^{22} longer on his side of the fulcrum to balance his mass against the Earth. If the fulcrum were one meter from Earth, Archimedes would be in the Andromeda galaxy if he stood on the other end of that long lever. 6×10^{22} is a big number, but it does exist.

We said above that undefined terms are concepts that one does not have to explain to a child; the adult is just giving names to concepts that are already in the child's mind. But defining natural numbers as $1, 2, 3, \ldots$ is only intuitive up to as many fingers as the child has. We think 6×10^{22} exists because countably infinite fields are consistent; but so are big Galois fields. This axiom is why it is traditional in America to tell children that every snowflake is unique; it helps them visualize big numbers. (Dinosaurs help them visualize vast gulfs of time.) That Archimedes' axiom is not intuitive to small children is one reason why similarity is delayed until blue belt. Note that visualizing big numbers – the vast number of snowflakes in just one field – is what this parable meant when I was a child. But lately, psychologists have commandeered this expression in their happy talk for depressed people, resulting in the sneering retort, "Well, aren't *you* a special snowflake!" So, be careful when mentioning this parable in the context of the Archimedes axiom!

But these are issues of concern to black belts; first, the student must take a short jog through the colored belts, which are concerned with what Mihalescu (2016) refers to as the remarkable elements of triangles and quadrilaterals. By this we initially mean the principal triangle centers. The medians intersect at the medial point, the angle bisectors intersect at the incenter, the altitudes intersect at the orthocenter, and the mediators intersect at the circumcenter. In this introduction the student does not need to know what any of these things are, only that medians – the segment from a vertex to the midpoint of the **opposite** side – and the bisectors of vertex angles are always inside their vertex angle. In $\overline{EFG}$, if the vertex is F, then they are inside $\angle EFG$.

Crossbar Theorem

Given triangle $\overline{EFG}$ and a point P inside it, the ray $\overrightarrow{EP}$ intersects the segment $\overline{FG}$.

Proof

Let Q be on the ray $\overrightarrow{GE}$ so E is between G and Q. Consider the triangle $\overline{QFG}$. The line $\overleftrightarrow{EP}$ passes between the vertices Q and G because E is between G and Q, and it does not pass through the other vertex, F, because P is inside $\overline{EFG}$, which means that it is not on $\overline{EF}$. Thus, the conditions of Pasch's axiom are met and $\overleftrightarrow{EP}$ must intersect either $\overline{FG}$ or $\overline{FQ}$. By construction, $\overrightarrow{EP}$ and $\overline{FQ}$ are on **opposite** sides of $\overleftrightarrow{EF}$, so $\overrightarrow{EP}$ cannot intersect $\overline{FQ}$. The ray in the other direction of $\overrightarrow{EP}$ does not intersect either $\overline{FG}$ or $\overline{EF}$ because both segments are on the other side of $\overleftrightarrow{GQ}$. Thus, $\overrightarrow{EP}$ intersects $\overline{FG}$.

■

The midpoints of segments are denoted by the letter M with a double subscript, which are the endpoints of the segment. Thus, two medians of the triangle $\overline{EFG}$ are $\overline{EM_{FG}}$ and $\overline{FM_{GE}}$. Consider the triangle $\overline{EM_{FG}G}$. The line $\overleftrightarrow{FM_{GE}}$ passes between the vertices G and E because M_{GE} is between G and E, and it does not pass through the other vertex, M_{FG}, because M_{FG} is not F. Thus, the conditions of Pasch's axiom are met and $\overleftrightarrow{FM_{GE}}$ must intersect either $\overline{EM_{FG}}$ or $\overline{M_{FG}G}$. Since it intersects $\overleftrightarrow{M_{FG}G}$ at F, it cannot also intersect this line in the segment $\overline{M_{FG}G}$. Thus, it intersects $\overline{EM_{FG}}$. This proves that the medial point of a triangle is always inside the triangle. Note that midpoints are defined in C. 1.2, and their existence inside the segment assured. Triangle centers will be defined later, and their existence assured. On this page we speak casually of things that will be treated rigorously later.

Analogously, the incenter of a triangle is always inside the triangle. The only difference in the proof is that, instead of knowing that the bisectors of vertex angles E and F intersect the opposite sides at M_{FG} and M_{GE}, respectively, we must first invoke the crossbar theorem to prove that they intersect the opposite sides *somewhere* on them, and give these points labels; say, E^* and F^*.

By the triangle postulate, three noncollinear points fully define a triangle and, since the medial point and the incenter have now been proven to be inside the triangle, they are fully defined. Because we nowhere invoked the parallel postulate, medial points and incenters always exist in **neutral geometry** and are thus topics of discussion for white and yellow belts. But what about the orthocenter? A triangle's apex altitude is inside it only if the base angles are **acute**, so white and yellow belts may only discuss the orthocenter if the triangle is known to be acute. By a somewhat more involved argument, the circumcenter also exists for acute triangles. Sometimes these centers exist for triangles that are slightly **obtuse**, though giving a precise meaning to "slightly obtuse" is beyond the scope of this book; thus, white and yellow belts are advised to just defer most discussions of these triangle centers to orange belt.

An Example Theorem with Proof

This concludes our discussion of the postulates of geometry. But you may still be wondering, what is geometry about? The first line of a book is often the only thing people remember about it; for instance, "Call me Ishmael" is the first line of *Moby Dick*. I think it is about a whale – I don't remember. Like Herman Melville, Euclid is also famous for his first line – but not in a good way. "A point is that which has no part." Beginning geometry students are like, "Oh, so this is a book about Japanese koans?" In the first paragraph of *Geometry–Do*, there are a dozen boldface terms for the student to look up in the glossary, so you may be thinking, "Oh, so this is a book about memorizing vocabulary? It is like learning a language spoken in a country that I will never visit?"

When I was a freshman in college, I rather inadvisably took an upper-division course on groups, rings and fields. Why not? If not with knowledge, I was at least filled with ambition! Most of the material in this introduction came from that textbook, but what I remember most is the first line:

The main business of mathematics is proving theorems.

John Fraleigh (1989) set this sentence between horizontal lines, just as I have done above. He must have thought it important! He is right; the business of mathematicians is proving theorems.

Example Theorem

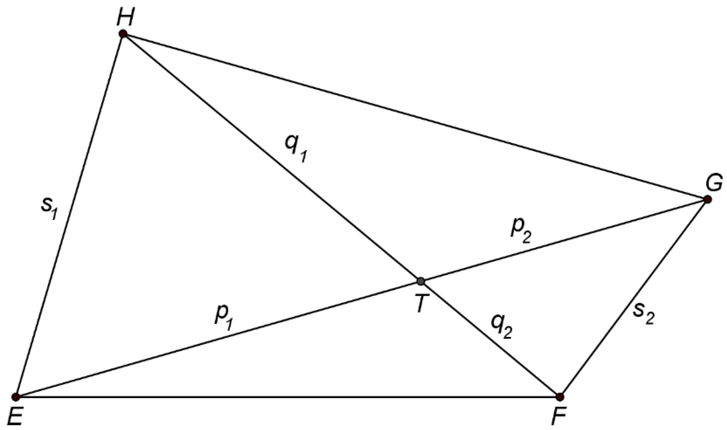
*The sum of quadrilateral **diagonals** exceeds the sum of either pair of **opposite** sides.*

Let us try proving a theorem, and do so now, before the add/drop date, while there is still time for students to make a run for it! This will be fun. We will do it step by step, so I can lead the reader by the hand through a genuine geometry proof. It is easy, and it requires only the basics.

Step One: The first step is to remind yourself of the definitions of terms that you already know, and to look up any terms that you have not yet learned. We read about the quadrilateral earlier; but let us look it up to make sure that we know it. Look up adjacent, convex, and diagonal too!

Quadrilateral	The union of two triangles adjacent on a side such that it is convex; $\overline{EFGH}$
Adjacent	Two disjoint triangles with a common side (common for its full length)
Convex	Any segment between two points interior to two sides is inside the figure
Diagonal	Segments connecting non-consecutive quadrilateral vertices

Step Two: The next step is to draw the figure, and to do so in a way that the definitions of terms are satisfied. For instance, if our two triangles are like the blades on an arrowhead, then the figure is not convex; a segment between the trailing edges of the two blades would not be inside the figure. This is not a quadrilateral; the proof below does not work for it because its diagonals do not intersect. In the figure below, we see that $\overline{EG}$, the side common to the two triangles, $\overline{EFG}$ and $\overline{GHE}$, is a diagonal; indeed, because it defines the quadrilateral, it is called the **definitional diagonal**. The same quadrilateral can be defined two ways, with two different pairs of adjacent triangles. Sometimes it matters which diagonal is definitional, but the problem at hand mentions both diagonals, so draw both, $\overline{EG}$ and $\overline{FH}$, and label the cut segment lengths p_1, p_2, q_1, q_2. The intersection of the diagonals is labeled T, and two of the side lengths are labeled s_1 and s_2. Lowercase letters denote lengths and can be added; they are not a symbol for the segment itself.



Example Theorem Figure

Step Three. The next step is to go through the index and look for relevant postulates, axioms, and theorems. The index is fifty pages long; so, later, this can be a daunting task. Intuition and experience when carrying out this search is what divides passing green- and red-belt geometers from failing ones. But, at this early stage in your career, the index for the introduction amounts to only two pages, so it is not a long search. The problem is about comparing two sums, so let us remind ourselves about additive groups. By segment addition, the two diagonals are $p_1 + p_2$ and $q_1 + q_2$. Their sum is $(p_1 + p_2) + (q_1 + q_2)$. We are comparing two magnitudes; so, relevant is a theorem about one magnitude being less than another. It is the triangle inequality theorem!

Step Four: The final step is to carry out the proof. There are two triangles with their sides labeled. In $\overline{ETH}$, by the triangle inequality theorem, $s_1 < p_1 + q_1$. In $\overline{FTG}$, by the triangle inequality theorem, $s_2 < p_2 + q_2$. Add the two inequalities together: $s_1 + s_2 < (p_1 + p_2) + (q_1 + q_2)$. We do not have to go through this for the other pair of opposite sides; just say, "analogously."

Thus, you have seen the business of mathematicians. If you have not concluded that being a waiter with a psychology degree is the life for you, then I will see you tomorrow! We will prove the dreaded side–angle–side (SAS) theorem, which stumped both Euclid and David Hilbert!

Experts only!!! (Those uninterested in Hilbert's *Foundations* skip to the notation section.)

Hilbert's "straight line" is redundant; there is no such thing as an unstraight line, so we will just say "line." Hilbert uses the letters $A, B, C, \ldots$ for points, but these will be changed to $E, F, G, \ldots$ to be compatible with *Geometry–Do*, where the first four letters have special meanings. "Always completely determine" is the same thing as "fully define," so we will use the *Geometry–Do* term. "Situated in the same line" means collinear; indeed, "situated on a line" can just be "on a line." "Passes through a point of the segment" means "intersect." I am trying to make this easy!

One reason why beginners are uncomfortable with Hilbert's axioms is their verbosity; sadly, this has often resulted in any mention of foundations being delayed until the students have become advanced. But going back and filling in foundations later is not the right way to teach geometry. This verbosity is largely because German is difficult to translate into English. Economists who have read Carl Menger and philosophers who have read Friedrich Nietzsche have also noticed this. The solution is to not translate quite so literally, which is what I have done below.

I. Axioms of Connection

1. Two distinct points fully define a line.
2. Any two distinct points of a line fully define it.
3. Three points not collinear fully define a plane.
4. Any three points of a plane not collinear fully define the plane.
5. If two points of a line are in a plane, then every point of the line is in the plane.
6. If two planes have a common point, then they have at least one other common point.
7. Lines have at least two points, planes at least three noncollinear points, and space at least four noncoplanar points.

II. Axioms of Order

1. If E, F, G are collinear and F is between E and G, then F is also between G and E.
2. If E and G are two points on a line, then there exists at least one point F that is between E and G and at least one point H so situated that G is between E and H.
3. Of any three collinear points, there is exactly one between the other two.
4. Any four collinear points E, F, G, H can always be arranged so F is between E and G; also, between E and H. Furthermore, G is between E and H; also, between F and H.
5. If E, F, G are not collinear and a line in the plane they determine does not pass through any of them and it intersects $\overline{EF}$, then it will also intersect either $\overline{EG}$ or $\overline{FG}$.

Some jokers have noticed that Euclid never said there had to be more than one point, and so they defined their own geometry with *exactly* one point. Every segment is of zero length and is at the same point; analogously, every circle has zero radius and has the same center. They took navel gazing to a whole new level, just staring at that one point, and seeing how many geometry theorems are true about it! This must have been meant as a joke, but I think Hilbert was a little too concerned about excluding these degenerate geometry theories and got a bit pedantic doing so with his axioms. *Geometry–Do* is comfortable leaving terms like plane and point undefined and assuming that the students are not going to play any jokes by twisting their meanings; they are just trying to learn some geometry that will be useful in their everyday lives. Thus, I. 7 is not made explicit. II. 1 – 3 are the glossary definition of "between" except that II. 1 has "between" assume collinearity rather than imply it. II. 4 is redundant and is omitted in *Geometry–Do*. II. 5 is Pasch's Axiom, which I include among the secondary axioms at the end of the introduction.

I. 5, 6 are omitted because *Geometry–Do* does not include solid geometry. Two reasons:

1. High-school students have enough on their plates with plane geometry. *Geometry–Do* is a three-year course, assuming I can squeeze blue belt, *Cho–Dan* and *Yi–Dan* into a single year. It is possible, especially if *Sam–Dan* is included, that this will be a four-year course.

2. Traditional solid geometry (*e.g.,* Wentworth or Kiselev) is not very useful. This material is better taught as an application of Calculus III. Wolfe and Phelps have an advanced version of *Practical Shop Mathematics* that is about solid geometry, but it does not cite any of Wentworth's theorems; civilian machinists are just not that into cones and spheres.

Indeed, while Wentworth is harmless, teaching teenagers too much about machining cones and paraboloids is risky because of their use in shaped charges and explosively formed projectiles. In high school, the volume formulas are just food for memorization. In Calculus III, these formulas can be derived, and the students are mature enough not to do anything crazy like making an EFP.

Geometry–Do postulates comparable to Hilbert's *Axioms of Connection and Order*

Segment	Two points fully define the segment between them.
Line	By extending it, a segment fully defines a line.
Triangle	Three noncollinear points fully define a triangle.

We are left with I. 1, 2, 3, 4, which are comparable to my segment, triangle, and line postulates. Hilbert's axioms are about points and lines; he defines segment almost as an afterthought. But *Geometry–Do* follows Euclid by having distinct segment and line postulates. This is wise because segments are foundational; they should not just be tossed in later. Also, I. 1, 2 are redundant; two points define a unique line, and a line is defined by any two points on it is just one postulate. I. 3, 4 is also just one postulate; let us compare it to the triangle postulate of *Geometry–Do*.

Hilbert is overreaching when he states that three noncollinear points fully define a plane. The Euclidean plane and the Lobachevskian plane are different things. Without a parallel postulate, existence of triangle centers is only assured inside the triangle with these vertices. To say, "the plane" requires explanation of what, exactly, has been defined. In the introduction, I write:

> *By the triangle postulate, three noncollinear points fully define a triangle and, since the medial point and the incenter have now been proven to be inside the triangle, they are fully defined. Because we nowhere invoked the parallel postulate in the preceding proofs, medial points and incenters always exist in neutral geometry… But what about the orthocenter? A triangle's apex altitude is inside it only if the base angles are acute, so white and yellow belts may only discuss the orthocenter if the triangle is known to be acute. By a somewhat more involved argument, the circumcenter also exists for acute triangles. Sometimes these centers exist for triangles that are slightly obtuse, though giving a precise meaning to "slightly obtuse" is beyond the scope of this book.*

III Axiom of Parallels

In a plane there can be drawn through any point not on a line, one and only one line that does not intersect the given line. This line is called the line's parallel through that point.

Hilbert's third group of axioms consists of only one axiom, which is the same as in *Geometry*.

IV Axioms of Congruence

1. If E and F are two points on a line and J is a point on the same or another line, then, on a given side of J on this line, there exists a unique point K such that $\overline{EF}$ is congruent to $\overline{JK}$, which is written $\overline{EF} \equiv \overline{JK}$. Every segment is congruent to itself; $\overline{EF} \equiv \overline{EF}$.

I am not an historian; but, as far as I know, this is the first time anyone ever used the term congruent to mean that two segments are the same length. Euclid would have said that they are equal and, as evidenced by Kiselev and Wentworth, this continued to be the practice through the 19th century in both the East and the West. Equal refers to magnitudes because they are fully defined by a single measurement, *e.g.*, the length of a segment. Triangles have three sides and three angles but – only after proving some theorems – we know that it is possible to measure three magnitudes and have equality for all six. Congruence is not just a single measurement.

Also, Hilbert's notation is confusing, though this may be due to the typesetting of his day. He did not use overlines while we use $\overline{EF}, \overrightarrow{EF}$ and $\overleftrightarrow{EF}$ to mean segment, ray, and line, respectively. He used only $\equiv$ while we use $=$, $\cong$ and $\equiv$ to mean equals, congruent and coincident, respectively.

IV Axioms of Congruence

1. Given $\overline{EF}$ and $\overrightarrow{JK}$, there exists a unique point L on $\overrightarrow{JK}$ such that $\overline{EF} = \overline{JL}$.
2. If $\overline{EF} = \overline{JK}$ and $\overline{EF} = \overline{LM}$, then $\overline{JK} = \overline{LM}$.
3. F is between E, G; also, K is between J, L. If $\overline{EF} = \overline{JK}$ and $\overline{FG} = \overline{KL}$, then $\overline{EG} = \overline{JL}$.
4. Given $\angle EFG$ and $\overrightarrow{KJ}$, there exist rays $\overrightarrow{KL}$ and $\overrightarrow{KL''}$ such that $\angle EFG = \angle JKL = \angle JKL''$.
5. If $\angle EFG = \angle JKL$ and $\angle EFG = \angle MNO$, then $\angle JKL = \angle MNO$.
6. If $\angle EFG = \angle JKL$ and $\overline{EF} = \overline{JK}$ and $\overline{FG} = \overline{KL}$, then $\angle FGE = \angle KLJ$ and $\angle GEF = \angle LJK$.

Hilbert's axioms of congruence are here written using *Geometry–Do* notation. I wrote all six of them in six lines, while Hilbert uses a total of 33 lines. This verbosity is one reason why Hilbert is no longer taught to beginners, though this does not justify omitting any discussion of the axiomatic method or just giving it lip service, as is typical these days.

Hilbert is not saying much here. IV. 1, 4 are the replication axiom, IV. 2, 5 are transitivity, and IV. 3 is substitution of equals in addition, which apparently applies only to segments, but not to angles. Frankly, my statement that "a set with both an equivalence relation, $=$, and a total ordering, $\leq$, is called a magnitude" and that there are three geometric magnitudes – lengths, angles, and areas – is a *lot* clearer and more succinct. Also, it is more complete. Why does IV. 3 not have an analogous statement about angles? What about area? Why is only transitivity mentioned and not the reflexive, symmetric and anti-symmetric relations? This is a *very* sketchy description of the properties of equivalence relations, total orderings, and additive groups.

IV. 6 is SAS congruence, though Hilbert makes $\overline{EG} = \overline{JL}$ a theorem. I prove SAS by citing the triangle postulate, which Hilbert could not do because he said that three noncollinear points fully define the plane, which is not what is needed to prove SAS. Hilbert is defining the plane to distinguish it from other planes in the context of solid geometry; we just want to prove SAS.

There is no axiom comparable to my circle postulate; Hilbert just inserts the definition of circle immediately before moving on to Archimedes' axiom, which is a bad idea for the same reason that casually inserting the definition of segment is. Segments and circles are foundational and deserve their own postulates.

Geometry–Do also has Archimedes' axiom; it is among the secondary axioms in the introduction.

Straight angles equal each other if and only if right angles equal each other. Straight is undefined and we could say that it is intuitive that they are all equal, as Hilbert does, or we could use Euclid's postulate, as I do. It is the same thing; Hilbert is too hard on Euclid when he calls him wrong. My right-angle postulate is, "all right angles are equal; equivalently, all straight angles are equal."

Notation

$\alpha,\ \beta,\ \gamma,\ \delta$	Angles of a triangle or quadrilateral; usually $\angle E, \angle F, \angle G, \angle H$, respectively. If α and β are base angles of a triangle, then $\delta = \lvert\alpha - \beta\rvert$, the skew angle.
$\rho,\ \sigma,\ \varphi$	ρ is right, σ is straight, and φ is the interior angle in an equilateral triangle.
$E,\ F,\ G, \ldots, W$	Points. H, I, O, R, S, T, U, V have assigned meanings; do not use arbitrarily.
$M,\ I,\ X,\ Y,\ Z$	M is usually inside a segment; M_{EF} is the midpoint of $\overline{EF}$. Otherwise, double subscripts denote reflection. I is the incenter, X, Y, Z are the excenters and, when subscripted with E, F, G, their pedal points.
$E',\ F',\ G'$	The feet of perpendiculars from E, F, G, particularly the altitudes of $\overline{EFG}$
$E^*,\ F^*,\ G^*$	Infeet; intersections of angle bisectors with the opposite sides of a triangle
$E^\times,\ F^\times,\ G^\times$	Exfeet; intersection of exterior angle bisectors with the opposite sides of a triangle
$e,\ f,\ g$	Lengths of the sides of a triangle opposite the E, F, G vertices, respectively
$a,\ b,\ c$	The coefficients of $ax^2 + bx + c = 0$; use u, v, w for right triangle sides.
$H,\ h,\ h_E,\ h_F,\ h_G$	H is usually a triangle's orthocenter unless it is the fourth vertex of a quadrilateral. h is the height of a triangle or parallelogram if given a base. h_E, h_F, h_G are the altitudes dropped from $E,\ F,\ G$.
$A,\ B,\ C,\ D,\ d$	A is the area of a triangle or quadrilateral, *e.g.*, $\overline{EFG}$ has area $A = \lvert\overline{EFG}\rvert$; B is a solid's base area; C is a triangle's medial point or a parallelogram's bi-medial point; D is the circumdiameter; and d is the indiameter.
P	A point, usually interior. P_E, P_F, P_G are the pedal vertices of P in $\overline{EFG}$.
$L_E,\ L_F,\ L_G$	Long centers of $\overline{EFG}$, where the mediators and angle bisectors meet on ω
$r,\ R$	R is circumradius; r is inradius or other radii if there is no incircle present.

s, S, T, U, V — s is the semiperimeter; S is the anticenter if T is not; and T is the bi-medial. U and V are the first and second Torricelli points.

ω, O — ω (omega) is a circle, usually the circumcircle; O is usually a circle's center

$\equiv, \cap, \cup, -, \in, :=$ — Coincident, intersection, union, removal, element of a set, assign to a label

$\perp, \parallel, \nparallel, \cong, \ncong\ \sim$ — Perpendicular, parallel, not parallel, congruent, not congruent, and similar

$|P|, |\overline{EF}|, |\overline{EFG}|, |\overline{EFGH}|, |x-y|$ — Power of a point, unit length, area, area, absolute value

White Belt Instruction: Foundations

Side–Angle–Side (SAS) Theorem ***(Euclid, Book I, Prop. 4)***

*Given two **sides** and the angle θ between them, $0 < \theta < \sigma$, a triangle is fully defined.*

Proof

By the segment postulate, the segments have two endpoints and, since they form an angle $0 < \theta < \sigma$, they share an endpoint. This is three noncollinear points so, by the triangle postulate, the triangle is fully defined. Congruence is transitive, so any two anywhere are congruent.

■

Euclid had five postulates, not six, but proof of his fourth proposition, SAS congruence, relied on superposition, which tacitly assumes a whole slew of additional and unmentioned postulates. Many have cast doubt on Euclid, pointing out that superposition – sliding figures around and flipping them over to position one on top of the other – is nowhere defined.

Robin Hartshorne (2000, p. 2), writes, "Upon closer reading, we find that Euclid does not adhere to the strict axiomatic method as closely as one might hope… The method of superposition… cannot be justified from the axioms… we can develop geometry according to modern standards of rigor." But, when *Common Core* was formulated, Hartshorne was shunted aside because Bill Gates was offering big money to redefine congruence in terms of transpositions – sliding figures around on a computer screen to superimpose them – assuring that geometry ceases to exist the moment a student rises from his school computer. By this definition, is a $3:4:5$ triangle drawn in this book congruent to one drawn on the wall of a 4000-year-old pyramid in Egypt? Neither moved! For that matter, did a figure in this book fly through the air and land on your homework?

Isosceles Triangle Theorem ***(Euclid, Book I, Prop. 5)***

If two sides of a triangle are equal, then their opposite angles are equal.

Proof

Given $\overline{EFG}$ with $\overline{GE} = \overline{GF}$, by SAS, $\overline{FGE} \cong \overline{EGF}$ because $\overline{FG} = \overline{EG}$ and $\angle FGE = \angle EGF$ and $\overline{GE} = \overline{GF}$. By congruence, $\angle EFG = \angle FEG$.

■

Observe that, when we cite SAS, the triangle vertices are ordered by the side, angle and side that are equal; later, in more advanced proofs, we will not write "because" and list the equalities. $\overline{FGE}$ and $\overline{EGF}$ have the same vertices but they are different triangles. $\overline{FGE} \cong \overline{EGF}$ is not a trivial statement proven by reflexivity; it requires proof, and it has important implications. The triangle postulate states that three noncollinear points fully define a triangle, but only in the order given.

Equilateral Triangle Theorem

Given a triangle, the following are equivalent:

1. *It is **equilateral**;*
2. *All interior angles are equal;*
3. *The **medians**, the **altitudes**, and the angle **bisectors** are pairwise coincident;*
4. *The three medians are equal;*
5. *The three altitudes are equal;*
6. *The three angle bisectors are equal.*

Half Equilateral Triangle Theorem

*A triangle is **half equilateral** if and only if it is right and one **leg** is half of the **hypotenuse**.*

Proof of the SSS theorem will use a proof by **contradiction**; that is, show that q not true and p true is contradictory. We have defined dichotomy and trichotomy; now we assume that G and J are distinct and then consider the four places where J can be if it is not G. Like aiming a rifle at a target, there are only five alternatives: a bullseye or a miss to the left, right, above, or below. We show that the latter four are impossible. The **lemma** is based on what "inside" means.

Lemma 1.1

*If a triangle is **inside** another triangle, it has less area.*

Side–Side–Side (SSS) Theorem ***(Euclid, Book I, Prop. 8)***

Given three sides that satisfy the triangle inequality theorem, a triangle is fully defined.

Proof

Given $\overline{EFG}$ and $\overline{EFJ}$ with $\overline{EG} = \overline{EJ}$ and $\overline{FG} = \overline{FJ}$, suppose that G and J are distinct. By lemma 1.1, if J is inside $\overline{EFG}$ or inside the angle **vertical** to $\angle EGF$, then $|\overline{EFJ}| < |\overline{EFG}|$ or $|\overline{EFJ}| > |\overline{EFG}|$, respectively, which implies $\overline{EFG} \ncong \overline{EFJ}$. Suppose J is on the E side of $\overrightarrow{FG}$ but not inside $\overline{EFG}$. $\overline{EG} = \overline{EJ}$, so $\overline{EGJ}$ is isosceles. $\angle EJG = \angle EGJ$ by the isosceles triangle theorem. By analogous reasoning, $\overline{FGJ}$ is isosceles and thus $\angle FGJ = \angle FJG$.

$\angle EJG = \angle FJG + \angle EJF$	and by analogous reasoning	$\angle FGJ = \angle EGJ + \angle FGE$
$\angle EJG > \angle FJG$		$\angle FGJ > \angle EGJ$
$\angle EJG > \angle FGJ$		$\angle FGJ > \angle EJG$

A contradiction; J on the F side of $\overrightarrow{EG}$ but not inside $\overline{EFG}$ is also contradictory.

■

In the following constructions, rays and lines are announced without invoking the line postulate; this is in keeping with our plan to avoid tedious proofs with mincing steps. By construction, midpoints, angle bisectors and perpendiculars to a line through a point are fully defined. Metric geometry textbooks begin with the midpoint theorem – every segment has exactly one midpoint – which they prove by dividing by two. But they never explain how a real number was assigned to the length or, after division, how to locate the midpoint. It just appears!

Construction 1.1 *Bisect an angle.* ***(Euclid, Book I, Prop. 9)***

Solution

Given $\angle EFG$, take any point J on $\overrightarrow{FE}$. There exists a point K on $\overrightarrow{FG}$ such that $\overline{FJ} = \overline{FK}$. Construct an isosceles triangle with **base** $\overline{JK}$ and **apex** L on the other side of $\overleftrightarrow{JK}$ from F. By SSS, $\overline{JFL} \cong \overline{KFL}$, which holds the equality $\angle JFL = \angle KFL$.

■

To construct an isosceles triangle when the base is given, a geometer sets his compass to any length longer than half the base and draws arcs from each endpoint. Where these arcs intersect is an apex; there are two possible, one on each side of the base. These arcs are each called a **locus**, and together, **loci** (lō' sī). To construct an isosceles triangle when the apex angle is given, lay off the same arbitrary length on both rays from the **vertex** and then connect these points.

Construction 1.2 *Bisect a segment.* ***(Euclid, Book I, Prop. 10)***

Solution

Given $\overline{EF}$, construct an isosceles triangle with $\overline{EF}$ the base and G the apex angle. Using C. 1.1, bisect the apex angle, $\angle EGF$. (When finding G, swing your compass around to find G'' on the other side of $\overleftrightarrow{EF}$.) Let $\overrightarrow{GG''}$ cut $\overline{EF}$ at M. By SAS, $\overline{EGM} \cong \overline{FGM}$, which holds the equality $\overline{EM} = \overline{FM}$; that is, M is the midpoint of $\overline{EF}$, so $M \equiv M_{EF}$. ∎

Moise (1990, p. 83) derides the "lighthearted use of the word *let*." Not us! We *proved* the crossbar theorem!

Construction 1.3 *Raise a perpendicular from a point on a line.* ***(Euclid, Book I, Prop. 11)***

Solution

Given a line with M on it, lay off the same arbitrary length to the left and to the right of M, so $\overline{EM} = \overline{FM}$. Construct an isosceles triangle with base $\overline{EF}$ and apex G. By SSS, $\overline{EMG} \cong \overline{FMG}$, which holds the equality $\angle EMG = \angle FMG$, so these are right angles.

∎

Construction 1.4 *Drop a perpendicular from a point to a line.* ***(Euclid, Book I, Prop. 12)***

Solution

Given G not on $\overleftrightarrow{EF}$, construct an isosceles triangle with apex G and base $\overline{JK}$ on $\overleftrightarrow{EF}$. The apex angle bisector, $\overrightarrow{GG''}$ (construct it in the same way as in C. 1.2) cuts $\overline{JK}$ at M. By SAS, $\overline{JGM} \cong \overline{KGM}$, which holds the equality $\angle JMG = \angle KMG$, so these are right angles. ∎

These constructions are the four basic techniques that will be used in combination throughout geometry. At the most fundamental level, all four are much alike. This is analogous to how the jab, hook, uppercut, and cross are the basic techniques that are used in combination throughout boxing. But all four involve giving somebody a poke in the nose, so they are much alike. Did you get the equilateral triangle theorem? You only had two theorems in your kit! Like a carpenter who only owns a claw hammer, for every nail, he is either going to hit it or pry it out. What else?

Construction 1.5 *Replicate an angle.* ***(Euclid, Book I, Prop. 23)***

Solution

Construct an isosceles triangle with the given angle as its apex angle by laying off equal lengths and connecting them. By SSS, reconstruct this triangle elsewhere.

∎

Construction 1.6 *Given a ray and a point on the angle bisector, find the other ray of the angle.*

Solution

Given $\overrightarrow{EF}$ and P on the angle bisector, construct an isosceles triangle with apex E and base $\overline{PJ}$ with J on $\overrightarrow{EF}$ so $\overrightarrow{EJ} \equiv \overrightarrow{EF}$. By C. 1.5, construct $\angle KEP$ equal to $\angle JEP$ by using SSS to construct $\overline{KEP} \cong \overline{JEP}$ with J and K on opposite sides of $\overrightarrow{EP}$. $\overrightarrow{EP}$ bisects $\angle JEK$.

■

The perpendicular bisector of a segment is called its **mediator**. The perpendicular from a triangle vertex to the (extension of the) opposite side is the altitude. Altitudes and angle bisectors can be extended past the opposite side, but when lengths are assigned to an altitude or to an angle bisector, it means the length of the segment from the vertex to the opposite side.

Center Line Theorem

An angle bisector and a perpendicular bisector coincide if and only if the triangle is isosceles.

Proof

Assume the angle bisector and perpendicular bisector coincide. By SAS (segment reflexivity, the right-angle postulate and segment bisection), the two **right triangles** are congruent, so their hypotenuses are equal. Thus, the given triangle is isosceles.

•

Assume the triangle is isosceles. By the isosceles triangle theorem, the base angles are equal. Construct a median from the apex. By SAS (opposite sides, opposite angles, and bisection), the two triangles are congruent. The apex angle is bisected and the angles at the **foot** of the median are equal; both right because they bisect a straight angle.

• ■

The **center line** is the mediator of the base and the apex angle bisector of an isosceles triangle.

The center line theorem is **bi-conditional** and so it requires two independent proofs, concluded with •. The mediator theorem will also be like this. The two proofs may be done in either order.

Technically, p and q are equivalent even if proof that q implies p requires citing the previously proven statement that p implies q. However, students see it as a trick if I say, “prove that p and q are equivalent,” but I do not mention that they must prove that p implies q first, and *then* prove that q implies p. No tricks! If this is the case, then I will call the statement that p implies q a theorem, and the statement that q implies p its converse, but I will not call them equivalent.

Interior and Exterior Angles Theorem

The bisectors of an interior and ***exterior*** *angle of a triangle are perpendicular to each other.*

Proof

Given $\overline{EFG}$ and J on $\overrightarrow{EF}$ past F, $\angle EFG$ is the interior angle and $\angle JFG$ is the exterior angle at vertex F. By C. 1.1, find K and L on the angle bisectors of $\angle EFG$ and $\angle JFG$, respectively. $\angle EFK = \angle GFK$ and $\angle JFL = \angle GFL$, so $\angle EFK + \angle JFL = \angle GFK + \angle GFL$ by addition. The union of these four angles is a straight angle and, if a straight angle is cut in two equal angles, then each one is right; thus, $\angle GFK + \angle GFL = \rho$ and $\overrightarrow{FK} \perp \overrightarrow{FL}$. ■

Mediator Theorem

A point is on the perpendicular bisector iff it is ***equidistant*** *from the endpoints of the segment.*

Proof

Assume that G is on the perpendicular bisector of $\overline{EF}$, but it is not M_{EF} (if it is, then we are done). By SAS, $\overline{EM_{EF}G} \cong \overline{FM_{EF}G}$, which holds the equality $\overline{GE} = \overline{GF}$. •

Assume $\overline{GE} = \overline{GF}$. Connect $\overline{GM_{EF}}$. By SSS, $\overline{EGM_{EF}} \cong \overline{FGM_{EF}}$, which holds the equality $\angle EGM_{EF} = \angle FGM_{EF}$. Thus, $\overrightarrow{GM_{EF}}$ is the angle bisector of $\angle EGF$ and, by the center line theorem, it is the perpendicular bisector of $\overline{EF}$. • ■

Problem 1.1 *Draw a line through a point so it cuts off equal segments from the rays of an angle.*

Solution

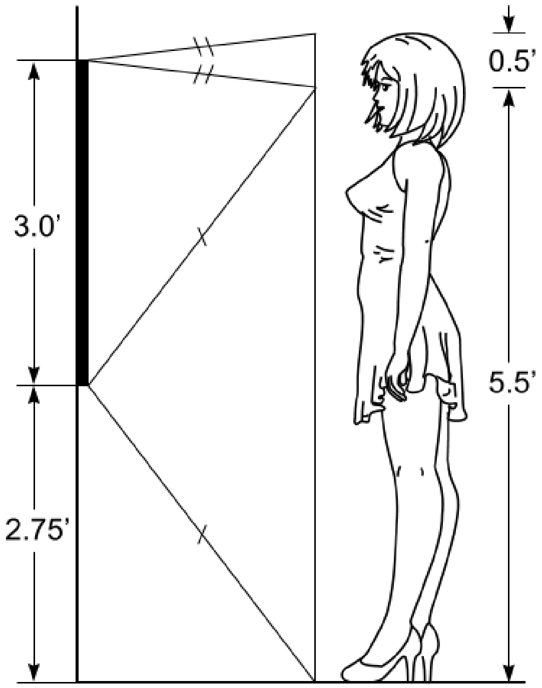
By the definition of isosceles, the desired line is the base of an isosceles triangle with the given angle at its apex. By the center line theorem, the base is perpendicular to the apex angle bisector. Bisect the angle and drop a perpendicular on it from the point. ■

Just solving a problem is not enough; you must also explain in what situations your solution might fail. One can always drop a perpendicular on a line, but not always on a ray, so this may not work. Sometimes there are two or more solutions to a problem, and you must explain why and under what conditions the number of solutions changes. This is called the **discussion**.

Problem 1.2 *A fink truss consists of an equilateral triangle built on the middle third of the ceiling joists. The rafters rest on the walls and meet at the triangle apex. Beams from the feet of the triangle meet the rafters at right angles. Draw it. The boards need not have width.*

Here, the roof's slope is $\frac{\varphi}{2}$; steep, but very strong. The king post and queen post trusses are more versatile, handling arbitrary and flatter slopes. Look them up if you are interested.

Problem 1.3 *Suppose your girlfriend asks you for a wall mirror. She is six feet tall in heels and her eyes are six inches below the top of her hair. What is the smallest mirror that allows her to see her entire self and how high should it be above the floor? Does it matter how far away she stands?*



Problem 1.3 Figure

Construct two isosceles triangles with bases from her eyes to her feet and to the top of her hair.

A carpenter constructs an A-frame with E and F the feet, G the apex, $\overline{EG} = \overline{FG}$ and a crosspiece between M_{GE} and M_{FG}, just like a commercial steel A-frame. But, when it is overloaded, the legs bow outward and start to pull free of the crosspiece. Reasoning that wood can take a compressive load but cannot pull things together while steel is just the opposite, he determines to connect $\overline{EM_{FG}}$ and $\overline{FM_{GE}}$ with wire rope to pull the bowed legs in tight with the crosspiece.

Problem 1.4 Suppose that you are the carpenter who built the A-frame described above.

1. There are two different ways to prove that $\overline{EM_{FG}} = \overline{FM_{GE}}$. Prove this both ways.
2. Another carpenter criticizes your design, stating that, if the wire ropes are both attached to an anchor hammered into the ground at M_{EF}, he can prove that the two wires are equal and, thus, that this is the best design. How do you respond?
3. You wish to build the strongest possible A-frame with the given boards and believe that this is accomplished by having the wire rope pull on the legs perpendicular to the bow in the boards. Prove that this is true if and only if $\overline{EFG}$ is equilateral.
4. Construct an A-frame with wire ropes from each foot to the trisection points of the opposite legs and with the bottom wire ropes meeting the opposite legs at right angles. Constructing this is too difficult; just draw it with a base of 13 cm and legs of 15.9 cm.

   Connect the upper trisection points with a board so you can tighten the wire ropes against it. If you agree to call this the "Aguilar A-Frame," I will make it easy for you by just telling you that the base is 81.65% of the legs' length. Note that, because the solution is a ratio, this must be a blue-belt problem. Geometry with multiplication!

White Belt Exit Exam

Saccheri Theorem I

*If $\overline{EFGH}$ is a **Saccheri quadrilateral**, so $\angle E = \angle F = \rho$ and $\overline{HE} = \overline{FG}$, then prove that*

1. $\overline{EG} = \overline{FH}$
2. $\angle G = \angle H$
3. $\overleftrightarrow{M_{EF}M_{GH}} \perp \overleftrightarrow{EF}$ *and* $\overleftrightarrow{M_{EF}M_{GH}} \perp \overleftrightarrow{GH}$
4. *The mediators of the base and the **summit** coincide.*

Rhombus Theorem

*Given a **rhombus** $\overline{EFGH}$, connect $\overline{FH}$. Without adding any **auxiliary** lines, prove that*

1. $\angle EFG = \angle GHE$
2. $\angle FGH = \angle HEF$
3. $\overline{FH}$ *bisects both* $\angle EFG$ *and* $\angle GHE$
4. *Draw the other diagonal,* $\overline{EG}$, *and prove that they are perpendicular bisectors.*

Isosceles Triangle Theorem Converse (White Belt)

If two angles of a triangle are equal, then the opposite sides are equal.

Perform these constructions:

1. *Construct a right triangle given one leg and the median from (a) that leg (b) the other leg.*
2. *Construct an isosceles right triangle so its apex altitude lies on a given line.*
3. *Construct an equilateral triangle so its apex altitude lies on a given line.*

Practice Problems

Construct each triangle using only the information given about it.

1.5 Construct a right triangle given the lengths of the legs.

1.6 Construct a triangle given the lengths of the three sides.

1.7 Construct a triangle given the apex angle and the lengths of the legs.

1.8 Construct a triangle given the lengths of the base, the median to the base and one leg.

1.9 Given $\overline{EFGH}$, if $\overline{EF} = \overline{GH}$ and $\overline{FG} = \overline{HE}$, prove that $\overline{EFG} \cong \overline{GHE}$ and $\overline{FGH} \cong \overline{HEF}$.

1.10 Given $\overline{EFG}$ with $\overline{GE} = \overline{GF}$, $\overrightarrow{GE}$ is extended to E'' and $\overrightarrow{GF}$ to F''. Prove $\angle FEE'' = \angle EFF''$.

1.11 Given $\overline{EFG}$ with $\overline{GE} = \overline{GF}$, construct an isosceles triangle, $\overline{EFJ}$, with the same base but not necessarily congruent to $\overline{EFG}$. Prove that $\angle GEJ = \angle GFJ$.

1.12 Given $\overline{EFG}$ with $\overline{GE} = \overline{GF}$, find points J and K on $\overline{EF}$ such that $\overline{EJ} = \overline{FK}$. Prove that J and K are also equidistant from the vertex; that is, $\overline{GJ} = \overline{GK}$.

1.13 The same as P. 1.12, but with J on $\overrightarrow{FE}$ past E, and K on $\overrightarrow{EF}$ past F.

1.14 Given $\overline{EFG}$ with $\overline{GE} = \overline{GF}$, prove that,

1. $\overline{M_{FG}M_{GE}M_{EF}}$ is isosceles.
2. $\angle GM_{GE}M_{EF} = \angle GM_{FG}M_{EF}$
3. $\angle EM_{EF}M_{GE} = \angle FM_{EF}M_{FG}$

1.15 Given two lines that intersect to make one right angle, prove that the others are also right.

1.16 Ancient hieroglyphics describe a $350'$ tall pyramid that had all the same dimensions as the Luxor hotel in Las Vegas, but it was reduced to rubble thousands of years ago. Could a *Common Core* student prove it congruent to the Luxor hotel by using superposition?

1.17 Your school has a foreign exchange student – from Mars! He accepts all our postulates except the parallel postulate. The symbol of his people is a $13 : 14 : 15$ triangle chiseled into a stone temple on Olympus Mons. He insists that it is not congruent to any Earthling triangle. By comparing rulers, you find that his unit of length is 3.219 cm. Can you draw a triangle and prove that it is congruent to his symbol? Can a *Common Core* student?

Pisa Tree Problem: You bought a laser rangefinder! *Yay!* But now, your geometry seon-saeng [teacher] has challenged you to measure the vertical height of the Pisa Tree in front of your school, so called because it leans like the Tower of Pisa. Because all the branches obscure your view, you cannot aim your laser straight up, so you take two measurements from either side: From an arbitrary point, you measure the distance to the treetop as 17 meters and, from 32 meters away and directly across from a point directly below the treetop (this is called its projection), you measure the distance to the treetop as 22 meters. What is the vertical height of the tree in meters? *Beware!* We have no assurance that our world is Euclidean and not hyperbolic, at any scale.

In the following constructions, you are not allowed to use a protractor. They are inaccurate when the angle is extended to the size of a house. Also, the students were not asked to buy one and so most of them did not. It is unfair for some students to use equipment the others do not have.

1.18 Construct an equilateral triangle, $\overline{EFG}$. In the *Notation* section, we define φ to be the interior angle of an equilateral triangle. Is this the same thing as defining it to be a third of a straight angle? Is $\overline{M_{EF}M_{FG}M_{GE}}$ equilateral in hyperbolic geometry, or only Euclidean? Can you prove that the interior angles of $\overline{M_{EF}M_{FG}M_{GE}}$ equal the interior angles of $\overline{EFG}$?

1.19 Given the hypotenuse, construct a half equilateral triangle. Is this a 30–60–90 triangle?

1.20 Inscribe a square in a given square. Now inscribe a different square in the given square.

1.21 Draw a king post roof truss with a right apex. The boards need not have width.

1.22 You wish to have black metal water pipes laid vertically on your roof, so the sun may heat water that is pumped through them. The plumbing supply store sells $45°$ elbows and you wish to use them so your pipes bend over the apex of your roof and lay flat on both sides. Draw a king post roof truss with this apex angle. The boards need not have width.

1.23 The same as problem 1.22, but with $22.5°$ elbows. This is quite a flat roof, so it is like the king post roof truss, but with the addition of vertical boards from the rafter midpoints dropped onto the ceiling joists because the angled boards are at such a low angle that they do not fully support the midpoints of the rafters. The boards need not have width.

1.24 Draw a queen post roof truss with a right apex. In this design, lay off equal lengths from the apex onto the rafters, connect these points and drop perpendiculars onto the ceiling joist. It is not particularly strong for holding up a snow load, but it makes for a neat box shape in the attic that can be paneled as a room. The boards need not have width.

Comparison with *Common Core* Geometry*Common Core* teachers present the isosceles triangle theorem after showing students the button on *Geometer's Sketchpad* for bisecting a segment. They never demonstrate bisecting a segment with compass and straightedge; they rely heavily on that magical midpoint button.

Common Core Proof of the Isosceles Triangle Theorem (*Glencoe Geometry*, p. 286)

ΔLMP with $\overline{LM} \cong \overline{LP}$	Given
Let N be the midpoint of $\overline{MP}$.	Every segment has exactly one midpoint.
Draw an auxiliary segment $\overline{LN}$.	Two points determine a line.
$\overline{MN} \cong \overline{PN}$	Midpoint Theorem
$\overline{LN} \cong \overline{LN}$	Reflexive Property of Congruence
$\overline{LM} \cong \overline{LP}$	Given
$\Delta LMN \cong \Delta LPN$	SSS
$\angle M \cong \angle P$	CPCTC 😊

"Although a good proof of the theorem was known in antiquity, it has become customary in later centuries to prove it in needlessly complicated ways; and probably the worst of these rambling detours is the proof that starts by telling you to bisect [the apex angle] (Moise, 1990, p. 83)." C. 1.2 cites C. 1.1, so *Common Core* is this proof.

This is more complicated than the *Geometry–Do* proof: given $\overline{EFG}$ with $\overline{GE} = \overline{GF}$, $\overline{FGE} \cong \overline{EGF}$ by SAS, so $\angle EFG = \angle FEG$. It requires an auxiliary line (bisecting a segment is 4 more steps, so 12 total), but it is easier because students need not understand that the same three points can define different triangles depending on how they are ordered. This is important! Good job Grasshopper! You are still with us! Many got to page one and wailed, "He just renamed $\overline{FGE}$ as $\overline{EGF}$. It's the same triangle!" Then they dropped out. When you are an engineer, one of them will vacuum your office.

The Common Core proof requires SSS and thus cannot be used in *Geometry–Do* because the proof of SSS requires the isosceles triangle theorem. David Coleman dodges the charge of circular reasoning by the simple expedient of not proving SSS. For him, SAS and SSS are both postulates or, if called theorems, they are "proven" with tracing paper. *Cheater! Cheater! Booger eater!*

Common Core states the triangle similarity theorem as an axiom – we prove it in the blue belt chapter – calling it either the similarity axiom or the dilation axiom, and then state without proof the AA, SAS and SSS similarity theorems. SAS, SSS, ASA, AAS and HL are then just special cases of the similarity/dilation axiom with the scale (dilation factor) being the multiplicative identity – which requires assuming the field axioms for real numbers – and the mid-segment theorem is a special case with the scale (dilation factor) being one half. *Common Core* students who claim to know of easier proofs to the isosceles triangle theorem and its converse can only say this because they did not have to prove SAS, SSS, ASA, AAS and HL. *Common Core* is just boring memorization!

The orange-belt chapter concludes with a section on how to pass a standardized exam of the type that is designed for *Common Core* students. Most of the people now reading these lines will not survive orange belt, so I will here tell you how a *Geometry–Do* white belt can pass *Common Core* exams. First, recognize that it is really an algebra exam in disguise, so review Algebra I. But the big secret is to bring a center-finding metric ruler and a compass to the exam so you can construct the figures – the ones provided are purposefully wrong – and measure the unknown quantity.

Varsity Tutors Advanced Geometry Exam, www.varsitytutors.com/advanced_geometry_diagnostic_1-problem-36916p, problem #14, is solved below, first using geometry, and then using the algebra that masquerades as geometry in *Common Core*. Which is easier?

Problem 1.25 *If a triangle has base* 14 *cm and legs* 13 *cm and* 15 *cm, what is its apex height?*

Geometry Solution

Use SSS to construct the triangle and then measure its height. It is 12 cm! ∎

Algebra Solution

Let x and y be projections of the 13 cm and 15 cm legs onto the base, respectively. Then $x + y = 14$ cm and, by the Pythagorean theorem, $13^2 = x^2 + h^2$ and $15^2 = y^2 + h^2$. Solve both equations for h^2, set them equal and substitute $y = 14 - x$ into the latter.

$169 - x^2 = 225 - (14 - x)^2$

$$169 - x^2 = 225 - 196 + 28x - x^2$$

$$0 = -140 + 28x$$

$$x = \frac{140}{28} = 5 \text{ cm}$$

Substitute $x = 5$ into the first Pythagorean equation, $13^2 = x^2 + h^2$, then solve it for h.

$$h = \sqrt{13^2 - 5^2} = \sqrt{169 - 25} = \sqrt{144} = 12 \text{ cm}$$ ■

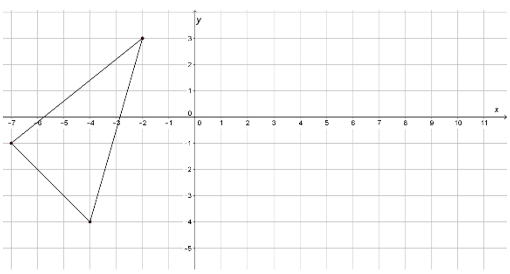
Varsity Tutors considers this advanced because almost no American geometry student can answer it correctly or, if they do, it takes them thirty minutes to work through all the algebra. But, if you construct the geometric figure with a ruler and compass (*Duh!* It is a geometry exam!), you can solve it in one minute using the most basic white-belt theorem you know.

Teachers! If you have read this far hoping for advice on how to get your #%$^@ students through the *Common Core* standardized exam, here it is: Ask for the perimeter of a triangle with vertices $(-2,3), (-4,-4), (-7,-1)$ and make it a race. The easy way is to lay the three sides end-to-end on a line. Taking the sum of three applications of the algebraic distance formula is the hard way.

$$\sqrt{(-2-(-7))^2+(3-(-1))^2}+\sqrt{(-2-(-4))^2+(3-(-4))^2}+\sqrt{(-7-(-4))^2+(-1-(-4))^2}\approx 17.9$$

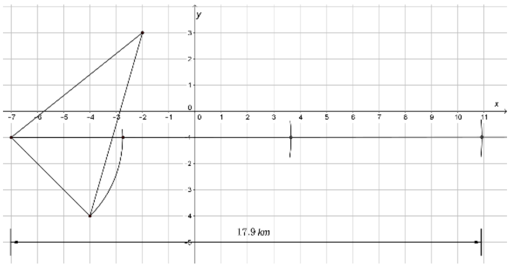
First-Day Exam in Geometry

The first task of the high-school geometry teacher is to disabuse students of the notion that geometry is just a boring review of Algebra I. (Nothing new here. *Blah!!!*) You own a triangular pasture with vertices $(-2,3), (-4,-4), (-7,-1)$, as measured in kilometers. To the nearest 100 meters, how long is the fence around it? Make it a race with the *first* solver getting an A.



First Day Exam

The easy way is to lay the three sides end-to-end on a line. Put the compass pin at $(-7,-1)$ and rotate it to lay off the lower left side on the horizontal. Without moving the pin, measure the upper left side and lay it off on the horizontal past the one you just did. Finally, measure the upper right side and lay it off on the horizontal past the one you just did. *It is segment addition!*



First Day Exam Solution

Taking the sum of three applications of the algebraic distance formula is the hard way to do this.

$$\sqrt{(-2-(-7))^2+(3-(-1))^2}+\sqrt{(-2-(-4))^2+(3-(-4))^2}+\sqrt{(-7-(-4))^2+(-1-(-4))^2}$$

$$=\sqrt{(5)^2+(4)^2}+\sqrt{(2)^2+(7)^2}+\sqrt{(-3)^2+(3)^2}$$

$$=\sqrt{25+16}+\sqrt{4+49}+\sqrt{9+9} \;=\; \sqrt{41}+\sqrt{53}+\sqrt{18} \;\approx\; 6.40+7.28+4.24 \;\approx\; 17.9\text{ km}$$

The following are very easy geometry problems that will put *Common Core* graduates to shame:

Yellow Belt: Prove that the sum of the legs of a right triangle is less than twice the hypotenuse.

Orange Belt: Given a triangle with vertices $(0,0)$, $\left(\frac{25}{3},0\right)$ and $(3,4)$, drop an altitude from the right vertex. What is the sum of the inradii of the three triangles thus formed?

White Belt Geometry for Construction Workers

Problem 1.26 *Rip a board into equal-width slats. (Three in this example.)*

Solution

Because no carpenter has ever made it to orange belt, I will here present the two transversals theorem unproven: Parallel lines that equally cut one **transversal** equally cut any transversal. Traverse the edges twice with a ruler held so it is easy to divide; *e.g.*, trisect a 5.5" wide board by angling the ruler so 0" and 6" lie on the edges. Set the saw guide so two thirds of the kerf is towards the edge and one third is towards the center.

■

George Birkhoff's axioms are called metric because they assume the field axioms for real numbers; those of David Hilbert and this author are called intrinsic because they do not. Birkhoff is assuming tape measures longer than one's workspace that do not droop and protractors that measure angles to such precision that they can be projected across one's workspace and the opposite side of the triangle is as accurate as can be measured with one's tape. Carpenters have no means of measuring angles with such precision and their tapes are only $25'$ long. The **Egyptian triangle** can verify that an angle is right, but it does not create a right angle. Finding the corners of a rectangle can be frustrating for carpenters who know only this. It works only if the sides are rigid and reach across the entire workspace, so there is no extrapolation error. The only time I recommend that construction workers use the Egyptian triangle is if they build an $8'$ wall, nail it to the floor, measure $6'$ from it, and then have two men stretch a tape diagonally; when their tape measures $10'$, nail the wall to the ceiling joists. It is vertical!

Squaring a $16'$ cabin is easy (the diagonal is $22'\ 7.5''$), but a rectangle with sides longer than a tape measure requires Thales' diameter theorem. No construction worker has ever made it that far, so I will break my vow against using unproven theorems and just present a cook-book recipe. A string can be extended six times longer than a tape measure and, because it is light weight, it does not droop when stretched across these long distances. Because a rectangle may be several times longer than your tape measure, you will need two strings in addition to your tape. Use a spring scale to put uniform tension on the string, about one Newton (100 grams) per meter.

Squaring a foundation must be achieved with no auxiliary lines outside it. This is because it may be in a hole if it is for a basement, or it may be surrounded by trees or cliffs if a plot of land was cleared and graded for a house being built in a forest or cut into a hillside. To make the house face a road, give the front the same compass heading as the center line of the road. To make the house face south, stand at the SW corner and aim $90°$ minus magnetic declination off magnetic north; *e.g.*, in Los Angeles, aim for $78°$ east. Note that this is a Euclidean construction.

Problem 1.27 *Square a house's foundation before pouring the concrete floor.*

Solution

Mark the front segment, $\overline{EF}$, with two stakes measured with a tape and oriented with a compass to be parallel to a road or to the east-west line; do not neglect declination. Loop the end of string S_1 over the E-stake, stretch it across the front and tie it to the F-stake. Drive a stake, O, into the ground near the center, but slightly towards the front and slightly towards the F-stake. Loop the end of string S_2 over the O-stake, stretch it to the F-stake, pinch it and then swing this radius around the O-stake until the arc intersects $\overline{EF}$. Drive in a stake at this intersection, E_1. Do not lose your pinched-off length! Lift the S_1 string off the E-stake and loop it over the E_1-stake. Stretch it over and past the center stake, O;

simultaneously, swing string S_2 around the O-stake to point in the opposite direction, away from E_1. Stretch both strings so they coincide (lie on top of each other) and drive a stake, G_1, in at the end of the length pinched-off on S_2. $\angle E_1FG_1$ is right by Thales' diameter theorem. Loop the end of string S_1 over the F-stake, stretch it into ray $\overrightarrow{FG_1}$ and drive a stake G on this ray past G_1 to where a tape measures the length of the side of the house. Pinch off this length, $\overline{FG}$, lift the S_1 string off the F-stake and loop it over the E-stake. Lift the S_2 string off the O-stake, loop it over the F-stake, pinch off the length $\overline{EF}$, then lift it off the F-stake and loop it over the G-stake. Stretch both strings out and where their pinched off lengths intersect, drive a stake, H. $\overline{EFGH}$ is a rectangle. Yay Thales! Down with Pythagoras! ■

This leads directly to a rectangle while the Pythagorean theorem converse (if $u^2 + v^2 = w^2$, then the triangle with these sides is right) is hit and miss. To "X it" is to measure the four sides to construct a parallelogram and then adjust it until the diagonals are equal. Like the Pythagorean theorem converse, it can verify a right angle, but its failure does not tell you how to adjust. P. 1.26 and P. 1.27 are orange- and green-belt, respectively, but we must help the carpenters, and they almost never get that far.

Many come to *Geometry–Do* with prejudice against deductive logic. Now is the time to rid ourselves of these losers! They are baggage we will not need to bring to yellow-belt geometry. Put construction workers and others who come to geometry with an open mind on Team Euclid. Put those who have closed their minds to deductive logic and believe only in coordinate geometry on Team Prástaro. In two classrooms, push the desks to the walls, staple butcher paper to the ceiling and draw a chalk line on it. Give each team a yardstick, two spools of chalked string and two ladders. A team that can draw a chalk line on the floor directly underneath the one on the ceiling gets an A, else an F. They cannot use a plumb bob, but you will test their answers with it. If the losers on Team Prástaro demand a tape measure instead of a yardstick, explain that, unless you are building an outdoor toilet, rulers are always less than the length of one's workspace.

The Egyptian or $3:4:5$ Right Triangle

In the preceding section I wrote, "Finding the corners of a rectangle can be frustrating for carpenters who know only this." So true! I remember when I was eight that my father had my mother, my brother and I at stakes marking three corners of the foundation of the basement for our house. He kept measuring sides one at a time with his only tape measure and ordering a stake moved a few inches this way or that. The Pythagorean equation never came out exact and it offered no hints on how to move the stakes to make it exact. Bad day!

In *Volume Two: Geometry with Multiplication*, the Pythagorean equation will be expressed as $u^2 + v^2 = w^2$ with u, v, w being real numbers. However, real numbers were only introduced in the 1800s and the modern theory of rational numbers did not precede them by much. Yet Egyptologists assure us that triangles with sides of $3, 4$ and 5 units appear in four-thousand-year-old hieroglyphics. We will do the ancient proof and, in *Volume Two*, we will do it rigorously.

Egyptian Triangle Theorem

A triangle with sides three, four and five times a unit length is right.

Proof

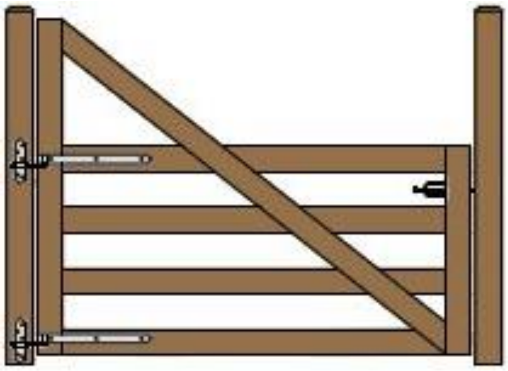
Let F be on a line and G and G'' be on the line four units to each side of F. Let E be an intersection of circles of five-unit radii centered at G and G''. Observe that $|\overline{EF}| = 3$. By SSS, $\overline{EFG} \cong \overline{EFG''}$, which holds the equality $\angle EFG = \angle EFG''$. Thus, $\angle EFG = \rho$. ■

An analogous proof shows that a triangle of sides $5, 12$ and 13 is right; this was unknown to the Egyptians. Plumbers can use this triangle when installing $22.5°$ elbows. Integer solutions to the Pythagorean equation are known as Pythagorean triples. Students should be aware that Euclid devised a formula that generates Pythagorean triples: $u = m^2 - n^2,\ v = 2mn,\ w = m^2 + n^2$ for positive integers $m > n$. Verification is basic algebra; that ku, kv, kw for $k = 1, 2, \ldots$ gets them all is advanced. Try it with $n = 1$ and m even, or $n = 2$ and m odd.

$3 : 4 : 5$ right triangles are ubiquitous in *Common Core* because the programmers who compose their exams want to keep things neat by using only integers. *Varsity Tutors* Advanced Geometry Exam, problem #22 gives a rhombus of sides 5 units inscribed in a rectangle with height 4 units and asks the area. Problem 1.25 is the $3 : 4 : 5$ right triangle scaled up threefold and joined to the $5 : 12 : 13$ right triangle to be a $13 : 14 : 15$ triangle. A $13 : 20 : 21$ triangle has a 12-unit altitude for the same reason. A $15 : 20 : 25$ triangle is right – it is the $3 : 4 : 5$ right triangle scaled up fivefold; also, it is the threefold and fourfold $3 : 4 : 5$ right triangles joined along a 12-unit altitude; thus, it is the standard example of the geometric mean. Draw these triangles on your palm before exams and you have geometry mastered as *Common Core* defines the subject!

Basic Principles for Design of Wood and Steel Structures

As a geometer, you may be asked to design structures like gates, towers, gantries, or bridges. Everybody knows that a diagonal is required to make a rigid triangle, but a drive through the country indicates that few know which way it goes. Wood beams can withstand a tremendous compressive load – 1700 psi for Douglas Fir – but cannot lift a load because the screws pull out. Steel is just the opposite; $\frac{1}{8}$" wire rope can lift 340 pounds, but stainless-steel tubes kink and fold under any large compressive load. A single apostrophe means feet; a double apostrophe means inches.



A Badly Designed Gate

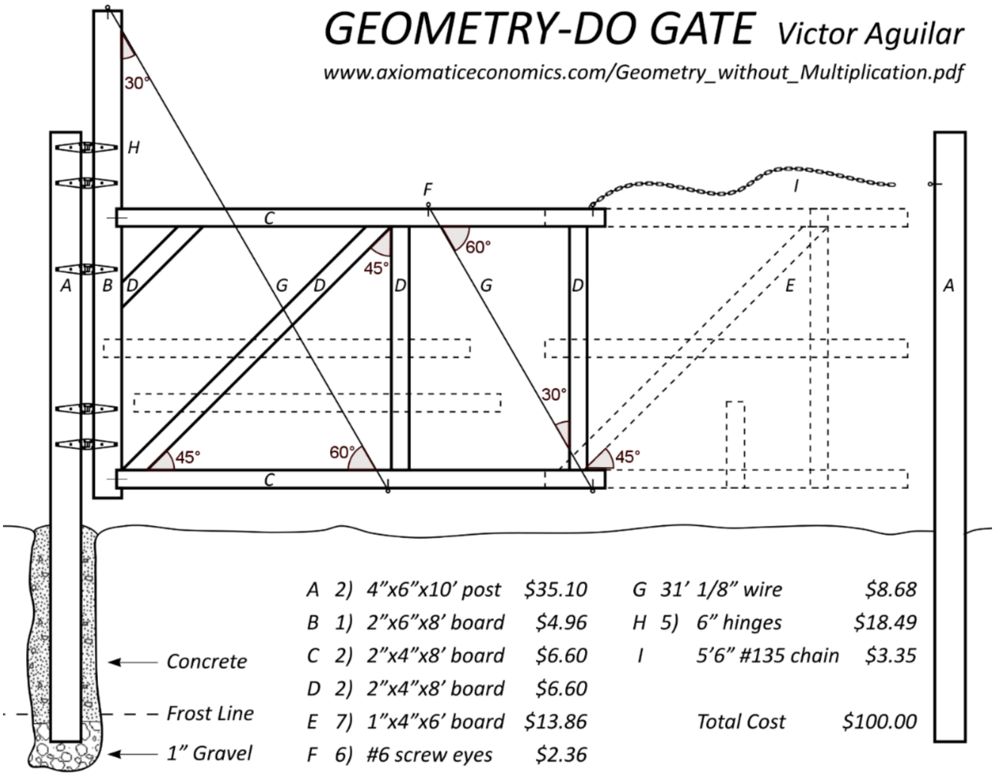
Wooden diagonals go from the foot of the gate post upwards and wire rope diagonals go from the top of the gate post downwards. For a wooden tower to be rigid, it must have crossed wooden diagonals so there are some that are angled upwards towards any direction of wind.

A gantry is two A-frames with a beam between them and a hoist that slides along the beam. Mimicking the all-steel commercial ones with wood does not work because, when overloaded, the legs spread apart and bow outwards. The crossbar is pulling them together, which is not what wood does well. Make the base of the A-frame 81.65% of the leg length and attach wire ropes from the feet to the trisection points; the lower one will meet the leg at a right angle. Install a wooden crossbeam between the upper trisection points to tighten the wire rope against.

A drive through the country indicates that almost all wooden gates have collapsed. This is because they have a wooden diagonal angled downwards and it reaches across the entire $12'$ or $14'$ gate, making too horizontal an angle. Also, failed gates were over-engineered on the latch side, adding unnecessary weight far from the hinges. $1''$ planks are all it takes to stop cattle.

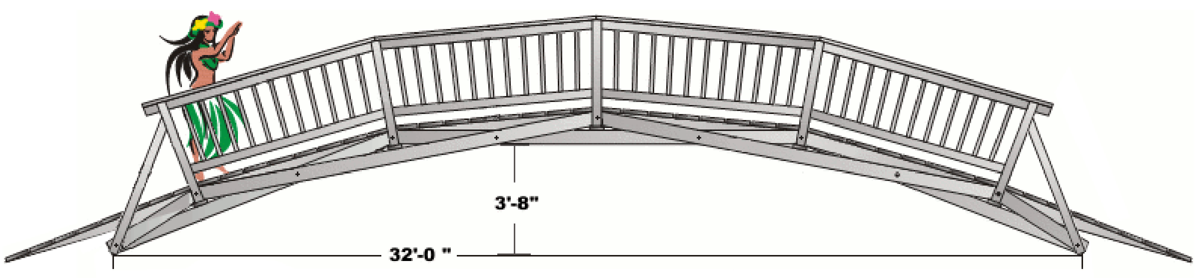
The gate shown below is $14'$ wide for farm equipment and is designed to stop cattle, not people. The wire rope loops through the eyes and around both sides of the gate. Solid lines are $2''$-thick boards or $4''$-thick posts, dashed lines are $1''$-thick planks. Note that the boards and posts are all assembled edgewise, so their widest sides are coplanar.

The C boards are inset into B and glued with wooden dowels to add strength. There are five hinges, and the gate post is rectangular; two hinges attached to a round post are weak. In the winter, the ground freezes to the frost line and, in the spring, the top few inches thaw but do not drain through the frozen ground below, which is why it is so muddy. Water that soaks into the gate post can only drain out the bottom if it extends below the frost line. Also, there should be gravel, not concrete, below it to aid drainage. Gates often collapse because the post rots.



A Better Design for a Gate

For automotive bridges too high to be supported with pillars, put a $4'' \times 6'' \times 12'$ post vertical and two $4'' \times 4'' \times 4'$ posts at $45°$ under the center of each of the two stringers and lift them with $0.5''$ steel cables attached to eye bolts in the concrete footers. The two vertical posts should have crossed braces – it is a mistake to look only at the side view and neglect twisting forces. Yellow belts will learn to build stone bridges cut from river rocks that can support truck traffic!



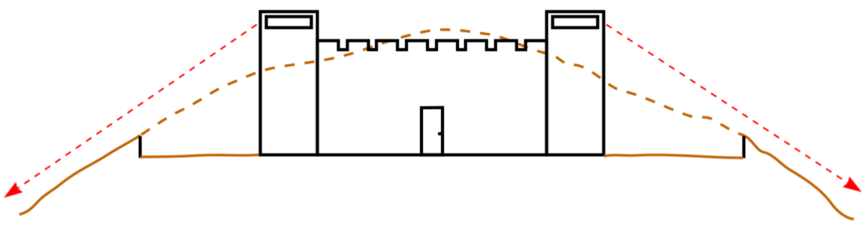
A Wooden Footbridge

Detailed plans for wooden foot bridges of various sizes are available. Sorry Grasshopper, but, while the plans are free, the hula girl coming out to dance on your completed bridge is extra.

Defense Positioning and Geometry

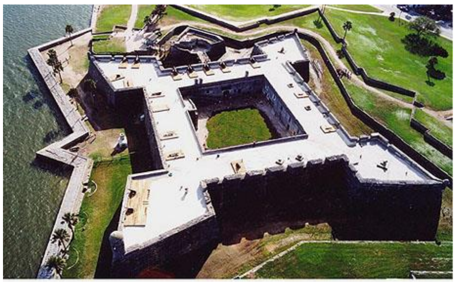
Steel cannons with rifled bores brought an end to state-sponsored castle construction, but some of what was learned during the time of smoothbore bronze cannons is still relevant today for people engaged in low-intensity conflicts. By low-intensity I mean, by mutual consent, both the homeowners and the bandits restrict themselves to small arms, usually defined as 7.62 mm rifles and hand grenades, because they are under a real army, but it will ignore small-arms fire.

The **first principle** of building fortifications is to build them for yourself, not for the enemy. If you dig trenches or set out some Jersey barriers, they may stop the enemy's wheeled vehicles, but they will also provide cover for enemy infantry. Thus, you should have a vertical retaining wall facing rearward and an earthen glacis slope facing forward. Flatten the top of a gently rounded hill, digging deep enough that the cut-down area requires a three- to four-foot-high retaining wall all around it. The windows are high enough that the defenders can graze the slope with rifle fire, but the attackers cannot fire at the base of the house wall until they crest the retaining wall.



An Example of a Glacis Slope

The **second principle** is to not have blind spots. The defenders should have bastions protruding from the corners of the building so attackers cannot press themselves up against the wall and be hidden from the windows. But, if the bastions are round, like the turrets in a medieval castle, there are blind spots directly in front of them. They should be tapered, like the points on a star.



An Example of a Star Fort

The **third principle** is that stone shatters when hit by bullets, but concrete and brick do not. Also, landscape with crushed stone to make walking noisy. Get rid of boulders that can be thrown.

There is little application for geometry in the design of fortifications, but white-belt geometers should be familiar with the basics. Green belts will learn of machine gun emplacement, which really does require geometry. It would be embarrassing for the *Geometry–Do* practitioner to boast of these advanced techniques while showing ignorance of basics like glacis slopes.

Next we turn to the positioning of troops along a frontier that is plagued with cross-border raids.

Having heartily mocked the NES for getting the equation for a parabola wrong (See the appendix. For a more thorough kicking of the *National Council of Teachers of Mathematics*, read my review of their geometry manual: www.researchgate.net/publication/335893456_Review_of_Essential_Understanding_of_Geometry), let us be more positive and look to the work of someone who knows what the terms directrix, focus and latus rectum mean. Raj Gupta (1993) wrote a book about the most basic function of an army: defense against cross-border incursions. It often happens that the politicians and high-ranking officers have the wit to understand that an all-out war would be disasterous for both countries. But small units will cross the border to pillage; they have the tacit approval of their officers, but they also know that, if they get in trouble, their officers will not send anyone to rescue them.

It is reasonable to assume that both the bandits and the defenders move with equal speed over the same terrain. Thus, the set of points equally distant from the defenders' base and from the border are where the enemy can be met on the run; points inside this graph are where the defenders can reach first, giving them a few minutes to lay machine guns and find depressions in the dirt for riflemen to lie in; points outside this graph are where the enemy can get past the base and must be intercepted by soldiers from another base. Here we are using the perpendicular length theorem, which states that the perpendicular is unique and is the shortest segment from a point to a line. This is proven by yellow belts; so, if you are white belt, please read ahead now.

For simplicity, we will assume that the border is locally straight. In Cartesian coordinates, we will make it the x-axis and label the base's coordinates $(0, 2w)$ with $0 < w$. (Having the parabola upward and with $h = 0$ is the simplest case. $w < 0$ requires using absolute value; switching x and y turns the parabola sideways. The orange-belt appendix on linear algebra explains how to rotate and, in that case, you need to know that the distance from a point, (x_0, y_0), to a line, $Ax + By + C = 0$, is $\frac{|Ax_0+By_0+C|}{\sqrt{A^2+B^2}}$.) Consider the parabola, $y - k = \frac{1}{4w}(x-h)^2$. The point midway between the base and the border is on the desired graph and it is w distant from each of them. Make this point the vertex of the parabola so $h = 0$ and $k = w$. The parabola is $y - w = \frac{x^2}{4w}$ or $y = \frac{x^2+4w^2}{4w}$. The vertex is equally distant from the base and the border. If we can prove this for every point on the parabola, then it defines the graph described in the previous paragraph. Thus, we must prove that the distance from (x, y) to $(0, 2w)$ is $y = \frac{x^2+4w^2}{4w}$, the distance from (x, y) to the x-axis. By the distance formula:

$$\sqrt{(x-0)^2+(y-2w)^2} = \sqrt{x^2+\left(\frac{x^2}{4w}-w\right)^2} = \sqrt{\frac{u^2}{16w^2}+\frac{u}{2}+w^2} \qquad \text{with} \qquad u = x^2$$

$$= \frac{1}{4w}\sqrt{u^2+8w^2u+16w^4} = \frac{1}{4w}\sqrt{(u+4w^2)^2} = \frac{x^2+4w^2}{4w} = y$$

Proven! When the bandits were teenagers, they were too busy thieving to have learned how to factor a quadratic. They will surely regret sleeping through Algebra I when you get in front of them with five minutes to spare! That is *plenty* of time to lay a squad automatic weapon and for your riflemen to find depressions in the dirt where they can settle into their shooting positions.

The discussion above defines the parabola for a single army base located $2w$ klicks from the border. (Klicks is an abbreviation for kilometers; clicks refer to increments of angle adjustment on an artillery piece.) But the more general question is, given the distance between army bases, how far should they be located from the border? The distance between the army bases is fixed by the budget; for instance, unless the politicians free up some more money, you may only have enough troops to man bases every four klicks. How far from the border should they be located to be sure that the bandits never get behind your line of bases? The parabolas of adjacent bases must intersect at or in front of the line of bases. So the question is, what must x be so that $y = 2w$? Since the parabolas of adjacent bases intersect halfway between them, the distance between bases is $2x$.

$$2w = \frac{x^2+4w^2}{4w} \quad \Rightarrow \quad 8w^2 = x^2+4w^2 \quad \Rightarrow \quad 4w^2 = x^2 \quad \Rightarrow \quad 2w = x$$

Thus, the distance between bases is $4w$, the width of each parabola when the bases are $2w$ from the border. In other words, the bases are twice as far from each other, $4w$, as they are from the border, $2w$. In the example above, if budget constraints require bases every four klicks, then the line of bases must be two klicks from the border. This is assuming that you know immediately when the border has been crossed – you are probably using electronic sensors – and your troops immediately move to intercept the bandits who are driving straight into your country. Of course, if Murphy has his way, none of these things will ever quite happen, so you will probably want to position your bases a little farther back – surrender a little more of your territory – to avoid allowing the bandits to ever get behind your line. Once into the interior, they are hard to catch.

Parabolas have other applications, so we must use more abstract language. The line that defines the border is called the **directrix**; the army base is at a point called the **focus**; and the segment parallel to the directrix that passes through the focus and has endpoints on the parabola is called the **latus rectum**. (No giggling allowed when you hear the word rectum! It is Latin; it does not refer to any part of your anatomy.) For the parabola $y - k = \frac{1}{4w}(x - h)^2$, w is the distance from the vertex to either the focus or the directrix, $2w$ is the distance from the focus to the directrix, and $4w$ is the width of the latus rectum. For parabolas that were defined by the *National Evaluation Series* in which they got $\frac{1}{4w}$ upside down, the constant w is meaningless, as is most of what they teach. (The NES and many textbooks use c, not w, but that is confusing because c is the constant term in parabolas.) Screeching, *"It's just a constant!!!"* is not a valid argument. We need to end *Common Core*.

The preceeding two pages are algebra and, if taken as a review of a past Algebra I course, it can be taught at any time. If the geometry teacher will be absent and must ask the algebra teacher to substitute, the algebra teacher can lecture from these two pages. Next comes a Euclidean construction; purists will teach it in orange belt, though many will teach all four pages together.

To make this really useful to a field officer, we must teach the compass-and-straightedge construction of a parabola. An army captain does not have a computer in his tent with graphic-design software that allows him to superimpose a parabola on a map image. And he does not have a color printer to print out this new map. All he actually has in his tent is a desk and a paper map. The rule about the bases being twice as far from each other as they are from the border is something he can remember. But to make this really useful, he must draw the parabolas on his map so his mortar gunners can treat the outside of the parabolas as a free-fire zone while his ground troops can be careful to stay inside their parabola. Also, they may unroll concertina wire along the parabolas to slow the enemy, but leave gaps where – after the mortar gunners have ceased fire – the ground troops can exit to pursue enemy troops back to the border.

This construction is Euclidean because it assumes that parallel lines are everywhere equidistant.

1. With a colored pen, mark the location of the base and, if the border is not perfectly straight, draw a straight line that follows the border as closely as possible.

2. Drop a perpendicular from the base to the border and locate its midpoint. This is the parabola vertex; mark it another color. Measure this length in centimeters and call it w.

3. With a pencil, draw a line parallel to the border through the parabola vertex. Then draw a series of lines parallel to this line each one centimeter apart and continue past the base.

4. Set your compass to $w + 1$ centimeters and, with pencil, draw arcs centered at the base that cut the first parallel line from the one that goes through the vertex. Mark these intersections with a dot of the same colored ink that was used for the vertex.

5. Repeat step #4 with a $w + 2$ cm arc intersecting the second parallel, then a $w + 3$ cm arc intersecting the third parallel, and so on for all the parallel lines.

6. Connect the dots with the same color of ink. You may want to free-hand this to make the parabola smoother than if it were composed of a series of straight segments.

7. Repeat this construction for each of the several bases in your area of operation.

The "twice as far from each other as they are from the border" rule depends on there being multiple units, like a four-platoon company. The captain decides where each platoon's base is to be built while the lieutenant in command of an individual platoon controls his troop's movements within their parabola and the shelling of targets outside their parabola. For instance, if the captain has four platoons and is tasked with guarding a straight length-M segment of the front line where $M = 16$ klicks, he will position bases 2 and 6 klicks inwards from the edges and 2 klicks back from the border. But what if he has only one unit to position in his area of operation?

Raj Gupta writes, "For an arbitrary probability density function of attack, all defending units must base themselves μ along the length-M front and distance σ inward from the border ($\sigma - \mu$ Theorem) in order to meet and defeat the invading forces as close to the front as possible (p. 8)." Proof of the $\sigma - \mu$ Theorem is beyond the scope of this book; but suffice it to say, μ and σ are the mean and standard deviation of the probability density function (pdf), respectively. (σ means a straight angle, but in statistics it is the symbol for standard deviation; on this page only, that is its use.) The pdf is an assignment of probabilities of the chance of attack at each point along the length-M front. The sum of the probabilities assigned to all the points on the front must add up to unity.

How are these probabilities assigned? This depends a lot on whether the enemy knows where your bases are. For the first line of defense, the platoon-size bases only two klicks from the border and featuring tall watch towers, it is obvious that they know. Thus, within each base's 4-klick wide subfront, there is zero probability of the enemy going hey diddle diddle, straight up the middle and a 50% probability of them attacking on either edge of the subfront. The mean is in the middle of the subfront, and the standard deviation is half the width of the subfront.

Thus, if each lieutenant were given the freedom of positioning his base anywhere behind his subfront regardless of what the other lieutenants are doing, logic would lead him and each of his fellow lieutenants to position their bases exactly as their captain would. Now suppose that the captain has a fifth platoon held in reserve. It does not have a watchtower and is positioned some distance from the front where it can move to reinforce any one of the four platoons. (Zulu chief Shaka had his reserves in a gully with their backs to the enemy and under orders that, if any turned to peer over the edge, they would be shot. He did this to prevent them from attacking before they were ordered to.) Because the enemy does not know where it is, its probability density function is 20% at $0, 4, 8, 12$ and 16 klicks from one edge of its 16-klick front. Use your scientific calculator to find μ and σ, but do not use sample standard deviation like you would if you were doing confidence intervals. For this example, $\mu = 8$ klicks, the midpoint, and $\sigma \approx 5.657$ klicks back. Try this with different numbers of platoons. It is always optimal to have one reserve unit no matter how many bases there are; but the more bases, the closer the reserve can be to the front. If the enemy does not fear a platoon, they may invade anywhere; in this case, $\sigma = M/\sqrt{12} \approx 0.2887M$.

Glossary of White-Belt Terms

Altitude The perpendicular from a triangle vertex to the opposite side's extension

Angle Two rays, called the sides, sharing a common endpoint, called the vertex. $\angle F$ if there is one angle at F or $\angle EFG$ for the angle between $\overrightarrow{FE}$ and $\overrightarrow{FG}$.

Acute	An angle that is less than a right angle
Apex	The angle opposite the base of a triangle
Base	In a triangle with a base, the angles at either end
Complementary	Two angles that sum to one right angle
Exterior	The angle supplementary to an interior angle
Interior	An angle inside a triangle or quadrilateral at a vertex
Obtuse	An angle greater than right and less than straight
Right	The bisection of a straight angle
Straight	An angle whose rays are collinear and opposed
Supplementary	Two angles that sum to one straight angle
Vertical	Angles across from each other at an intersection

Apex The triangle vertex opposite the base

Arc Part of a circle; within equal circles, angles at the center and the arcs they cut off are a transformation of each other.

Area The measure of the size of a triangle or a union of disjoint triangles

Auxiliary Lines or arcs not given whose intersection goes beyond analytic

Axiom A proposition that is assumed without proof for the sake of studying the consequences that follow from it

Base The side of an isosceles triangle bracketed by the equal angles

The side of a triangle designated as such, or the one that it is built on

Between

1. If F is between E and G, then F is also between G and E and there exists a line containing the points E, F, G. (Between implies that the three points are distinct.)
2. If E and G are two points on a line, then there exists at least one point F lying between E and G and at least one point H such that G lies between E and H.
3. Of any three collinear points, there is exactly one between the other two.

Bi–Conditional A statement of the form p if and only if q. It is true if both p and q are true or both p and q are false. p implies q; also, q implies p. Proof of neither implication can cite the other implication. If and only if is abbreviated iff.

Bisect $\frac{1}{2}$ To divide a segment or an angle into two equal parts, called halves

Center Line The mediator of the base of an isosceles triangle or a semicircle

Circle All the points equidistant from a point, which is called the center

Collinear A set of points that are all on the same line

Congruent $\cong$ Two triangles whose areas and whose sides and whose interior angles are equal

Contradiction, Proof by To prove that statement p implies statement q, assume that p is true and q is not true and show that this is impossible.

Converse Given the statement that p implies q, the statement that q implies p

Convex Any segment between two points interior to two sides is inside the figure

Diagonal Segments connecting non-consecutive quadrilateral vertices

Definitional The adjacent side of the two triangles in a quadrilateral

Dichotomy Proof by contradiction when there are two alternatives

Discussion The necessary and sufficient conditions for a solution, and how many solutions

Disjoint Figures that do not overlap; their areas form an additive group

(This includes touching circles and adjacent triangles, if outside each other.)

Endpoint	A point at the end of a segment, arc, or ray	
Equal	Comparable magnitudes that are not less than nor greater than each other	
Equidistant	Two pairs of points that define two segments of equal length	
Equivalence	**Class**	A set of objects that are equal, congruent, similar, or parallel
	Relation	A set and a reflexive, symmetric and transitive relation
Equivalent	Conditions, any two of which are bi-conditional	
Extend	Given $\overline{EF}$, construct $\overline{EG}$ such that F is inside $\overline{EG}$ or E is inside $\overline{FG}$.	
Figure	A set of points either alone or joined in segments, rays, lines, arcs or circles	
Foot	The intersection when one drops a perpendicular from a point to a line	
Fully Defined	A figure with the given characteristics exists, and it is unique.	
Hypotenuse	The side of a right triangle opposite the right angle	
Inside	**Segment**	A member of the set of segment points, but not an endpoint
	Figure	A point such that any line through it intersects the figure at exactly two points and the point is between them
	Triangles	A triangle whose every point is inside of or on a side of another triangle, but the triangles do not coincide
Isometric	A transformation that preserves lengths; by SSS, it also preserves angles	
Legs	**Triangle**	The sides other than the base or the hypotenuse
Lemma	A theorem used for proving other more important theorems	
Length	The measure of the size of a segment; the distance between its endpoints	
Line	A segment extended past both endpoints; denoted $\overleftrightarrow{EF}$ if $\overline{EF}$ is the segment	
Locus	All the points that satisfy a condition; the plural is loci (lō’ sī)	

Magnitude	A set with both an equivalence relation, $=$, and a total ordering, $\leq$	
Median	A segment from a vertex of a triangle to the midpoint of the opposite side	
Mediator	The perpendicular bisector of a segment	
Midpoint	The point where a segment is bisected	
Neutral Geometry	A postulate set that does not mention parallel lines; absolute geometry	
Opposite	**In a Triangle**	An angle and a side across from each other
	Of a Line	Endpoints of a segment cut by the line
	In a Quadrilateral	Two sides or two angles across from each other
Ordering, Total	A set and a relation, $\leq$, that is not symmetric, but is reflexive, anti-symmetric and transitive	
Parallel	Two lines that do not intersect	
Perpendicular	A line whose intersection with another line makes a right angle	
Polygon	The union of multiple triangles adjacent on their sides such that it is convex	
Postulate	The axioms that are specific to geometry, not to other branches of math	
Quadrilateral	The union of two triangles adjacent on a side such that it is convex; $\overline{EFGH}$	
	Rhombus	A quadrilateral with all equal sides; plural, rhombi
	Saccheri	A quadrilateral with two opposite sides equal and perpendicular to the base
Radius	A segment from the center of a circle to the circle; plural, radii	
Ray	A segment extended in one direction; denoted $\overrightarrow{EF}$ if $\overline{EF}$ is the segment	
Reflexive Relation	A binary relationship over a set such that every element is related to itself	
Relation	A true/false operator on an ordered pair of elements from a given set	

Segment	All the points along the shortest path between two points; $\overline{EF}$	
Side	**Triangle**	One of the three segments that form a triangle
Summit	The side of a Saccheri quadrilateral that is opposite the base	
Symmetric Relation	A relation that can be stated of two things in either order	
Theorem	A statement requiring proof using postulates or already proven theorems	
Transitive Relation	If a relation is true for a and b and for b and c, then it is true for a and c	
Triangle	Segments connecting three noncollinear points, called vertices; *e.g.*, $\overline{EFG}$.	
	Acute	A triangle with all angles acute
	Degenerate	The vertices are collinear; this is not a triangle
	Egyptian	A triangle with sides 3, 4 and 5 units long
	Equilateral	A triangle with all sides equal
	Half Equilateral	An equilateral triangle cut at its center line
	Isosceles	A triangle with two sides equal
	Obtuse	A triangle with one angle obtuse
	Right	A triangle with one angle right
Trichotomy	Proof by contradiction when there are three alternatives	
Undefined Terms	Intuitive concepts: plane, point, shortest path, straight	
Under Defined	Not enough given information; the solutions are infinite in number	
Vertex	The intersection of two lines, rays, or sides of a triangle or quadrilateral	

Appendix: How Administrators Can Address Parents Concerned About *Common Core*

Everybody look and laugh at the *Common Core* equation for a parabola. Obviously, American high-school mathematics teachers are incapable of explaining how the Army defends against cross-border incursions as I do above in the section *Defense Positioning and Geometry*. Also, they cannot explain how to square a foundation.

NES Profile: Mathematics (304)

SECONDARY MATHEMATICS FORMULAS

Formula	Description
$V = \frac{1}{3}Bh$	Volume of a right cone and a pyramid
$V = Bh$	Volume of a cylinder and prism
$V = \frac{4}{3}\pi r^3$	Volume of a sphere
$A = 2\pi rh + 2\pi r^2$	Surface area of a cylinder
$A = 4\pi r^2$	Surface area of a sphere
$A = \pi r\sqrt{r^2 + h^2} = \pi rl$	Lateral surface area of a right cone
$S_n = \frac{n}{2}[2a + (n-1)d] = \frac{n}{2}(a + a_n)$	Sum of an arithmetic series
$S_n = \frac{a(1-r^n)}{1-r}$ Wrong!!!	Sum of a finite geometric series This needs the condition $r \neq 1$
$\sum_{n=0}^{\infty} ar^n = \frac{a}{1-r}, \ \lvert r \rvert < 1$	Sum of an infinite geometric series
$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$	Law of sines Is c the side of the triangle or $\frac{1}{4}$ of the latus rectum as shown below?
$c^2 = a^2 + b^2 - 2ab\cos C$	Law of cosines
$(x-h)^2 + (y-k)^2 = r^2$	Equation of a circle
$(y-k) = 4c(x-h)^2$ Wrong!!!	Equation of a parabola $(y-k) = \frac{1}{4c}(x-h)^2$
$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$	Equation of an ellipse
$\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$	Equation of a hyperbola

The *National Evaluation Series* (NES) are tests for prospective teachers in each high-school subject; 304 is mathematics. The fifteen formulas are all that are required to become a high-school math teacher and they do not even have to be memorized; the formula sheet can be taken into the exam. *The parabola equation is wrong!!!* When done right, c is the distance from the vertex to either the focus or the directrix; $4c$ is the length of the latus rectum. Also, it is stupid to use c (not w) for this *and* for the constant term in $y = ax^2 + bx + c$. It is no surprise to me that new teachers who scored in the top quartile on their collage entrance exams are nearly twice as likely to leave teaching than those with lower scores. They are appalled to discover that *Common Core* is teaching garbage!

Glencoe Geometry (p. 256) declares two triangles congruent, one with all its sides and angles labeled: $a = 38.4$ mm, $b = 54$ mm, $c = 32.1$ mm and $\alpha = 45°$, $\beta = 99°$, $\gamma = 36°$. The other triangle has the side corresponding to a labeled $(x + 2y)$ mm and the angle corresponding to β labeled $(8y - 5)°$. *Glencoe* then solves $8y - 5 = 99$ and $x + 2y = 38.4$ simultaneously to get $x = 12.4$ and $y = 13$. The former equation implies that y is an angle and the latter equation implies that x is something that, when added to an angle, is a length. *What?* x is the mysterious lengle!

Ridiculing *Glencoe Geometry* for adding a length to an angle is the best way to turn parents against *Common Core* because most of them do not remember the equation for a parabola from when they were in high school. But let us not overlook the fact that *Glencoe* set up a triangular system (one coefficient is zero) because this is all that is expected of *Common Core* students in 10th grade. When I was in high school – and this is still true in Europe – we solved two simultaneous linear equations with Cramer's Rule, and larger systems with Gaussian elimination.

Also worthy of ridicule is the practice of *Common Core* to attempt to give themselves the weight of antiquity. The Russian text of Kiselev's *Planimetry* is here: www.axiomaticeconomics.com/geometr-kiselev-1892.djvu Givental does not say he is doing an abridgment, but Kiselev has 302 sections and Givental has only 260. Also, Givental is a faithless translator. Равенство means equality, not congruence. Consider this: "**11. Равенство конечных прямых.** Два отрезка прямой считаются равными, если они при наложении совмещаются." This should be, "**11. Equality of finite lines.** Two line segments are considered equal if superposition makes them coincide." For Givental, this is section six because he is omitting sections. He translates it, "**6. Congruent and non-congruent segments.** *Two segments are congruent if they can be laid one onto the other so that their endpoints coincide.*"

Modern American textbooks use "congruent" to the complete exclusion of "equal," but this does not give the translator of an historical document the right to make this change unannounced. Also, notice that Givental talks around "superposition" because, while modern American textbooks rely on superposition, they attempt to write three grade levels below their students and hence omit this big five-syllable word in favor of "lay one onto the other." Givental is trying to make this 19th century Russian geometer sound like an early founder of *Common Core* geometry. He is not. While I do not agree with Kiselev on everything – specifically, I do not rely on superposition – *Planimetry* is a useful historical document. I cannot recommend this faithless translation.

Read the djvu file in Russian if you know the language. But, whatever you do, do not allow *Common Core* shills to convince you that their textbooks are based on the work of A. P. Kiselev, Felix Klein, or any other 19th century geometer. *Common Core* is based entirely on Bill Gates' desire to monopolize educational software sales. Gates (p. 3, usprogram.gatesfoundation.org/-/media/dataimport/resources/pdf/2016/12/geometry-outline2014.pdf) said "AAS is not sufficient for congruence," thus effectively banning *Geometry–Do* and every other geometry textbook that does not toe the *Common Core* line. It was at Gates' insistence that David Hilbert's good name be scrubbed, and Felix Klein be elevated to be the founder of all modern geometry. Klein was Hilbert's assistant, but the small original contribution he did make involved motion of geometric figures, which Gates latched onto because it helps him adapt his animation software to be sold as educational software.
So now geometry ceases to exist for students the moment they rise from their school computers running animation *cum* educational software sold by Gates for huge sums of taxpayer money. And no American carpenter can square a foundation without surveying equipment!

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Supply Chain: Challenges and Future

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Abstract: A supply chain exists to deliver the desired goods and/or services to the final consumer. It is an organization among several entities that share objectives, with strategic alignment and cooperation between the parties. Participating in a supply chain is beneficial for small companies, helping in their development and transversely improving their activity. The evolution of trade influences the way a supply chain is structured along the value chain, to respond effectively to consumer needs. There has been an evolution in the quantity and variety of products available for consumption, which has led to a change in the points of sale, from the traditional proximity trade to large establishments with a greater variety of offers, where consumers are able to meet their needs for consumption. The consumer went from being an almost passive subject, purchasing the goods made available to him, to a situation of greater power, now choosing what and where to buy. The increase in consumer power, combined with commercial competition, has caused supply chain management to move downstream in the value chain, in the past it was manufacturers that pushed their production to the market, now it is retail that pulls the production desired by the consumer.

Keywords: Trade, Logistics, Supply chain, Value, Consumer

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Introduction

One of the characteristics of a supply chain is the existence of an interconnection between several companies with the aim of satisfying the needs of the consumer. It aims to deliver the goods or services that the consumer needs, in the time, space and conditions required by this. For this to be possible, the companies belonging to the value chain cooperate with each other, with a constant multidirectional flow of goods, capital, and information, creating a complex network of procedures that, when added together, culminate in the production of the good to be delivered to the market. This cooperative network has been evolving along with technological advances, boosting the fast and effective exchange of information. We cannot fail to mention that Logistics also plays a fundamental role in the maintenance and development of supply chains, its activities generate value to the processes, reducing costs and promoting economies of scale in the trade that today can be called Global. Throughout the work, we will understand the reasons that motivated companies to organize themselves around common goals, how the evolution of commerce and the role of the consumer influenced the way of offering goods to the market and, consequently, their impacts on production. It will be possible to understand why the role of managing a supply chain is assumed by some companies, as well as to understand how a company can benefit just by being a participant in a supply chain. Finally, Logistics. Often confused with the concept of Supply Chain, Logistics and its activities are one of the pillars that sustain the necessary complexity existing in a network of constant and fast interactions between companies.

Method

The present work was produced using the qualitative research methodology, focused on the supply chain, and its reasoning is based on books, papers, journals and websites that cover this subject. The theoretical research, besides allowing the perception of the evolution of the supply chain, allowed its current context and interpretation, from the perspective of the authors.

What is a Supply Chain?

A supply chain can be defined, according to (Souza et al., 2006), as a set of geographically dispersed companies, interacting with each other, consisting of suppliers, producers, distributors, retailers and customers through which products, raw materials, and information flow. The purpose of the supply chain is to deliver the good/service required by the final consumer, comprising all the activities, installations and means of distribution necessary to carry out the sales process, from the origin to its delivery to the consumer. (Cox, 1999) describe a supply chain as a network of business relationships that transform raw material into a product through various stages of transformation, where value is added with the aim of satisfying the final customer. Therefore, we can say that a supply chain is a chain formed by links, through which the raw material is transformed into a product that will be delivered to the final customer to satisfy their needs. It should be noted that all efforts in the supply chain must be focused on customer satisfaction. According to (Moura, 2006), the supply chain begins to have a network perspective, more dynamic, with multiple interconnections. The underlying philosophy of the network concept is interdependence between all participants, based on partnerships and other cooperation solutions as a basic requirement for creating value for customers, with profitability for organizations. The author quotes J. Aitken, who defines the supply chain as a network of organizations, interconnected and interdependent, working mutually and cooperatively, to control, manage and improve the flow of materials and information, from suppliers to final customers. According to (Gomes & Rodriguez, 2008) globalization is one of the biggest motivators in the configurations and reconfigurations of the structures of supply chains in the world, with the aim of becoming more competitive and asserting themselves in the world market.

The Origins of Trade

Commerce as we know it today originated from the direct exchange of products. Each person or family specialized in the production of a certain good, either by skill or by having physical resources available, dedicated their time to that same production, which was later exchanged for another good that they needed. With no concept of currency, the exchange of goods was counterbalanced by the time or resources needed to obtain each product. With the emergence of money, a value began to be attributed to goods, enabling a family to sell the good it produced and purchase a set of other products that they needed. One cannot fail to mention the importance of the evolution of the means of production and its relationship with commerce and the satisfaction of consumer needs. At a time when production was manual, the craftsmen's work was carried out in small quantities, to satisfy local needs, with the skilled workers being responsible for carrying out the entire production cycle. After a period, to respond to a greater number of orders, the artisans began to work in workshops, with a division of labor among the craftsmen, to make the most of the working instruments. A distinction is then observed between the owners of the workshops, who quickly became entrepreneurs, and the craftsmen who contributed only with their workforce. At this point, the craftsman was no longer the exclusive player in the production cycle, often the raw materials were supplied by the trader who had ordered the products, the production was handed over to him to be sold on the market to consumers. A new rule was established in the relations in the production chains, but with the growth of the market, the offer proved to be insufficient and soon it became necessary to look for more efficient ways of producing and interacting with the market (Pires, n.d., 2009, 2016, in press). With the development of James Watt's steam engine in 1769, came the invention of machines that could repetitively, faster, and in a more standardized way, produce better quality products. With the increase in productivity and in production volume, there was a need to look for new markets and to transport goods more efficiently, that is, to improve the performance of the logistical processes. The discovery of the steam engine made possible the development of the locomotive and steamships, which generated a significant advance in terms of travel, compared to sailboats that, literally, traveled at the mercy of the winds. The industrial revolution took place when artisanal production methods gave way to machine production, which marked a significant transformation in labor relations in the production chains. Then, two classes emerged with distinct performances in the new industrial world: that of entrepreneurs who own companies and that of workers who only own the workforce.

Importance of focusing on the Consumer: from direct exchange to e-commerce

The Industrial Revolution and the constant evolution of means of transport made it possible for an increasingly varied set of products to be placed on the market to satisfy the needs of the consumers. The role of marketing was mainly to advertise the products, either because they were unknown, or because their usefulness was not obvious. We are talking about products that have changed consumption habits, such as refrigerators or plastic, for example. In the aftermath of World War II, there was a strong industrial capacity that, with the end of the armed conflict, redirected its production towards the consumer market, creating conditions for the emergence of new forms of commerce. The strong productive capacity of the industry boosted the emergence of specialized trade, large retail chains and shopping centers in large urban agglomerations, in contrast to street retail, whose inability to evolve and respond to the threat of large retailers saw its importance reduced. and consequent loss of turnover, leading to a slow asphyxiation and struggle for survival. At that time, driven by competition between retailers, consumers had an almost infinite range of goods at their disposal, with marketing geared towards stimulating consumers' desire for a given product. At the same time, the large retail chains expanded their activity geographically, and gaining considerable negotiating weight with suppliers. The last revolution, the digital one, made e-commerce possible, that is, that a product could be offered globally, while the consumer now has at his disposal an almost infinite display of consumption options. Marketing initiates a new communication strategy, with a more demanding, attentive, and informed consumer. In addition to product disclosure, other strategic concerns for brands are added, such as: environmental issues, digital presence, brand reputation, association with social responsibility causes, among others. The massive use of social networks made the communication established between companies and consumers stop being unidirectional to become bidirectional, with the consumer's opinion being increasingly valued. More and more people move from the mass market to the niche market, from standard production to customized production, causing profound changes in the supply chains. Currently, the consumer has a very important role in determining what is produced and how products are produced, consequently causing changes in supply chains.

When does it make sense to talk about Supply Chain Management?

As previously mentioned, a supply chain aims to satisfy the needs of the final consumer, delivering the goods he/she needs. A supply chain is based on the relationship of several entities, which may be sporadic, with purely commercial objectives, or be an extended relationship in time, with cooperation between entities that, driven by shared objectives, unite around adding value to its activities, better serving the final consumer. The supply chain exists because there was a need to minimize costs, through the organization between entities and the harmonization of their processes, with a view to improving their competitive position, whether in terms of costs and/or better responding to the market demands. In this way it makes sense to talk about supply chain management.

Who manages a Supply Chain?

So we can understand a supply chain as an alliance between several entities that share a common goal, we will have to identify a dominant entity that effectively manages the supply chain. The manager of a supply chain initially found himself upstream of the value chain, the manufacturers were the ones who established the distribution channels for their products, with the small retailer having as only goal to sell them to the final consumer. This structure is characterized by the fact that the wholesalers had to deal with large levels of stock so they can satisfy their customers, the small retailers. Currently, we can observe this distribution channel in breweries that, selling a wide range of beverage brands, maintain geographically dispersed wholesalers to serve their HORECA channel customers. This close presence makes it possible to add other activities that add value to the final customer, such as equipment assistance and maintenance, merchandising distribution, obtaining direct feedback on product sales, among others. An example in which supply chain management takes place downstream are the large retailers. Given its current weight in terms of turnover, there was a need to manage a distribution chain that allowed them to gain a competitive advantage over traditional trade. In addition to lower sales prices, it manages to offer a wide range of products in the same sales space, attracting and retaining the final consumer. To this end, large retailers use their own logistics warehouses to replenish their stores daily, which is where manufacturers deliver their products, losing the dominant role in managing the supply chain that brings their products to the consumer. Another example provided by e-commerce is the case of marketplaces. With no physical stores, this gigantic supply chain must be carefully managed, because the final consumer, when feeling that the service does not meet their expectations, easily abandons the online purchase. This way, it is necessary to maintain a structure capable of responding to each request in a carefully manner, but also to have an after-sales service that ensures that the final consumer is served in an appropriate way. We can thus conclude that there is no ideal supply chain typology, as they are structures that change according to the power that the final consumer has in the sales process, moving from a situation in which he/she could only purchase the products that were offered, to a situation in which you can buy the product you want, leaving the retailer with the task of having it immediately available under the best commercial conditions possible.

How can a Supply Chain benefit a Small and Medium-sized Enterprise (SME)?

A supply chain with an efficient management allows the reduction of costs, the creation of value, the improvement of processes, there so the importance that it can have in the life of some organizations, boosting their growth, could not be ignored. In small companies, the absence of written rules and norms and the lack, in most cases, of a clear definition of positions and tasks characterize administrative informality, which permeates all management activities and business relationships. However, this informality gives rise to behavioral and structural particularities that characterize the forms of interaction between the small business and its supplier and consumer market. The behavioral peculiarities are related to the personal aspects of the small entrepreneur. In general, they refer to conservatism and individualism, the centralization of power, the tendency towards obsolescence, the lack of skills in time management, the use of improvisation in relation to planned action, the immediacy of results, and the lack of knowledge of the management techniques (Nakamura, 2000). Among the structural idiosyncrasies, we underline the informality and personality in relationships, the unprofessional management, the inadequacy or non-use of management techniques and the lack of strategic and functional planning (Pinheiro, 1996). (Escrivão et al., 1996) claimed that informality resulting from inaccurate details and verbal communications disrupts internal and external communications, distorts goals and strategies, culminating in procedural and marketing inefficiency. Personality is another outstanding characteristic. Ownership and management in small businesses are usually carried out by the same person, the owner, and his personal characteristics have a great influence on the goals to be pursued and the strategies that will be adopted. An SME with all or some of the characteristics listed above that is incorporated as a partner in a supply chain benefits from this partnership. The entity that performs the supply chain management will define the objectives, processes, work methods (technological or procedural) and transmit knowledge that will allow the SME to quickly fill the management gaps that have been identified. Strategically, large corporations look for regional partners that have adequate physical or technical means, but that also have growth potential, with the SME eventually benefiting from this leverage provided by regular billing, eliminating some uncertainty and risk when deciding to make the necessary investments. An initial strategic constraint may be the dependence on a customer, but in the medium/long term the SME will be able to expand its market and eventually seek the internationalization of its operation.

The importance of Logistics in the management of a Supply Chain

The term *logistics* has already received different designations, such as: physical distribution, distribution engineering, business logistics, marketing logistics, distribution logistics, materials management, material logistics management, rapid response system, supply chain management, and industrial logistics. All these terms seek to designate the management of the flow of goods, from the origin still in raw material, to the delivery of the finished product to the final consumer or client. Logistics not only comprises physical distribution, but also stock management, warehousing, distribution, purchasing and transport management, and other supporting activities. Over time, logistics has evolved, moving from isolated actions to synergistic actions, that is, to integrated logistics and, currently, supply chain management. Logistics creates value through the services it provides to the company, associated with the transaction, customer relationships and distribution strategies. It also provides the increase of productivity, economies of scale, cost reduction, and supply chain integration, all of which contribute to creating competitive advantage.

Conclusion

Commerce had as its origin the direct exchange of goods between families, with the emergence of money these goods began to have a value and to be traded in local markets. Craft production offered the market goods in insufficient quantities to satisfy demand. Production underwent several transformations, from artisanal production, through the Industrial Revolution to the Post-World War period, being increasingly able to respond in terms of volume to what the market demanded. Trade, from the local market to the shopping center or electronic commerce, was also fueled by the quantity and diversity of goods possible to produce, for an increasingly demanding and informed customer, who has become the one who now has great influence on what to produce and how. The concept of a supply chain has evolved, as have the variables that determine its existence. It cannot be concluded that there is one, or several types of supply chain, they are constituted to satisfy goals such as efficiency, cost reduction or speed of response, for example.

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Validity Evidence for Teacher Self-efficacy (TSE) Scale

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Abstract: This study aimed to examine the validity and reliability evidence of Teacher Self-efficacy (TSE) scale (Tschannen-Moran & Hoy, 2001) for teacher in K-12 US schools. Particularly, our study gathered evidence for the internal structure validity, convergent validity, criterion validity and reliability of the TSES in US educational context. The survey was administered to Pre-K-12th grade teachers from a large school district in the Southwestern of the United States. The total sample size was 1,418. The majority of the sample was female (73.9%) and White (73.8%). Nearly half of the sample had BA in education (48.9%) and about 28% of them have master's degree in education. We conducted Confirmatory Factor Analysis (CFA) on Mplus. Data was screened, and all assumptions, normality, outliers and adequate sample size were met. We used CFA for internal structure, correlation for convergent validity evidence, and Analysis of Variance (ANOVA) for criterion validity evidence. Cronbach's Alpha and McDonald's Omega were used for the reliability. Our results showed that the data fits the model well based on the goodness-of-fit statistics. This study provides evidence of the validity and reliability of TSE using this sample.

Keywords: Teacher self-efficacy, Validity evidence, Reliability evidence

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Introduction

Teacher Self-efficacy (TSE) scale was developed by Tschannen-Moran and Hoy (2001) and has been widely used in literature. According to Tschannen-Moran and Hoy's (2001), teacher efficacy refers to a teacher's assessment of their own ability to achieve the desired results in terms of student participation and learning. TSE scale was developed by Tschannen-Moran and Hoy (2001) and has been the most commonly used scale for teacher self-efficacy studies (Ma et al., 2019). Their research was consistent of three parts. In the first part, 52 items were developed and reduced to 32 items using principal-axis factoring with a sample of 224 teachers. For the second part, the scale was reduced to 18 items using the same analysis and another sample of 217 teachers. Lastly, they created a short (12 items) and long (18 items) of the TSE scale using a sample of 410 teachers. In addition to the validity evidence provided by Tschannen-Moran and Hoy (2001), Nie et al. (2012) also validated the construct in Singapore.

Specifically, they conducted CFA and examined the distinction between the sub-constructs, which are teacher efficacy in relation to: instructional strategies, motivation, and classroom management. Researchers reported high correlations between teacher self-efficacy and teaching strategies, indicating strong prediction validity. While there were some international studies (Fathi & Rostami 2018; Klassen et al. 2009; Nie et al., 2012) that examine the validity of teacher self-efficacy scale, there is a need to validate the scale in the US educational context. This study aimed to examine the validity and reliability evidence of TSES for teacher in K-12 US schools. Particularly, our study gathered evidence for the internal structure validity, convergent validity, criterion validity and reliability of the TSES in US educational context.

Factors Associated with Teacher Self-efficacy: Job Satisfaction, Teacher-Student Interaction and Teaching Experience

Job satisfaction can generally be defined as having a positive reaction to the workplace (Worrell et al., 2006). Within the field of education, research suggests that teacher job satisfaction may come from several different sources. For example, research suggests that positive social relationships are more likely to increase teacher job satisfaction (Sylvia & Hutchinson, 1985) and might also play a crucial role for teachers (Van Droogenbroeck et al., 2014). In addition, positive relationships with colleagues, parents, students are related to teacher satisfaction (Cano-Garcia et al., 2005; Gavish & Firedman, 2010; Skaalvik & Skaalvik, 2011). A meta-analysis by Kasalak and Dagyar (2020) used over 100 from 50 countries independent data to examine the relationship between job satisfaction and teacher self-efficacy. They concluded there is a positive correlation between teacher self-efficacy and job satisfaction.

Previous research indicated that there is a connection between teacher self-efficacy beliefs are linked with positive interactions with students in the classroom (Bloom & Peters, 2012; Summers et al. 2017; Siwatu & Starker, 2010). Davis et al. (2017) investigates the effects of teachers' efficacy beliefs on students' perceptions of the quality of their relationship with their teacher. The study finds that students are more likely to perceive a positive relationship with their teacher when the teacher has a strong sense of efficacy, indicating confidence in their ability to teach effectively.

Literature suggest that teacher self-efficacy increase as they gain teaching experiences (George et al., 2018; Wolters & Daugherty, 2007). Gale et al. (2021) examined teacher self-efficacy based on teaching experience and found a significant difference between first year teacher, novice teacher and career teachers where first year teacher had statistically significantly lower teacher self-efficacy.

Method

Data Collection and Participants

The survey was administered to Pre-K-12th grade teachers between March 14th and April 1st, 2022 from a large school district in the Southwestern of the United States. Of the 3,264 teachers who received the survey, 2,260 teachers responded, for a response rate of 69.2%. If a participant responded at least 50% of the survey, the responses were analyzed. Out of 2,260 surveys, 62.7% (n=1,418) met this completion criteria and are included in the final sample size in this analysis. Table 1 shows the demographic characteristics of the sample. The majority of the sample was female (73.9%) and White (73.8%). Nearly half of the sample had BA in education (48.9%) and about 28% of them have master's degree in education.

Table 1. Demographic Characteristics of the Participants

	N	%
Gender		
Female	1,048	73.9%
Male	281	19.8%
Other	20	1.4%
Missing	69	4.9%
Race/Ethnicity		
Native American	8	0.6%
Asian	26	1.8%
Black/African American	15	1.1%
Hispanic/Latino	146	10.3%
White	1,046	73.8%
Multi-racial	47	3.3%
Other	54	3.8%
Missing	76	5.4%
Education		
BA in Education	693	48.9%
University based post-BA program	168	11.8%

Master's in education	398	28.1%
Alternative program	39	2.8%
Not listed here	52	3.7%
Missing	68	4.8%

The teaching characteristics of survey respondents, including the subject and grades they teach, as well as their teaching experience are presented in Table 2. Most of our sample teacher ELA (40.8%) and Math (39.1%). Teacher in higher school grades, 9, 10, 11, 12 were 20.7%, 21.7%, 22.5% and 21.2%, respectively.

Table 2. Teaching Characteristics of the Participants

	N	%
Subject*		
ELA	579	40.8%
Math	554	39.1%
Science	167	11.8%
Social Studies	172	12.1%
Other	684	48.2%
Grade*		
Pre-K	201	14.2%
Grade 1	185	13.0%
Grade 2	172	12.1%
Grade 3	187	13.2%
Grade 4	204	14.4%
Grade 5	207	14.6%
Grade 6	210	14.8%
Grade 7	199	14.0%
Grade 8	201	14.2%
Grade 9	293	20.7%
Grade 10	308	21.7%
Grade 11	319	22.5%
Grade 12	301	21.2%
Experience		
I am a pre-service teacher	5	.4%
0-2 years	115	8.1%
3-5 years	170	12.0%
6-10 years	251	17.7%

More than 10 years	813	57.3%
Missing	64	4.5%

Note. *Check all that apply type items.

Measures

Five scales were used in our study, and they were teacher self-efficacy, teacher job satisfaction, teacher commitment, teacher collaboration, teacher-student interaction.

TSES

Prior research defines teacher self-efficacy as a measure of a teacher's judgment of their own ability to reach desired outcomes (Bandura, 1977). Tschannen-Moran and Hoy (2001) developed TSES, which asks teachers questions about how well they can perform various tasks within schools. Nie et al. (2012) examine the validity of TSES and suggested the scale with tree factors and 12 items in Singapore educational context. We used Nie et al.'s version of TSES in our study. The full list of teacher self-efficacy questions is listed in Table 3. For example, teachers were asked, *"How well can you respond to difficult questions from your students?"* and *"How well can you help your students value learning*?" All questions used five-point Likert type responses from *not well* at all to *very well*.

Teacher Job Satisfaction

Teacher job satisfaction was validated with a large international sample, including the United States, using confirmatory factor analysis (Pepe, 2011; Pepe et al., 2017). Thus, research provides evidence that this teacher job satisfaction scale is an appropriate tool to understanding teachers' level of job satisfaction. Teacher job satisfaction was measured as three sub-constructs: satisfaction with co-workers, students, and parents with nine items. For example, teachers were asked, "*How satisfied are you with the following aspect of the school: The extent to which your co-workers encourage you and support you in your work,"* and "*How satisfied with the following aspect of the school: The degree of interest shown by parents in the education of their children."*

Three-factor CFA analysis showed that the data reasonably fit this teacher job satisfaction. Specifically, the chi-square goodness-of-fit statistics are statistically significant, suggesting that the model fit is not perfect. However, the other goodness-of-fit statistics suggest that the data are a reasonable fit for the model (Chi-square = 117.84 (df=24), $p < .001$; CFI=.986; RMSEA=.053 [90% CI: .043 to .062]; SRMR=.033). Similar to Pepe et al.'s (2017) results, the standardized correlation coefficients between factors range from .29, .30 and .62 for students with co-workers, parents with co-workers and parents with students, respectively.

Teacher Commitment

Teacher commitment measures how dedicated teachers are to remaining in their profession. The teacher commitment measure was developed and validated by Thien et al. (2014). The researchers analyzed the results of over 600 teacher respondents using exploratory and confirmatory factor analysis. Their results provide evidence of construct validity for the teacher commitment scale. We used the sub-construct of commitment to the profession as an indication of teacher commitment. The teacher commitment to the profession construct contains four questions. Teachers were asked, for example, "*To what extent do you agree or disagree with the following statements: If I could get a job different from being a teacher and paying the same amount, I would take it.*" and "*To what extent do you agree or disagree with the following statements*: *One of the best decisions that I have ever made was to become a teacher."*

Analysis of from this survey administration provides evidence that the data reasonably fit this teacher commitment model. Since Chi-square goodness-of-fit statistics are statistically significant, the model fit is not perfect. However, the other goodness-of-fit statistics suggest that reasonable fit for the model (Chi-square = 7.67 (df=2), $p < .001$; CFI=.995; RMSEA=.045 [90% CI: .015 to .080]; SRMR=.009).

Teacher-Student Interaction

Brand et al. (2008) validated this scale as a part of school climate survey for teachers with a sample of 234 teachers. The researchers provide evidence for construct validity based on confirmatory factor analysis. The survey measures teacher-student interactions as one construct that includes five questions. These questions focus on interpersonal interactions. For example, teachers are asked*, "To what extent do you agree with the following statements: My students share their concerns with me,"* and "*To what extent do you agree with the following statements: My students express their feelings."*
Analysis from this survey administration provides evidence that the data reasonably fit this teacher-student interaction model. Specifically, the chi-square goodness-of-fit statistics are statistically significant, which suggestions that the model fit is not perfect. However, the other goodness-of-fit statistics suggest that a reasonable fit for the model (Chi-square = 27.52 (df=5), $p < .001$; CFI=.987; RMSEA=.056 [90% CI: .037 to .078]; SRMR=.019).

Data Analysis

We used SPSS 26 for all data analysis except for Confirmatory Factor Analysis (CFA) which was conducted on Mplus. Data was screened, and all assumptions, normality, outliers and adequate sample size were met. We used CFA for internal structure, correlation for convergent validity evidence, and Analysis of Variance (ANOVA) for criterion validity evidence. Lastly, Cronbach's Alpha and McDonald's Omega were used for the reliability.

CFA as Internal Structure Evidence

The internal structure represents to what degree the relationship between items and factors fits the construct (AERA, APA & NCME, 2014). We examined the validity evidence for TSES by conducting second-order CFA with 12 items as suggested by Nie et al. (2012). Before conducting CFA, the data was screened, and all assumptions were examined. Based on this analysis, multivariate outliers (N=66, 0.04%) were detected. CFA models were conducted with and without outliers. There was not a significant difference between the results, so outliers were not deleted. A second order CFA model with three-factor was conducted for TSES. All CFA models are overidentified, which indicates there is more than enough information in the data to estimate the model parameters. CFA models were tested with *M*plus 8 (Muthén & Muthén, 2017) using maximum likelihood estimation with robust standard errors. The first indicator of each latent variable' coefficient was fixed to 1.00.

We assessed model fit using the Chi-square test and along with the following goodness-of-fit indices: root mean square error of approximation (RMSEA); standardized root mean squared residual (SRMR); and comparative fit index (CFI). The Chi-square test assesses the difference between the given model and an unspecified model that would fit to the covariance matrix of the data perfectly (Kline, 2016, p. 270). While p>.05 is desired for Chi-square test, significant p-values may or may not indicate inappropriate model fit in large sample studies. Thus, we used other indices to test how well the model fit the data. RMSEA is a based-on error terms; thus, zero is the best result (Kline, 2016, *p*.273). For RMSEA, values greater than .10 may indicate a lack of fit (Browne & Cudeck, 1992). CFI is a goodness-of-fit indices, and CFI values greater than .90 indicates that the proposed model is greater than 90% of than that of the baseline model, serve as an indicator of adequate fit (Kline, 2016). SRMR is standardized measure of the absolute covariance residual, and perfect model fit is indicated by SRMR = 0, and values greater than .10 may indicate poor fit (Kline, 2016).

Pearson Correlation as Convergent Validity Evidence

Examining the relationship between the construct and other related variables serves convergent validity evidence (AERA, APA, & NCME, 2014). We used Pearson correlation to analyze the relationship between overall teacher self-efficacy, three subscales of TSES, teacher job satisfaction, teacher commitment and teacher-student interaction. The overall teacher self-efficacy, three subscales of TSES, teacher job satisfaction, teacher commitment and teacher-student interaction variables were computed as the mean of all items in the scale.

ANOVA as Criterion Validity Evidence

Criterion validity examines the relationship between the target construct and a relevant criterion (AERA, APA, & NCME, 2014). Literature demonstrates a positive correlation between teacher self-efficacy and years of teaching experience (Gale et al., 2021). Therefore, we used years of teaching experience as a criterion. We grouped years of teaching experience into three groups, 0-5 years, 6-10 years and more than 10 years to conduct a one ANOVA because we expected teacher with more experience to have a higher teaching self-efficacy.

Reliability

We used Cronbach's Alpha and McDonald's Omega to provide reliability evidence. Cronbach's Alpha is a reliability index and a measure of internal consistency. Cronbach's Alpha shows the relationship between question responses in the same scale. A higher Cronbach's Alpha indicates a higher reliability of the scale. If Cronbach's Alpha is higher than the .70 for a group of questions, then those questions have an acceptable reliability index (Nunnally, 1978). Well-accepted value for McDonald's omega is .9 (Tervee et al., 2007).

Results

Our study demonstrates the three types of validity evidence for TSES, internal structure validity, convergent validity and criterion validity, and reliability evidence.

Internal Structure (CFA)

Table 3. Descriptive Statistics for Teacher Self-efficacy Items and Constructs

Item ID	Items and Constructs	Mean	SD
	Instructional strategies (IS)	**3.97**	**0.58**
TS1	How well can you respond to difficult questions from your students?	4.02	0.72
TS2	How well can you provide appropriate challenges for very capable students?	3.77	0.79
TS3	How well can you implement alternative instructional strategies in your classroom?	3.91	0.79
TS4	How well can you provide an alternative explanation, for example, when students are confused?	4.17	0.70
	Motivation (MOT)	**3.50**	**0.73**
TS5	How well can you help your students value learning?	3.68	0.83
TS6	How well can you motivate students who show low interest in schoolwork?	3.32	0.91
TS7	How well can you improve the understanding of a student who is failing?	3.57	0.81
TS8	How well can you get through to the most difficult students?	3.41	0.92
	Classroom management (CM)	**4.01**	**0.69**
TS9	How well can you make your expectations clear about student behavior?	4.34	0.71
TS10	How well can you get students to follow classroom rules?	4.07	0.77
TS11	How well can you control disruptive behavior in the classroom?	3.99	0.82
TS12	How well can you keep a few problem students from missing an entire lesson?	3.66	0.92
	Teacher self-efficacy (TS)	**3.83**	**0.56**

Our results showed that the data fits the model well based on the goodness-of-fit statistics. The chi-square goodness-of-fit statistics were statistically significant, suggesting the model fit is not perfect. However, all other goodness-of-fit statistics provide evidence that the data do adequately fit the model (Chi-square = 450.33 (df=51), p < .001; CFI=.941; RMSEA=.074 [90% CI: .068 to .081]; SRMR=.042). The unstandardized and standardized coefficients for teacher self-efficacy second-order CFA are reported in Table 4. All coefficients were statistically significant (p<.001) indicating that the coefficients are larger than zero. The squared valued of standardized coefficient shows the proportion of explained variance. Therefore, any standardized coefficient that falls below .70 indicates that less than half of the variation in that question response is accounted for in the factor. Thus, Table 4 shows that there are three questions with standardized coefficients below .70, within the Instructional Strategies factor. Although these values are below .7 threshold, they are not far from .7. For example, the standardized coefficient of TS1 was .65, indicating that this question explains 42% of variance in its factor. Figure 1 contains a visual representation of this model.

Table 4.Unstandardized Coefficients, Standard Error (SE), and Standardized Coefficients for Teacher Self-efficacy CFA Model

Item ID	Constructs and Questions	Unstandardized Coefficient	SE	Standardized Coefficient
	Instructional strategies (IS)			
TS1	How well can you respond to difficult questions from your students?	1.00	0.00	0.65
TS2	How well can you provide appropriate challenges for very capable students?	1.21	0.06	0.71
TS3	How well can you implement alternative instructional strategies in your classroom?	1.18	0.07	0.69
TS4	How well can you provide an alternative explanation, for example, when students are confused?	1.01	0.05	0.67
	Motivation (MOT)			
TS5	How well can you help your students value learning?	1.00	0.00	0.78
TS6	How well can you motivate students who show low interest in schoolwork?	1.18	0.03	0.84
TS7	How well can you improve the understanding of a student who is failing?	0.90	0.04	0.72
TS8	How well can you get through to the most difficult students?	1.09	0.04	0.77
	Classroom management (CM)			
TS9	How well can you make your expectations clear about student behavior?	1.00	0.00	0.74
TS10	How well can you get students to follow classroom rules?	1.27	0.05	0.87
TS11	How well can you control disruptive behavior in the	1.37	0.05	0.88

	classroom?			
TS12	How well can you keep a few problem students from missing an entire lesson?	1.31	0.06	0.75
	Teacher Self-efficacy			
	IS	1.00	0.00	0.85
	MOT	1.38	0.09	0.84
	CM	0.99	0.06	0.74

Note. IS=Instructional strategies, MOT= Motivation, CM= Classroom management

The path coefficients between the factors and second order factor are statistically significant at .85, .84 and .74 for instructional strategies, motivation, and classroom management, respectively. These factors explain 72%, 70% and 55% of the variance in teacher self-efficacy, respectively. The teacher self-efficacy second-order CFA model is shown in Figure 1. This figure provides a visual representation of the model. That is, the figure shows how the teacher self-efficacy (ts) construct, relates to the three sub-constructs of instructional strategies (is), motivation (mot), and classroom management (cm). Similarly, the figure shows how each question item relates to subconstructs and the overall construct.

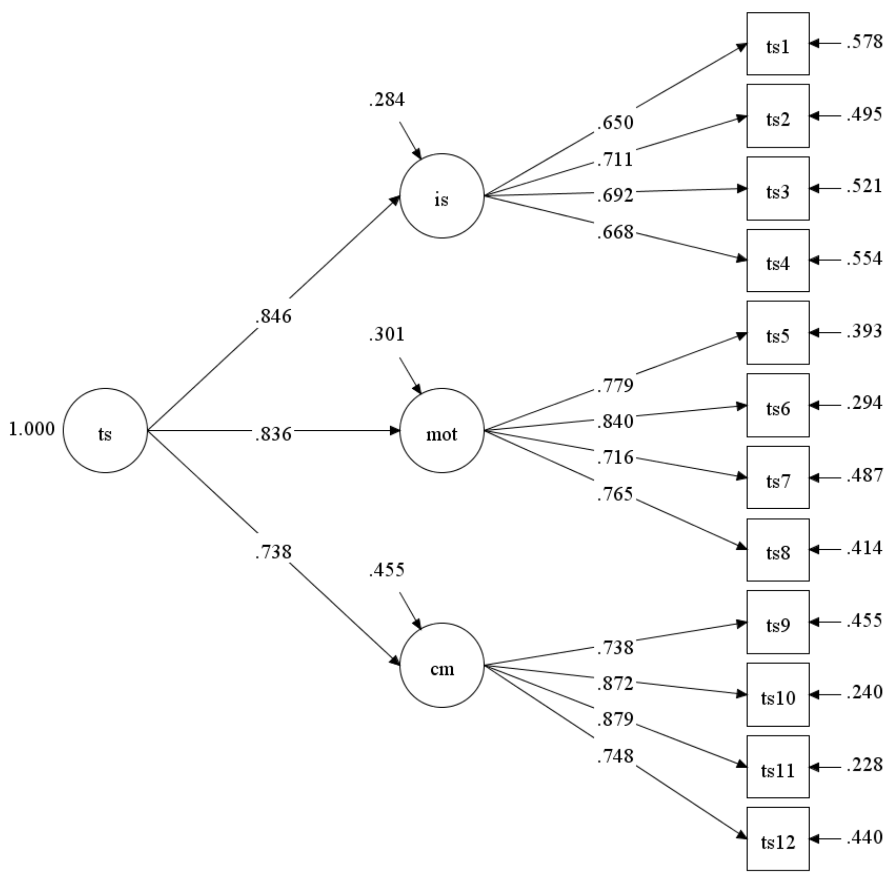

Figure 1. Teacher Self-efficacy Second-order CFA Model with Standardized Estimations

Note. is=Instructional strategies, mot= Motivation, cm= Classroom management, ts=Teacher self-efficacy.

Pearson Correlation as Convergent Validity Evidence

Table 5 displays the Pearson correlation among TSE, TSE subscales, teacher job satisfaction, and teacher student interaction. Our results showed that three subscales of TSE were highly correlated ($p< .01$). Besides, TSE is correlated with teacher job satisfaction and teacher student interaction.

Table 5. Correlation Matrix among TSE and other variables

Variables	1	2	3	4	5
1- TSE					
2-TSE-Instructional strategies	.818**				
3-TSE-Motivation	.867**	.589**			
4-TSE-Classroom management	.838**	.535**	.565**		
5- Teacher job satisfaction	.274**	.116**	.306**	.248**	
6- Teacher-student interaction	.334**	.246**	.381**	.205**	.249**

Note. *p<.05; **p<.01; ***p<.001

ANOVA as Criterion Validity Evidence

A one-way ANOVA was conducted to determine if there is mean difference in TSE based on teacher years of experience. According to Levene's test, there was heterogeneity among three groups, so we used Welch test (Lomax & Hahs-Vaughn, 2013). Our results indicated that there is a significant difference in TSE based on teacher years of experience ($F(2, 508.39) = 51.85$, $p<.001$, $\eta^2=.08$). The posthoc test indicated that there was a significant difference in TSE for 0-5 years of experience (M=3.54, SD= .6), 6-10 years of experience (M=3.82, SD=.55) and more than 10 years of experience (M=3.93, SD=.52) which indicated that more experience teachers have higher TSE.

Survey Reliability

Cronbach's Alpha, a common measure of reliability, is calculated for each scale and sub-scales. Table 6 presents the number of items and item reliability index, Cronbach's Alpha and Mc Omega for TSE and its subscales. TSE presented higher reliability based on Cronbach' Alpha (.901) and Mc Omega (.898). Therefore, we concluded that TSE scale has high reliability for this sample.

Table 6. The Item Analysis of the Scales

Scale	Subscales	Number of items	Cronbach's Alpha	Mc Omega
Teacher Self-efficacy		12	.901	.898

	Instructional Strategies	4	.773	.77
	Motivation	4	.855	.857
	Classroom Management	4	.876	.88

Conclusion

This study examined the validity and reliability evidence of TSE (TschannenMoran & Hoy, 2001) scale with a large US sample. CFA results provided construct validity evidence for TSE as suggested by (Nie et al., 2012) for teacher in Singapore. These results indicate that the scale can be used to measure teacher self-efficacy in the United States.

Our study presented convergent validity evidence and high reliability for TSE. Three factors of TSE, instructional strategies, motivation and classroom management, were highly correlated with overall TSE, and moderately correlated with teacher job satisfaction, and teacher-student interaction. These positive correlations between TSE and teacher job satisfaction and teacher-student interaction served as convergent validity evidence of TSE. The ANOVA results presented that there was a significant difference in TSE based on teaching experience as more experience teacher had higher level of TSE (Gale et al., 2021; George et al., 2018; Wolters & Daugherty, 2007). This result supported criterion validity evidence for TSE. Based on Cronbach's Alpha and Mc Omega TSE and its three factors have high reliability indices.

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Motivating Linstedt's Method Using Multiple Time Scales

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Abstract: Although the mathematical simulation of nonlinear devices can be numerically implemented using software, for design tradeoff analyses it is essential to have closed-form formulas, even if they are only approximations to the solutions. The regular perturbation series method often provides such formulas in a straightforward manner, but frequently it spawns secular terms, which severely limit the usefulness of the formulas. Poincare and Linstedt devised tricks that avoid secular terms by invoking the concept of strained time. However, motivating these tricks for students is a daunting undertaking. This paper conducts a tutorial/review of these notions in the context of modeling the diode and the Duffing spring, explicates the relatively recent notion of multiple time scale analysis, and shows how the latter provides a neat and straightforward rationale for the strained-time approach. It also offers insight into why the method does not enjoy all the convergence features of the power series method.

Keywords: Multiple scale methods, Perturbations, Asymptotics, Engineering mathematics

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Introduction and Background

Modern engineering analysis has been tremendously enhanced by the availability of numerical software packages, particularly in the simulation of nonlinear devices. However, for design purposes closed-form expressions - even if they are only approximate - are handier when considerations such as optimization and parameter dependencies are important. The ("regular") perturbation series was developed by Lagrange, Poisson, and Laplace for developing analytic formulas that model nonlinearities. It is based on a straightforward extension of the power series method for obtaining the Taylor (Maclauren) series of the solutions to the relevant differential equations. However Linstedt (1882) and Poincare (1893) (working in the area of celestial mechanics) soon discovered that the accuracy of the formulas provided by regular perturbation theory was unacceptable when socalled *secular terms* occurred in the expansions. They concocted a workaround which became known as the *strained time* method. This trick vastly improved the range of validity of the perturbation formulas.

Unfortunately, secular perturbation theory suffers two deficiencies. A transparent rationale for the strained-time "trick" is lacking; it resembles sleight of hand to most students. And also the mathematical convergence theory is ragged - nothing like the elegance of Taylor series.

We shall briefly expound this narrative in the context of familiar systems containing the diode and the Duffing spring. Then we explicate the basics of the relatively recent notion of *multiple scale analysis* from a modestly novel perspective. We shall demonstrate that the multiscale apparatus provides the coveted motivation for the strained-time implementation, while offering insight into its frailties as well.

Two Nonlinear Devices

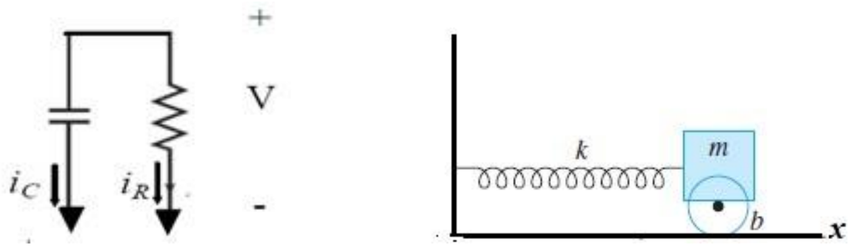


Figure 1. Left: diode modelled as a nonlinear resistor. Right: Duffing nonlinear spring

Fig. 1 depicts the two nonlinear devices we will study. On the left is a diode circuit that arises in the analysis of transistor-edge sensors (Irwin & Hilton, 2005). The diode is modeled as a nonlinear resistance R governed by the current-voltage (i-V) relation $i_R = \frac{V}{R} + gV^2$, where g is the small parameter quantifying the size of the quadratic nonlinearity, in parallel with a capacitance C. To avoid unnecessary numerical clutter we assume a system of units where Kirchhoff's Current Law for the circuit takes the form of a Ricatti equation with ϵ as the rescaled expansion parameter:

$$C\dot{V} + \frac{V}{R} + gV^2 = 0 = \dot{y} + y + \epsilon y^2. \quad (1)$$

On the right in Fig. 1 is a damped mass-spring oscillator with mass m, damping coefficient b, and a nonlinear spring stiffness $k = k(x) = K + gx^2$ where, again, g is the nonlinearity parameter, proposed by Duffing (1918). Newton's law, rescaled for convenience, is expressed

$$m\ddot{x} + b\dot{x} + Kx + gx^3 = 0 = \ddot{y} + 2\epsilon_1\dot{y} + y + \epsilon_2 y^3, \tag{2}$$

where both the damping coefficient and the spring nonlinearity are candidates for expansion parameters.

Synopsis and Critique of Taylor Expansions

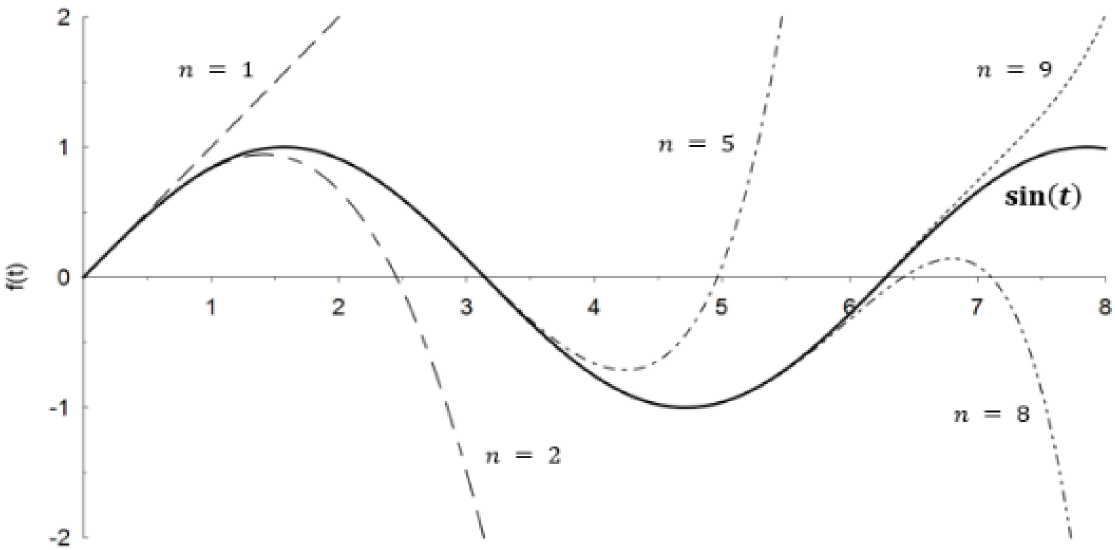
Taylor's Theorem says that any reasonable ("entire," say) function *f*(*t*) can be approximated by polynomials:

$$f(t) \approx a_0 + a_1 t + a_2 t^2 + a_3 t^3 + \cdots + a_n t^n \ . \tag{3}$$

The most celebrated result says roughly that the polynomials will converge to *f*(*t*), approximating it arbitrarily closely as long as one takes enough terms. Moreover, term-wise differentiation and integration are justified.

And the coefficients can be computed by virtually any convenient method. Most commonly, when the function *f* is known we use differentiation: $a_n = f^{(n)}(t)\big|_{t=0}/n!$. But when an (unknown) *f*(*t*) satisfies a differential equation (with initial conditions) we frequently find the a_n by inserting the power series format ("ansatz") $f(t) = \sum_{n=0}^{\infty} a_n t^n$ into the equation and solving for the coefficients recursively (Nagle et al., 2017).

This welcome news is tempered by the fact that the polynomials don't always provide useful approximations to the sinusoids or the exponentials - functions that are ubiquitous in engineering and statistical modeling. Fig. 2a displays the futility of Taylor approximation for sin *t*; the polynomials can't capture even *a single period* of the oscillation until the degree is at least 17. Fig. 2b shows that the degree-7 approximant for e^{-t} goes negative (!) within 3 time constants.



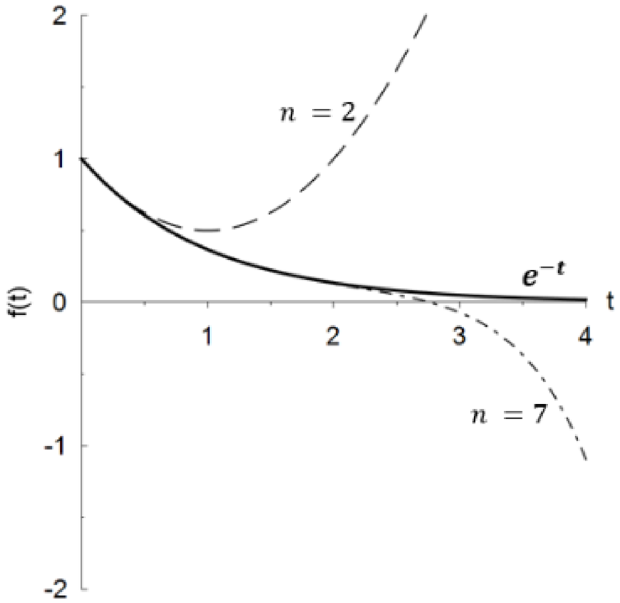


Figure 2. (a) sin t and its approximants $\sum_{i=1}^{n}(-1)^{i-1}t^{2i-1}/(2i-1)!$

(b) e^{-t} and its approximants $\sum_{i=1}^{n}(-1)^{i}t^{i}/i!$

So although Taylor polynomials are guaranteed to approach $f(t)$ at any point if we take the degree high enough, the range of feasibility for low-degree approximants is unsuitable for sinusoids and exponentials. As a species, polynomials are rambunctious; except for the constants, they *have* to diverge eventually. To employ them as approximants one must resort to periodicity or recursion to "rein in" the parameter t; cos $(2\pi n+t)$ = cos t , $e^{n+t} = e\times e\times\ldots\times e\times e^{t}$, etc.

Synopsis and Critique of Regular Perturbation Theory

Typically we cannot derive closed-form solutions to nonlinear equations. Computer software can provide accurate *tabulated* solutions for given values of the physical parameters, but to understand the tradeoffs in designing for specific applications, closed-form expressions - even approximate ones - are essential. Now mathematical theory states that the solution to an equation like (1) or (2) possesses convergent power series expansions, not only in t, but in the ϵ's as well. While the considerations of the previous section dissuade us from relying on low-degree polynomial approximants in the freewheeling parameter t, the nonlinearity parameter ϵ stays fixed (and small); so we can be more optimistic about finding suitable low-degree approximants in the form

$$y(t,\epsilon) \approx y_0(t) + \epsilon y_1(t) + \epsilon^2 y_2(t) + \cdots \qquad (4)$$

without presuming that the functions $y_n(t)$ are polynomials.

The approximation procedure based on the ansatz (4) is known as (regular) perturbation theory, and it was pioneered by Lagrange, Laplace, and Poisson. The computation of the recursion relations for the zeroth and first order perturbations can often be carried out with mental algebra; insertion of the series (4) into the diode equation (1) and grouping equal powers of ϵ leads to the relations

$$\dot{y}_0 + y_0 = 0\,,\;\; \dot{y}_1 + y_1 = -{y_0}^2\,,\;\; \dots . \tag{5}$$

And clearly the general solutions to (5) are

$$y_0 = Ae^{-t}\,,\;\; y_1 = Be^{-t} + A^2e^{-2t}\,,\;\; \dots . \tag{6}$$

For the initial condition $y(0) = 1$ the first-order approximant is

$$y_0 = e^{-t}\,,\; y_1 = -e^{-t} + e^{-2t}\,; \qquad y \approx y_0(t) + \epsilon y_1(t) = e^{-t} + \epsilon\,[-e^{-t} + e^{-2t}]\,. \tag{7}$$

We emphasize that this is a degree-1 polynomial *in* ϵ; its t dependence has not been restricted.

Fortuitously we can solve (1) in closed form by the methods described in Nagle et al. (2017). Fig. 3 displays the approximant (7) and the exact solution $\{(1+\epsilon)e^t - \epsilon\}^{-1}$ for $\epsilon = 0.05$. The agreement is excellent.

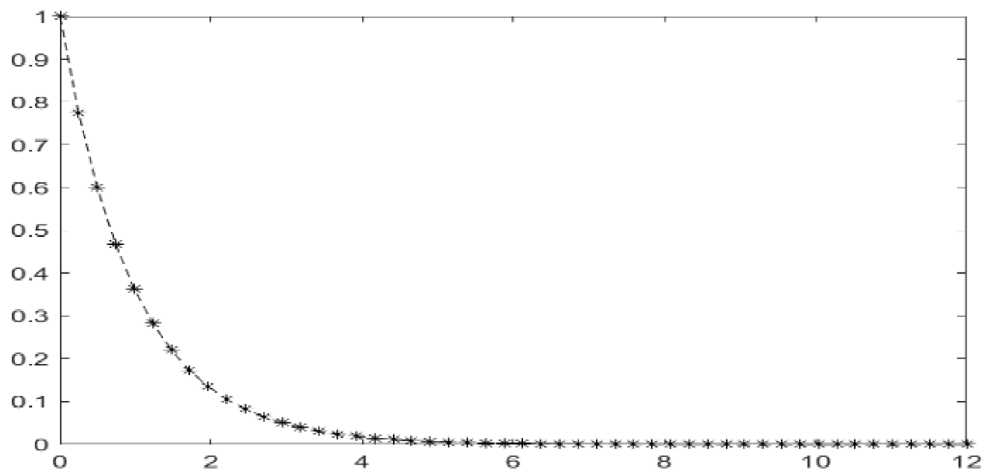


Figure 3. Approximant (7) (dashed) and exact solution (asterisk)

However, as we explore more equations we have to expect the kind of mischief that was exhibited in the sinusoid and exponential examples. The perturbation analysis of the weakly damped *linear* spring oscillator, described by (2) with $\epsilon_2 = 0$, exemplifies the situation. The exact solution of

$$\ddot{y} + 2\epsilon\dot{y} + y = 0\,,\;\; y(0) = 0,\;\; \dot{y}(0) = 1 \tag{8}$$

(the subscript is now superfluous) is the damped sinusoid

$$y(t;\epsilon) = (1-\epsilon^2)^{-1/2}e^{-\epsilon t}\sin\sqrt{1-\epsilon^2}\,t. \tag{9}$$

Substituting (4) into (8) and grouping results in

$$\ddot{y}_0 + y_0 = 0\,,\;\; \ddot{y}_1 + y_1 = -2\dot{y}_0\,,\;\; \dots . \tag{10}$$

The zeroth order equation has the solution

$$y_0 = A \sin t + B \cos t \equiv \sin t \tag{11}$$

for the initial conditions $y(0;\epsilon) = 0$, $\dot{y}(0;\epsilon) = 1$, and therefore

$$\ddot{y}_1 + y_1 = -2 \cos t \quad \Rightarrow \quad y_1 = \sin t - t \cos t\,. \tag{12}$$

The approximate solution

$$y_0(t) + \epsilon y_1(t) = \sin t + \epsilon \sin t - \epsilon t \cos t \tag{13}$$

and the exact solution (9) are displayed in Fig. 4 for $\epsilon = 0.02$. The approximation is not bad for $t < 20$, but then it deteriorates and becomes completely unacceptable. Indeed, it is 90° out of phase by $t = 50$, and it has oscillations that eventually *grow without bound* $(-\epsilon t \cos t)$.

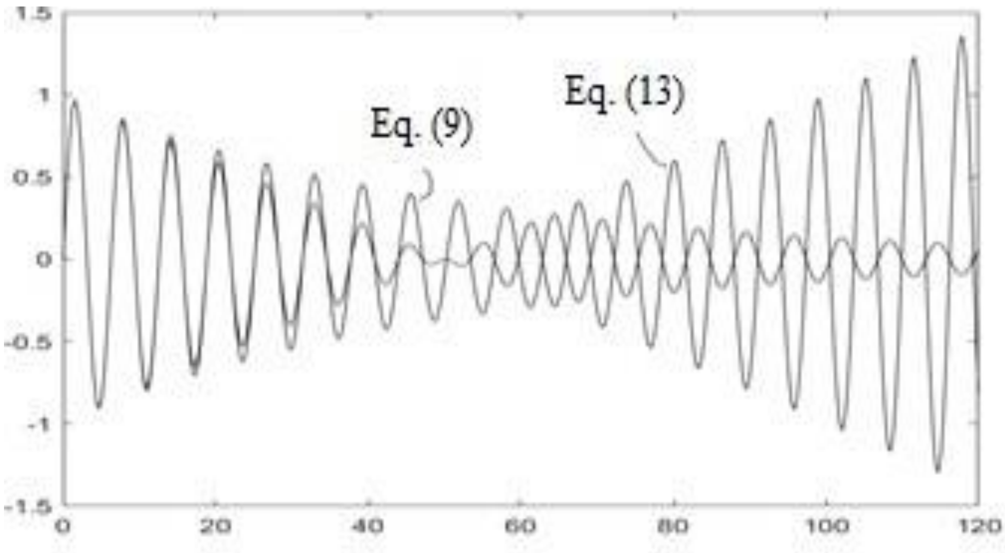


Figure 4. Approximant (13) and exact solution (9)

Theory guarantees that if we included *all* the terms in the higher-order approximants, the growing oscillations would eventually cancel and convergence would occur. Of course that is impractical.

The same phenomenon is observed when we seek a perturbation series for this oscillator (2) with the *non*linear spring (and no damping: $\epsilon_1 = 0, \epsilon$ replaces ϵ_2):

$$\ddot{y} + y + \epsilon y^3 = 0\,. \tag{14}$$

It is easy to verify that the total energy $E = \frac{\dot{y}^2}{2} + \frac{y^2}{2} + \frac{\epsilon y^4}{4}$ is constant, so $|y|$ is definitely bounded. (Salas et al. (2014) report that the exact solution can be expressed in terms of Jacobi elliptic functions.)

The regular perturbation equations are straightforward:

$$\ddot{y}_0 + y_0 = 0\,, \quad \ddot{y}_1 + y_1 = -y_0^3\,, \quad \ldots. \tag{15}$$

For the initial conditions $y(0;\epsilon) = 1, \dot{y}(0;\epsilon) = 0$, we get the zeroth order approximant $y_0 = \cos t$, and

$$\ddot{y}_1 + y_1 = -y_0^3 = -\cos^3 t = -\frac{1}{4}\cos 3t - \frac{3}{4}\cos t, \tag{16}$$

$$y_1 = \frac{1}{32}\cos 3t - \frac{1}{32}\cos t - \frac{3}{8} t \sin t\,, \tag{17}$$

$$y_0(t) + \epsilon y_1(t) = \cos t + \frac{\epsilon}{32}\cos 3t - \frac{\epsilon}{32}\cos t - \frac{3}{8}\epsilon t \sin t\,. \tag{18}$$

Again we see unbounded growth in the final term in (18), in violation of the fact that the total energy is constant. Fig. 5 compares the exact solution to (14) for $\epsilon = 0.1$ with $y_0(t) + \epsilon y_1(t)$ given by (18), and also with the unperturbed solution cos t. We see that formula (18) becomes unreliable for $t > 10$. *Regular perturbation theory spectacularly fails to provide a usable formula for Duffing's spring*.

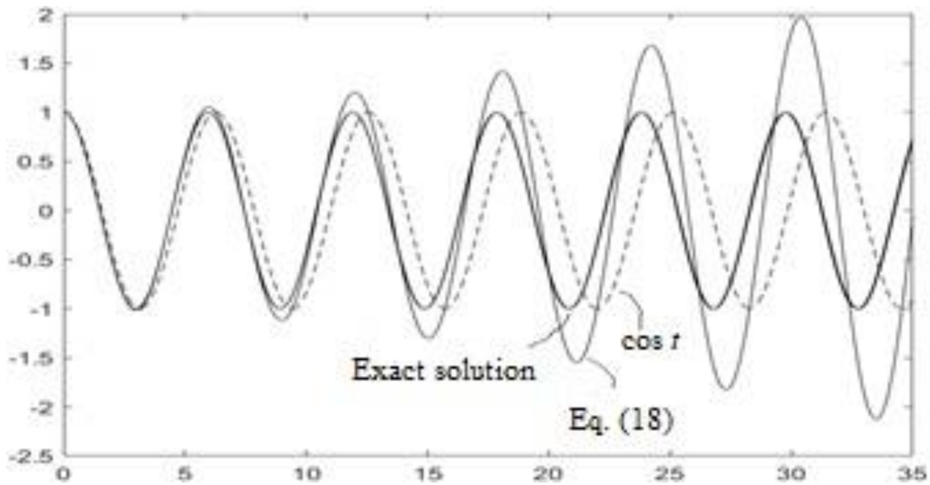


Figure 5. Tabulated ("exact") solution and approximant (18)

The unbounded terms in (13) and (18) are known as *secular* perturbations, and they were spawned by *resonant* terms in the perturbation equations. This is a consequence of an occasionally ignored detail in elementary differential equation theory:

Synopsis of Resonance and Secular Solutions

To summarize (Nagle et al., 2017): when the nonhomogeneity of a linear constant-coefficient differential equation is a superposition of sinusoids and exponentials, a particular solution can be found as a linear combination of these same sinusoids and exponentials, *unless* some of the latter are solutions of the associated *homogeneous* differential equation - in which case one must include powers of t times those terms, in the linear combination. In engineering parlance: when a linear autonomous system is driven by a sinusoid - say, sin Ωt - it can respond synchronously: $y(t) = A \sin \Omega t + B \cos \Omega t$. The *undetermined coefficients* A and B can found be found by direct substitution into the equation. But if the driving frequency Ω is a resonant frequency of the system - that is, if sin Ωt is, itself, a solution of the associated homogeneous equation - the response is not synchronous but rather has "runaway" terms $At^n \sin \Omega t + Bt^n \cos \Omega t$. The unruly terms in the solution are called *secular* and the offending term in the nonhomogeneity that spawns them is called *resonant*.

This is exactly what happened in our examples (12, 16). The associated homogeneous equation for both first order perturbations was $\ddot{y}_1 + y_1 = 0$ with the resonant frequency $\Omega = 1$ (solutions sin t, cos t); and the nonhomogeneities in (12) and (16) contain sinusoids at the same frequency. Thus secular perturbations were inevitable.

Studying perturbation calculations in the 1880s, Lindstedt and Poincare proposed that the "spoiler alerts" - the resonant terms in the perturbation equation nonhomogeneities - were the main villains in the piece, and they devised a methodology to suppress them. Unfortunately the motivation for the Poincare- Linstedt methodology is rather obscure. Expositors have paid lip service to buzzwords like "strained time", "variable frequency", and "expanding time as a power series", but few (none, that your authors are aware of) provide satisfactory clues as to what inspired these mathematicians to formulate the breakthrough that bears their names. In this paper, we describe a relatively new approach to approximation theory - *multiple time scales* - and demonstrate that it enables an intuitive and natural avenue to the Poincare-Linstedt mechanism, as well as providing insights into its performance.

Multiple Time Scales

We have encountered two problems in carrying out perturbation theory using truncations of the Taylor series (in ϵ) (4):

i. the trial solution ("ansatz") is a polynomial, and polynomials cannot track exponentials and sinusoids (in ϵ);

ii. the formalism often spawns resonant terms in the nonhomogeneities of the higher order perturbation equations, and the consequent secular terms in the solutions.

On the other hand, the Taylor series enjoys a very desirable *accuracy* property: if one retains the terms up to order ϵ^n, the residual goes to zero (at least) as fast as ϵ^{n+1} (for fixed t):

$$y(t,\epsilon) \approx y_0(t) + \epsilon y_1(t) \cdots + \epsilon^n y_n(t) + \mathcal{O}(\epsilon^{n+1}). \tag{19}$$

So we seek to design a new ansatz that retains this accuracy property but embraces a broader class than the polynomials - a class that has the flexibility to eliminate resonances. Thus we respect the hierarchy of (4) but allow its coefficients y_n to be functions of t *and* ϵ, somewhat along the lines of

$$y(t,\epsilon) = y_0\big(t, f_0(\epsilon,t)\big) + \epsilon y_1\big(t, f_1(\epsilon,t)\big) + \epsilon^2 y_2\big(t, f_2(\epsilon,t)\big) + \cdots. \tag{20}$$

(After all, this enables an excellent *one-term* approximation of $e^{-\epsilon t}$: namely, $e^{-\epsilon t}$ itself!)

A more specific form for the functions $\{f_k\}$ in (20)'s coefficients is suggested by examining the (known) exact solution for the damped linear ($\epsilon_2 = 0$) oscillator (9). Without the damping, the solutions are of the form $\sin t$. Thus the perturbation alters the *amplitude* through the factor $e^{-\epsilon t}$ and the *phase* through

$$\sin\sqrt{1-\epsilon^2}t \approx \sin(1-\frac{\epsilon^2}{2})t = \sin t\cos\frac{\epsilon^2 t}{2} - \cos t\sin\frac{\epsilon^2 t}{2}. \quad (21)$$

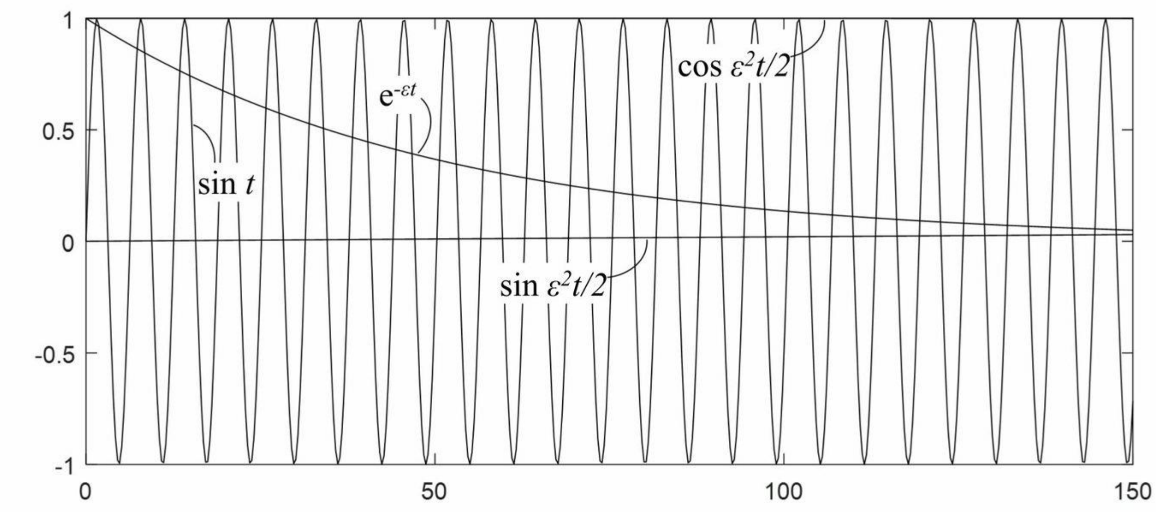


Figure 6. Fast oscillation, slow decay, slower oscillation components of Eq. (9).
The slow oscillators have barely moved.

The component functions $\sin t$, $e^{-\epsilon t}$, $\cos\frac{\epsilon^2 t}{2}$, and $\sin\frac{\epsilon^2 t}{2}$ are displayed in Fig. 6 for $\epsilon = 0.02$. The graphs suggest we regard the solution as evolving on three *time scales*: sin *t* is a fast oscillation, rising from 0 to 1 in a time interval $\Delta t = \frac{\pi}{2} \approx 1.6$; $e^{-\epsilon t}$ is a slow decay, falling from 1 to 0.1 in $\Delta t \approx 115$; and $\cos\epsilon^2 t/2$, $\sin\epsilon^2 t/2$ are slower oscillations, varying between 0 and 1 in $\Delta t = \frac{\pi}{\epsilon^2} \approx 8000$. One could say $e^{-\epsilon t}$ is sensibly constant while sin *t* goes through a period, and $\cos\epsilon^2 t/2$ is sensibly constant while $e^{-\epsilon t}$ decays by 1/*e*.

Clearly it is the *coefficient* of a particular occurrence of t (i.e., $1, \epsilon, \epsilon^2$) which renders it as a "fast" or "slow" actor in the unfolding of the solution. This is manifested if we apply the product rule for the derivative of $\sin t\, e^{-\epsilon t}\cos\frac{\epsilon^2 t}{2}$:

$$= \frac{d\sin t}{dt}\left\{e^{-\epsilon t}\cos\frac{\epsilon^2 t}{2}\right\} + \frac{de^{-\epsilon t}}{dt}\left\{\sin t\ \cos\frac{\epsilon^2 t}{2}\right\} + \frac{d\cos\frac{\epsilon^2 t}{2}}{dt}\{\sin t\, e^{-\epsilon t}\}$$

$$= (+1)\left\{\cos t\, e^{-\epsilon t}\cos\frac{\epsilon^2 t}{2}\right\} - \epsilon\left\{\sin t\, e^{-\epsilon t}\cos\frac{\epsilon^2 t}{2}\right\} - (\frac{\epsilon^2}{2})\left\{\sin t e^{-\epsilon t}\sin\frac{\epsilon^2 t}{2}\right\} \quad (22)$$

The Multiple Time Scale Ansatz

The display (22) hints that we could highlight the time scales in the solution by writing

$$\sin t\, e^{-\epsilon t}\cos\frac{\epsilon^2 t}{2} \equiv \left\{\sin\tau_0\, e^{-\tau_1}\cos\frac{\tau_2}{2}\right\}_{\tau_0=t,\,\tau_1=\epsilon t,\ \tau_2=\epsilon^2 t}, \quad (23)$$

which in turn suggests a specific format for the *multiple time scale ansatz* (20):

$$y(t,\epsilon) \approx y^{(0)}(\tau_0,\tau_1,\tau_2) + \epsilon y^{(1)}(\tau_0,\tau_1,\tau_2) + \epsilon^2 y^{(2)}(\tau_0,\tau_1,\tau_2) + \epsilon^3 y^{(3)}(\tau_0,\tau_1,\tau_2) + \cdots, \tag{24}$$

where $\tau_0 = t, \tau_1 = \epsilon t, \tau_2 = \epsilon^2 t.$

We can operate on this ansatz as if τ_0, τ_1, and τ_2 were *independent variables*, as long as we respect the total differential and the chain rule:

$$\frac{dy}{dt} \approx \left(\frac{\partial\tau_0}{\partial t}\frac{\partial}{\partial\tau_0} + \frac{\partial\tau_1}{\partial t}\frac{\partial}{\partial\tau_1} + \frac{\partial\tau_2}{\partial t}\frac{\partial}{\partial\tau_2}\right)\{y^{(0)}(\tau_0,\tau_1,\tau_2) + \epsilon y^{(1)}(\cdots) + \epsilon^2 y^{(2)}(\cdots) + \epsilon^3 y^{(3)}(\cdots)\}, \tag{25}$$

$$\frac{d^2y}{dt^2} \approx \left(\frac{\partial}{\partial\tau_0} + \epsilon\frac{\partial}{\partial\tau_1} + \epsilon^2\frac{\partial}{\partial\tau_2}\right)\left(\frac{\partial}{\partial\tau_0} + \epsilon\frac{\partial}{\partial\tau_1} + \epsilon^2\frac{\partial}{\partial\tau_2}\right)\{y^{(0)} + \epsilon y^{(1)} + \epsilon^2 y^{(2)} + \epsilon^3 y^{(3)}\}, \tag{26}$$

and substitute (24) at the end.

Employing subscripts to denote differentiation we insert (24, 25, 26) into the linear oscillator equation (8) and collect powers:

$$\boldsymbol{\epsilon^0}: \quad y^{(0)}_{\tau_0\tau_0}(\tau_0,\tau_1,\tau_2) + y^{(0)}(\cdots) = 0\,; \tag{27}$$

$$\boldsymbol{\epsilon^1}: \quad y^{(1)}_{\tau_0\tau_0} + y^{(1)} = -2y^{(0)}_{\tau_0\tau_1} - 2y^{(0)}_{\tau_0}\,; \tag{28}$$

$$\boldsymbol{\epsilon^2}: \quad y^{(2)}_{\tau_0\tau_0} + y^{(2)} = -2y^{(0)}_{\tau_0\tau_2} - 2y^{(0)}_{\tau_1} - y^{(0)}_{\tau_1\tau_1} - 2y^{(1)}_{\tau_0\tau_1} - 2y^{(1)}_{\tau_0} \text{ etc.} \tag{29}$$

The initial conditions for equation (8) are imposed powerwise also:

$$y(0,\epsilon) = 0 \approx y^{(0)}(0,0,0) + \epsilon y^{(1)}(0\cdots) + \ \epsilon^2 y^{(2)}(0\cdots)$$

$$\Rightarrow y^{(0)}(0,0,0) = y^{(1)}(0,0,0) = y^{(2)}(0\cdots) = 0\,, \tag{30}$$

$$\dot{y}(0,\epsilon) = 1 \approx \left(\frac{\partial}{\partial\tau_0} + \epsilon\frac{\partial}{\partial\tau_1} + \epsilon^2\frac{\partial}{\partial\tau_2}\right)\{y^{(0)}(0\cdots) + \epsilon y^{(1)}(0\cdots) + \epsilon^2 y^{(2)}(0\cdots)\}$$

$$= y^{(0)}_{\tau_0}\big|_{0\cdots} + \epsilon[y^{(1)}_{\tau_0} + y^{(0)}_{\tau_1}]_{0\cdots} + \epsilon^2[y^{(0)}_{\tau_2} + y^{(1)}_{\tau_1} + y^{(2)}_{\tau_0}]_{0\cdots}$$

$$\Rightarrow y^{(0)}_{\tau_0}\big|_{0\cdots} = 1,\ \ [y^{(1)}_{\tau_0} + y^{(0)}_{\tau_1}]_{0\cdots} = [y^{(0)}_{\tau_2} + y^{(1)}_{\tau_1} + y^{(2)}_{\tau_0}]_{0\cdots} = 0. \tag{31}$$

Solution of the Zeroth Order Perturbation Equation

Although (27) is a partial differential equation in τ_0, τ_1, and τ_2, because the latter two are held constant in the formula it becomes an ordinary differential equation in τ_0 with independent solutions $\cos\tau_0, \sin\tau_0$. However the undetermined coefficients in its general solution could be functions of τ_1 and τ_2:

$$y^{(0)}(\cdots) = A(\tau_1,\tau_2)\cos\tau_0 + B(\tau_1,\tau_2)\sin\tau_0. \tag{32}$$

Solution of the First Order Perturbation Equation

Again, the left hand side of (28) can be regarded as an *ordinary* differential operator in τ_0. The dependence of the right hand side on τ_0 has been determined by (32), and with a little rearranging we can express (28) as

$$y^{(1)}_{\tau_0\tau_0} + y^{(1)} = 2(A_{\tau_1} + A)\sin\tau_0 - 2(B_{\tau_1} + B)\cos\tau_0\,. \tag{33}$$

Now the solutions to the associated homogeneous form of (33) are, again, $\cos\tau_0$ and $\sin\tau_0$. Thus both terms on the right in (33) are resonant and will produce secular perturbations. But now we have the flexibility to suppress resonance; we simply choose the functions $A(\tau_1,\tau_2)$, $B(\tau_1,\tau_2)$ to satisfy the *ordinary* differential equations

$A_{\tau_1}(\tau_1,\tau_2) + A(\tau_1,\tau_2) = 0,\ \ B_{\tau_1} + B = 0$, or

$$A(\tau_1,\tau_2) = C(\tau_2)e^{-\tau_1}\ ,\ B(\tau_1,\tau_2) = D(\tau_2)e^{-\tau_1}. \tag{34}$$

$$\Rightarrow y^{(0)}(\cdots) = C(\tau_2)e^{-\tau_1}\cos\tau_0 + D(\tau_2)e^{-\tau_1}\sin\tau_0. \tag{35}$$

This is outstanding! We have obtained the fast-time (τ_0) and slow-time (τ_1) components of the exact solution

(9) and as of yet we haven't even solved the first-order perturbation equation (28) - which, by the way, has been reduced to $y^{(1)}_{\tau_0\tau_0} + y^{(1)} = 0$, identical with (27). Thus

$$y^{(1)}(\cdots) = E(\tau_1,\tau_2)\cos\tau_0 + F(\tau_1,\tau_2)\sin\tau_0\ . \tag{36}$$

(While we are patting ourselves on the back it would be a good time to point out that the reduction of *partial* to *ordinary* differential equations in (27, 33) conforms to our observation: $e^{-\tau_1}$ is sensibly constant while sin τ_0 goes through a period (27), as is $\cos\tau_2/2$ while $e^{-\tau_1}$ decays (34).)

Solution of the Second Order Perturbation Equation

Substitution of $y^{(0)}$ and $y^{(1)}$ (32, 36) into (29) and judicious rearrangement results in

$$y^{(2)}_{\tau_0\tau_0} + y^{(2)} = \{2(E_{\tau_1} + E) + (2C_{\tau_2} + D)\ e^{-\tau_1}\}\sin\tau_0 - \{2(F_{\tau_1} + F) + (2D_{\tau_2} - C)\ e^{-\tau_1}\}\cos\tau_0\ . \tag{37}$$

As before, we observe that both terms on the right are resonant, but they can be eliminated by the choices

$$C(\tau_2) = I\cos\frac{\tau_2}{2} + J\sin\frac{\tau_2}{2}\ ,\ D(\tau_2) = -J\cos\frac{\tau_2}{2} + I\sin\frac{\tau_2}{2}\ ,$$

$$E(\tau_1,\tau_2) = G(\tau_2)e^{-\tau_1},\quad F(\tau_1,\tau_2) = H(\tau_2)e^{-\tau_1}. \tag{38}$$

Multiscale theory has revealed the component functions for third time scale τ_2 (compare (22)).

The Zeroth Order Approximation

Assembling (35, 38) produces

$$y^{(0)}(\cdots) = \left(I\cos\frac{\tau_2}{2} + J\sin\frac{\tau_2}{2}\right)e^{-\tau_1}\cos\tau_0 + \left(-J\cos\frac{\tau_2}{2} + I\sin\frac{\tau_2}{2}\right)e^{-\tau_1}\sin\tau_0\ , \tag{39}$$

and enforcement of initial conditions (30, 31) in (39) implies $I = 0,\ J = -1$; so the zeroth order approximation is

$$y^{(0)}(\cdots) = -\sin\frac{\tau_2}{2}e^{-\tau_1}\cos\ \tau_0 + \cos\frac{\tau_2}{2}e^{-\tau_1}\sin\tau_0 = e^{-\tau_1}\sin(\ \tau_0 - \frac{\tau_2}{2}) \equiv e^{-\epsilon t}\sin(t - \frac{\epsilon^2 t}{2})\ . \tag{40}$$

$y^{(0)}$ is a near replica of the exact solution (9) (recall (21)), and it far surpasses the corresponding approximation (13) generated by regular perturbation theory. Indeed, on the time scale of Fig. 4, the graphs of (9) and (40) are indistinguishable. Fig. 7 exhibits a slight disagreement between the two around t = 1000, but by that time the amplitude (renormalized in Fig. 7) has decayed to about 10^{-9}.

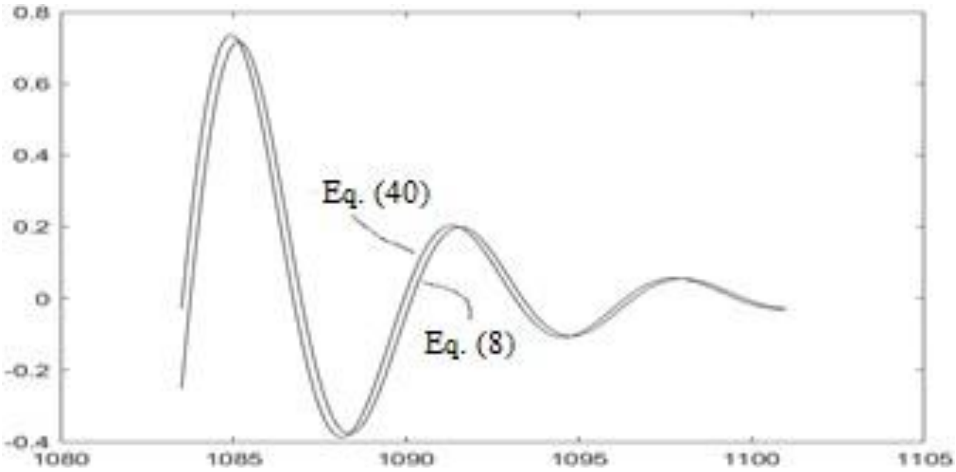


Figure 7. Exact (9) and zeroth-order (40) formulas (renormalized by 10^{-9})

Higher Order Approximations

Note that to obtain the explicit zeroth order approximant (40) we had to solve the second order perturbation equation (29). Thus we would expect that the first order approximant requires solving the third order perturbation equation, and so on. The calculations follow a familiar pattern, so we spare our readers the tedious details and simply cite the highlights of the computation. Judicious assembly of the terms in the equation for $y^{(3)}$ produces a close clone of (37):

$$y^{(3)}_{\tau_0\tau_0} + y^{(3)} = \{2(K_{\tau_1} + K) + (2G_{\tau_2} + H)\, e^{-\tau_1}\}\sin\tau_0 - \{2(L_{\tau_1} + L) + (2H_{\tau_2} - G)\, e^{-\tau_1}\}\cos\tau_0 \, . \qquad (41)$$

We suppress resonance with the choices

$$G(\tau_2) = P\cos\tfrac{\tau_2}{2} + Q\sin\tfrac{\tau_2}{2}\,, H(\tau_2) = -Q\cos\tfrac{\tau_2}{2} + P\sin\tfrac{\tau_2}{2}\,,$$

$$K(\tau_1,\tau_2) = M(\tau_2)e^{-\tau_1}, L(\tau_1,\tau_2) = N(\tau_2)e^{-\tau_1}\,,$$

yielding $$y^{(1)}(\tau_0,\tau_1,\tau_2) = \left(P\cos\tfrac{\tau_2}{2} + Q\sin\tfrac{\tau_2}{2}\right)e^{-\tau_1}\cos\tau_0 + (-Q\cos\tfrac{\tau_2}{2} + P\sin\tfrac{\tau_2}{2})e^{-\tau_1}\sin\tau_0. \qquad (42)$$

The initial conditions $y(0) = 0,\ \dot{y}(0) = 1$ (30, 31) imply $y^{(1)}$ is identically zero (!). This reflects the excellent agreement between the zeroth order (40) and the exact (9) solutions. (For comparison, Salih (2014) reports that the first-order approximant with the "complimentary" initial conditions $y(0) = 1,\ \dot{y}(0) = 0$ retains $y^{(1)}$:

$$y^{(0)} + \epsilon y^{(1)} = e^{-\tau_1}\cos(\tau_0 - \tfrac{\tau_2}{2}) + \epsilon e^{-\tau_1}\sin(\tau_0 - \tfrac{\tau_2}{2})\ .) \qquad (43)$$

The explicit second-order approximant satisfying (30, 31) is

$$y^{(0)} + \epsilon y^{(1)} + \epsilon^2 y^{(2)} = e^{-\tau_1}\sin(\tau_0 - \tfrac{\tau_2}{2}) + \epsilon^2\left[\tfrac{1}{2}e^{-\tau_1}\sin(\tau_0 - \tfrac{\tau_2}{2}) - \tfrac{\tau_2}{8}e^{-\tau_1}\cos(\tau_0 - \tfrac{\tau_2}{2})\right]. \qquad (44)$$

On the scale of Fig. 7, Eqs. (9) and (44) are indistinguishable.

The Duffing Nonlinear Spring

We return to eq. (14), the Duffing spring with no damping. For simplicity we employ only two time scales:

$$y(t,\epsilon) \approx y^{(0)}(\tau_0,\tau_1) + \epsilon y^{(1)}(\tau_0,\tau_1). \tag{45}$$

The hierachy of perturbation equations (analogous to (27-29)) becomes

$$\epsilon^0: y^{(0)}_{\tau_0\tau_0}(\tau_0,\tau_1) + y^{(0)}(\cdots) = 0\,; \tag{46}$$

$$\epsilon^1: y^{(1)}_{\tau_0\tau_0} + y^{(1)} = -2y^{(0)}_{\tau_0\tau_1} - [y^{(0)}]^3\,; \tag{47}$$

$$\epsilon^2: y^{(2)}_{\tau_0\tau_0} + y^{(2)} = -y^{(0)}_{\tau_1\tau_1} + 3y^{(1)}[y^{(0)}]^2 - 2y^{(1)}_{\tau_0\tau_1}\,. \tag{48}$$

Again, (46) is identical to (27) with solution (32), which (with hindsight) we write in the amplitude/phase form

$$y_0(\tau_0,\tau_1) = C(\tau_1)\cos[\tau_0 + \gamma(\tau_1)]\,. \tag{49}$$

Inserting into (47) produces

$$y^{(1)}_{\tau_0\tau_0} + y^{(1)} = 2C_{\tau_1}\sin[\tau_0+\gamma(\tau_1)] + 2C\gamma_{\tau_1}\cos[\tau_0+\gamma(\tau_1)] - \frac{3C^3}{4}\cos[\tau_0+\gamma(\tau_1)] + \frac{C^3}{4}\cos[3\tau_0 + 3\gamma(\tau_1)],$$

whose first three terms are resonant. Thus we require

$$2C_{\tau_1} = 0 \text{ and } 2C\gamma_{\tau_1} = \frac{3C^3}{4}, \tag{50}$$

with solutions $C = K$ and $\gamma = \frac{3K^2}{8}\tau_1 + \varphi$ (constant K,φ). (51)

For the initial conditions $y(0) = 1, \dot{y}(0) = 0$,

$$y_0(\tau_0,\tau_1) = K\cos[\tau_0 + \frac{3K^2}{8}\tau_1 + \varphi] = \cos\left[1 + \frac{3\epsilon K^2}{8}\right]t\,. \tag{52}$$

On the scale of Fig. 5 the multiscale approximant (52) is indistinguishable from the exact solution.

Conclusion

Where are the theorems? They are scarce, because multiscale methodology is somewhat vague. The basic ansatz (24) is ambiguous: a term $\epsilon^2 t$ can be considered as $[\epsilon^2 t]$ or $\epsilon[\epsilon t]$ or $\epsilon^2[t]$ (zeroth, first, or second order). Specialists (Kahn & Zarmi, n.d.) have reported examples where the series fails to converge as $n \to \infty$; where incorporating more perturbation terms deteriorates, rather than improves, the approximant; and where term-by-term differentiation fails. One cannot expect to be able to eliminate the secular terms at *all* orders. Indeed, there are "solvability conditions" which can hinder the elimination of a secular term of *any* order. The reader may have observed that $\epsilon^2 y^{(2)}$ in the second order approximant to the damped oscillator (44) contains a secular term, and eventually (44) will deviate noticeably from (9). (This resonance *can* be suppressed (at considerable labor) by including yet another time scale (τ_3)). But as a rule, after secular terms have been eliminated to a certain order, one should not be surprised to see them in the next order.

So multiscale perturbation methodology may almost qualify as an art as well as a science. However when it works it is invaluable, providing solution approximants in closed form. And it provides welcome insight into workings behind the astonishing, if fickle, success of the Linstedt-Poincare procedure.

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Tychonov's Solution: An Overlooked Opportunity to Blend Pure Mathematics into Mechanical Engineering Education

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Abstract: Tychonov's 1935 solution of the heat equation, exhibiting nontrivial heat fluxes spontaneously appearing along an isolated conducting rod initially held at zero degrees, has intrigued some specialists for almost a century. No doubt those practicing heat engineers who took mathematics seriously were initially relieved to learn that the construction was valid only for infinitely long rods; the integrity of their published exchanger designs could be defended by citing this weakness, together with the known discrepancies between the heat equation and physical reality. Some mathematicians contrived additional hypotheses to disqualify the Tychonov solution. Recently a computer simulation was executed, revealing just how astonishingly unbridled the solution is. But there remain incongruities in this singular example that invite metaphysical speculation. We fuel the latter with a recap of the history from a lighthearted perspective, providing heat transfer engineering students with a rare insight into the practical value of the mathematicians' exacting obsession with generality.

Keywords: Heat transfer, Nonuniqueness, Singular boundary conditions, Engineering mathematics

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Introduction and Background

In this paper we shall attempt to summarize some of the mathematical investigations spawned by Tychonov's discovery (Tychonoff, 1935) of a counterintuitive solution of the heat equation, share some recent insights, and reexamine the significance of the studies from the perspective of the student of heat transfer engineering. By so doing we hope to dispel the skepticism that such students acquire regarding the practical value of the mathematicians' exacting obsession with rigor and generality.

Synopsis of Heat Flow Physics

The heat equation (customarily attributed to Fourier (1822) governs the evolution of temperature T as a function of time t and position (x, y, z) in a conductor with uniform diffusivity (set equal to 1 by choice of units). The flow can be one-dimensional $T(t,x)$ if the conductor is a laterally insulated rod $x_1 < x < x_2$ with uniform cross section. The typical initial-boundary value problem encountered by engineers is expressed

$$\frac{\partial T}{\partial t} - \frac{\partial^2 T}{\partial x^2} = 0\,,\ x_1 < x < x_2,\ t > 0\,; \tag{1}$$

$$\mathrm{T}(0,\mathrm{x}) = \mathrm{T}_0(\mathrm{x}) \ \text{(initial condition)}\,; \tag{2}$$

$$\alpha_1 T(t,x_1) + \beta_1 \frac{\partial T(t,x_1)}{\partial x} = A_1\,; \qquad \alpha_2 T(t,x_2) + \beta_2 \frac{\partial T(t,x_2)}{\partial x} = A_2 \quad \text{(boundary conditions)}. \tag{3}$$

A and *B* are arbitrary *known* functions of *x* and *t*. If $\beta = 0$ the "Dirichlet condition" is specifying the temperature at the end of the rod; if $\alpha = 0$ the "Neumann condition" is specifying the heat flux; and if neither is zero the "Robin condition" is modeling leaky insulation. Technical issues, such as the precise nature of the continuity at *t* = 0 and the end points, do not concern us here.

(Since $\mathrm{e}^{-\pi^2 t}\cos \pi x, x_1 = -x_2 = -1/2$ is a solution, a unit rod possessing this diffusivity with its ends packed in ice and an initial half-sine-wave temperature profile would cool by a factor e^{-1} in $\pi^{-2} \sim 0.1$ time units.)

For rods of finite length (and reasonable initial values $T_0(x)$) the equations have one and only one solution. In fact the system is so well-behaved that it is often proffered as the inaugural example in textbooks studying partial differential equations. Indeed, this solution can be explicitly displayed as a Fourier series: for $x_1 = -L$, $x_2 = L$, and homogeneous Dirichlet boundary conditions ($\beta_1 = \beta_2 = A_1 = A_2 = 0$), we have (Nagel et al, 2018)

$$T(t,x) = \sum_{n=1}^{\infty} e^{-(\frac{n\pi}{2L})^2 t} \sin\frac{n\pi(x+L)}{2L} \int_{-L}^{L} T_0(\xi) \sin\frac{n\pi(\xi+L)}{2L} d\xi / L\,. \tag{4}$$

The convergence of the sum is at least as strong as that of the Fourier series representation of $T_0(x)$.

Uniqueness

For our purposes the crucial point of these deliberations is that the solution is *unique*. Now uniqueness of the solution has a special significance to engineers that may not occur to mathematicians. It implies that *they have got the physics right*; once they have measured the initial temperature T_0 and the two end temperatures or fluxes A_1 and A_2, the behavior is completely determined. There are no more "clean-up" or "fine-tuning" measurements that need to be made. Hadamard (1902) expressed three conditions for well-posedness of a system - existence, uniqueness, and continuous dependence on data. Of these, *uniqueness* is the most relevant to engineers. They need to predict the performance of a heat pipe precisely, without any extraneous possibilities lurking about.

A well-known property that is logically equivalent to uniqueness when all the governing equations are *linear* (as for (1-3)) is the following: the *only* solution of the associated *homogeneous* system

$$\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x^2}\,; T(0,x) = 0\,;$$

$$\alpha_1 T(t,x_1) + \beta_1 \frac{\partial T(t,x_1)}{\partial x} = \alpha_2 T(t,x_2) + \beta_2 \frac{\partial T(t,x_2)}{\partial x} = 0 \tag{5}$$

is $T(t,x) \equiv 0$. After all, if $T_1(t,x)$ and $T_2(t,x)$ were different solutions to (1-3), then $T_1(t,x) - T_2(t,x)$ would be a non-identically-zero solution to (5). This restatement of uniqueness is usually easier to apply.

The Infinite Rod and Poisson's Formula

If we let the (half-)length L go to infinity, the solution expression (4) approaches the *Poisson formula* (Poisson, 1835),

$$T(t,x) = (4\pi t)^{-1/2} \int_{-\infty}^{\infty} T_0(\xi) e^{-(\xi-x)^2/4t}\, d\xi \quad . \tag{6}$$

(The derivation is quite similar to the familiar extrapolation of the Fourier series to the Fourier transform.) So formula (6) gives a solution to the infinite-rod problem

$$\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x^2} : \ -\infty < x < \infty, t > 0 \ ; \quad T(0,x) = T_0(x) \ \text{(initial condition)}. \tag{7}$$

But as we shall see, Tychonov constructed another, non-identically-zero, solution to the homogeneous version of (7),

$$\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x^2} : \ -\infty < x < \infty, \ t > 0 \ ; \quad T(0,x) = 0. \tag{8}$$

This would predict that a rod, initially at 0 degrees and isolated from any external heat sources, can spontaneously attain nonzero temperatures – if Fourier's heat equation is valid! Even worse, it casts a shadow on all engineering designs premised on the Fourier equation (homogeneous or nonhomogeneous) since, as we indicated, it implies that solutions to eq. (7) are not unique(!)

Lest heat-exchanger consultants panic at the thought of having to refund their commissions, they can take some solace in the fact that these anomalies only apply to infinite rods. No one will ever build an infinitely long heat exchanger (Fig. 1). (*We shall see that this statement is not as inane as it sounds*.) And finite rods are described by systems (1) having unique solutions.

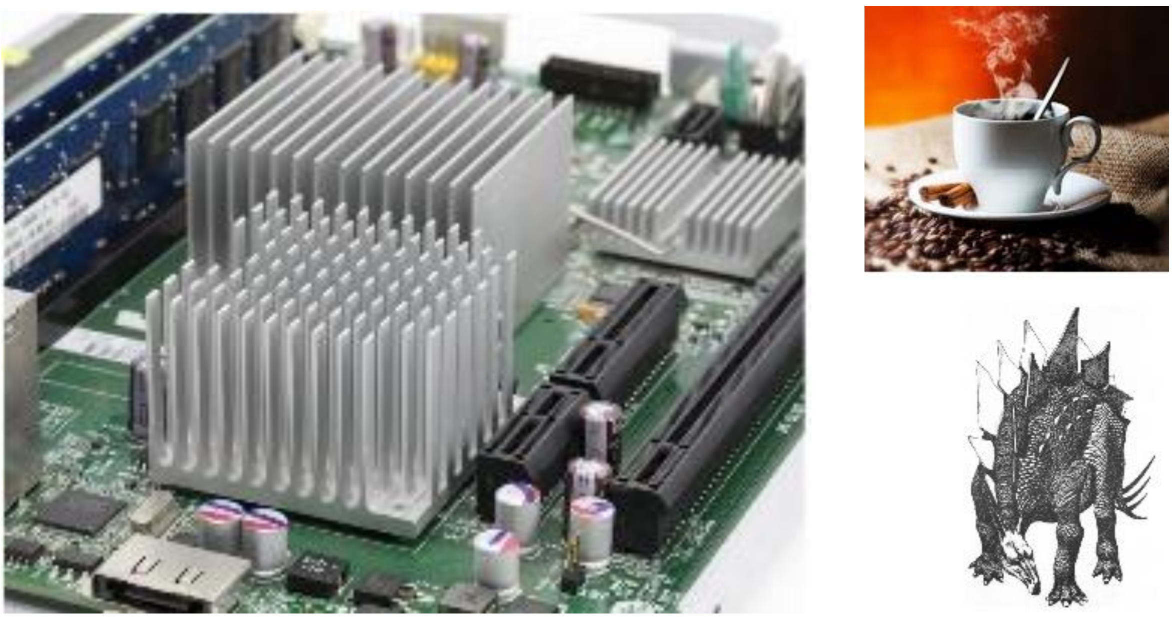


Figure 1. Heat Exchangers. (a) Electronic heat sink
(b) Metal spoon in a cup of coffee (c) Platelets on a stegosaurus.

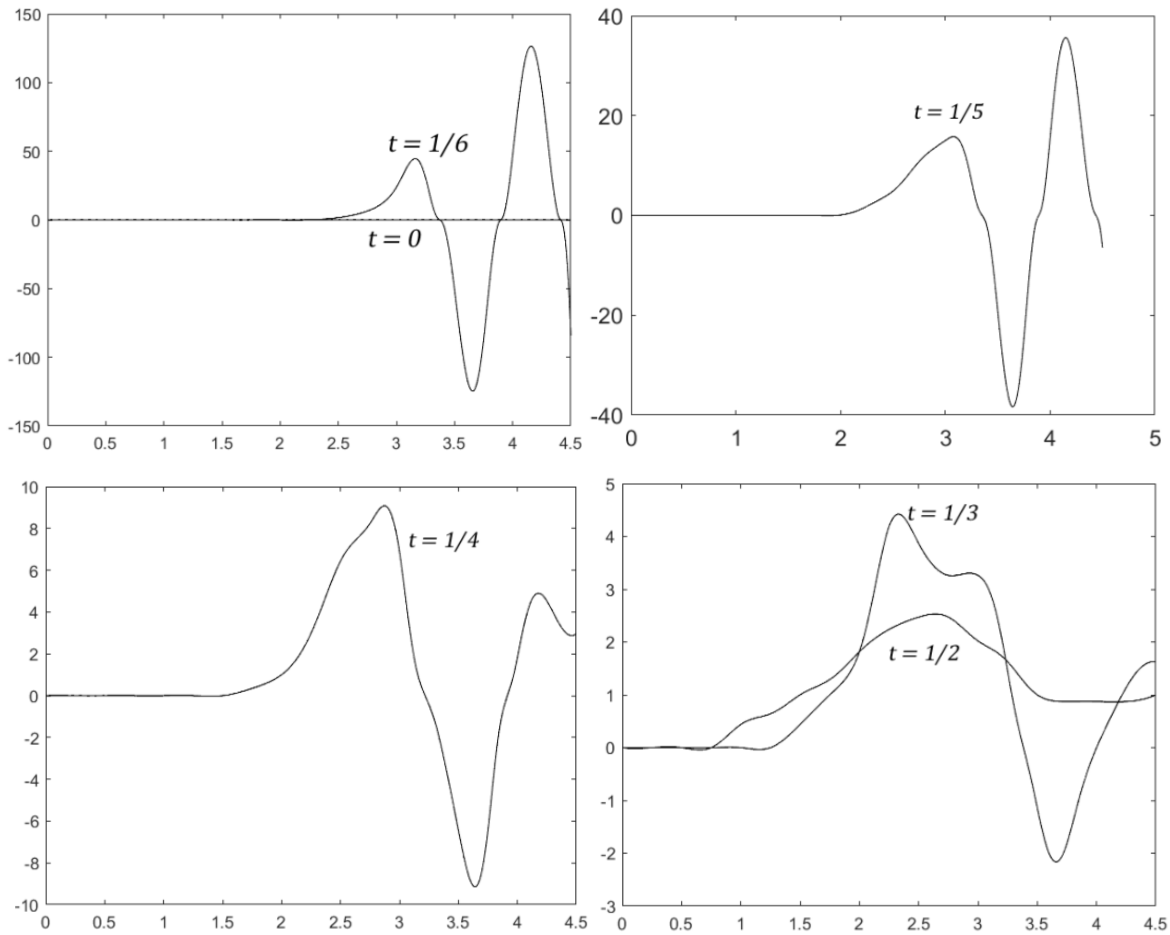
Admittedly, Poisson's formula (4) does find its way into respectable analyses, when it is invoked as a convenient approximation to these finite-length, unique, solutions. The logic is secure. But nothing in the statement of (7) dictates that its $T(t,x)$ has to be the limit of finite-rod solutions. (Forgive me, I can't resist: *Poisson's formula does not have to take the heat for Tychonov's epiphany*.)

Tychonov's Solution

Tychonov constructed his example as the sum of a series:

$$T_{Tychonov}(t,x) = \sum_{k=0}^{\infty} \frac{g^{(k)}(t)}{(2k!)} x^{2k} \quad \text{where} \quad g(t) = \begin{cases} e^{-t^{-\alpha}}, & t \geq 0 \\ 0, & t < 0 \end{cases} \quad (\alpha > 1). \tag{9}$$

He proved that the series converged and that $T_{Tychonov}$ was smooth – infinitely often termwise differentiable for *all t* and *x*, in fact. But although $T_{Tychonov}(x,t)$ is identically zero initially, it immediately fluctuates - quite violently, in fact. Rodland (2017) has meticulously computed some snapshots of the profiles (and we have brutally compressed them for display in Fig. 2, where the abscissa is length and the ordinate is temperature); note the different temperature scales on the graphs.



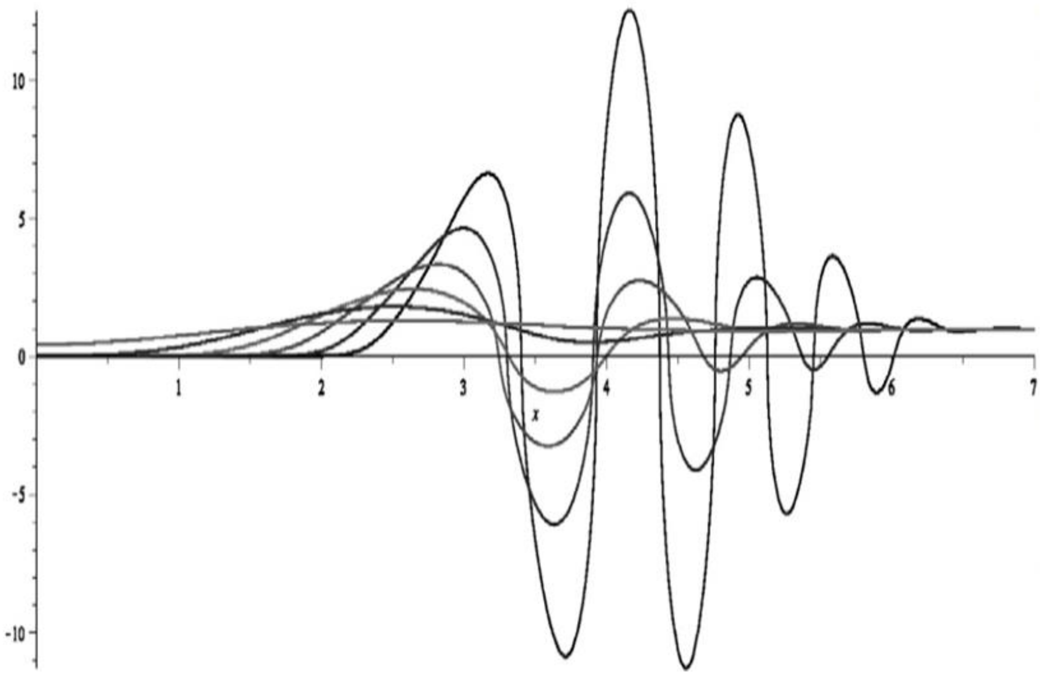


Figure 2. Sample snapshots of the Tychonov solution

Boundary Conditions at Infinity

The contradictory nature of the finite and infinite rod problems compel us to scrutinize the destiny of the boundary conditions as L approaches ∞. Physics is of no help. After all, what is the significance of the flux out of the end of an endless rod?

An intriguing observation emerges if we examine the evolution of the finite-rod solutions to the *Neumann* (insulated tip) and *Robin* (leaky tip) problems as the length increases. They both approach the same limit as the Dirichlet (fixed temperature) solution - i.e. the Poisson formula (6)! The *infinite-rod approximation* to the solutions of the finite-rod Dirichlet, Neumann, and Robin problems is immune to the choice of the boundary condition. But if we simply drop the boundary condition altogether as in (7), the Tychonov solution rears its ugly head and we forfeit uniqueness. The boundary condition at infinity is certainly an enigma.

Contrived Boundary Conditions

There are other mathematical conditions which, if imposed, would restore the uniqueness property (Doetsch, 1936; Täcklind, 1936). Tychonov himself proved, in his 1935 paper, that if we insisted that for some positive M and m

$$|T(t,x)| \leq M \exp(m|x|^2), \tag{10}$$

then the solutions to (7,8) would be unique. Chung and Kim (1994, 1999) have shown that if condition (10) is weakened to either

$$|T(t,x)| \leq M\exp(\frac{m}{t} + m|x|^2) \quad (11)$$

or

$$|T(t,x)| \leq M\exp\left(\left(\frac{m}{t}\right)^{\mu} + m|x|^2\right), \quad 0 < \mu < 1\,, \quad (12)$$

then, too, (7,8) would possess unique solutions.

Sketches of (10, 11) are displayed in Fig. 3 for $M = m = 1$ (so they can be amplified to any degree). Also note the log scales. The Chung-Kim restrictions (11, 12) effectively append a vertical asymptote to the time-independent Tychonov "umbrella" (10) as $t \downarrow 0$.

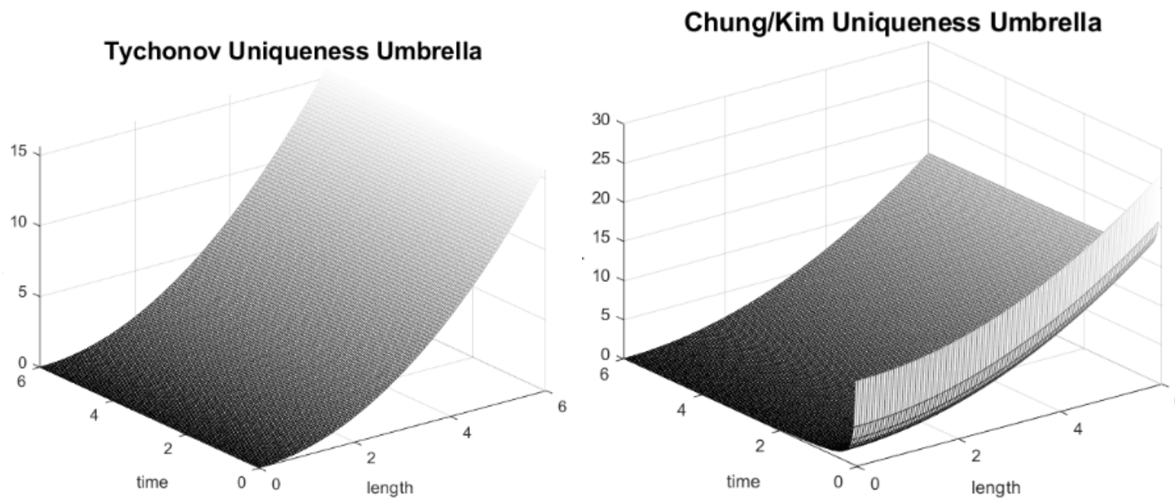


Figure 3. Tychonov and Chung/Kim Uniqueness Umbrellas

An alternate way of phrasing these infinite-rod uniqueness theorems is:

> If there *is* a non-identically-zero solution to (8), then for any positive M and m and any μ in (0,1) the magnitude of this solution will exceed $M\exp(\left(\frac{m}{t}\right)^{\mu} + m|x|^2)$ somewhere, at some time (x,t).

But none of these repairs (10-12) impress the practicing engineer, because they are academic; they can not be tested *a priori*. They would have to be checked all along the rod, for all times. No retrofitting can be applied to the rod to ensure their compliance.

A completely different constraint ensuring uniqueness was announced by Widder (1944).

> If we impose the additional constraint on (8) that its solutions must be nonnegative, then the only solution is identically zero. Alternatively, any non-identically-zero solution to (8) must be negative somewhere, sometime.

This may resonate with practitioners because of the physical interpretation of temperature as mean kinetic energy; absolute 0 degrees Kelvin is the lowest *possible* temperature, and no thermal governors have to be jury-rigged to ensure it is not undercut. Thus Widder proved that the solution to the infinite heat rod is unique among all *physically possible* solutions (i.e. those consistent with kinetic theory). However this is not totally satisfactory; after all, we did not have to restrict ourselves to "physically possible solutions" to establish uniqueness for finite length rods. And how did kinetic theory find its way into the heat equation?

Boundary Conditions for the Wave Equation

It is enlightening to compare this behavior with that of the wave equation system for, say, electromagnetic voltage *V*, whose one-dimensional homogeneous form reads

$$\frac{\partial^2 V}{\partial t^2} = \frac{1}{c^2}\frac{\partial^2 V}{\partial x^2}\ ,\ V(0,x) = \frac{\partial}{\partial t}V(0,x) = 0\ . \tag{13}$$

The general solution of the differential equation is the superposition of a waveform propagating to the left plus one propagating to the right, at speed *c* (*D'Alembert*, 1747):

$$V(t,x) = f(x+ct) + g(x-ct)\,. \tag{14}$$

This implies that the solution of the homogeneous system at every point *x* will remain zero until the nearest *non*zero initial disturbance reaches it, traveling at speed *c*; but there *is* no initial disturbance for (13), anywhere. So the homogeneous solution is identically zero; and as we have seen, that means the solution to the (nonhomogeneous) wave equation system is unique. (!)

Conclusions and Speculation

Why does the infinite homogeneous heat equation system have nonidentically zero solutions, but the homogeneous wave equation does not? Two fanciful observations have evolved to help us live with this dichotomy:

(*i*) Since voltage disturbances can propagate no faster than *c*, there is no electromagnetic disturbance *within range* of a point *x* to "rattle" it at any finite time. However, it can be argued (from Poisson’s formula) that an isolated *thermal* disturbance produces a nonzero effect everywhere, instantaneously - if the Fourier heat equation is to be taken as gospel. (Of course this reveals that the heat equation is nonrelativistic.) (A popular quip notes that if both the heat and wave equations were accurate, then when we strike a match we would feel the heat before we see the light.) So we can imagine Tychonov's thermal storm sitting out there at infinity, waiting for the right moment *t*=0, and *instantly* rushing in.

(*ii*) As noted, no one will ever build an infinitely long heat rod. Big Bang theorists assure us that the number of fundamental particles in the universe is limited, so we'll run out of material before we get to infinity. Equation

(7) is only valid as an approximation for long, finite, rods. So cosmology has insulated us from the Tychonov storms at infinity. Now this is not as inane as it sounds; we radiate *electromagnetic* waves to infinity every time we turn on our car radios, and we don't need to build conductors to escort them. We have no cosmological savior to protect us from electromagnetic storms at infinity; the uniqueness theorem is our salvation. (Antenna specialists note: Sommerfeld's radiation condition, which banishes incoming waves located at finite distances, is not connected to the uniqueness theorem.)

In a slightly more serious vein: the electromagnetic wave equation is a rigorous mathematical consequence of the electrodynamic laws of Coulomb, Ampere, Gauss, Faraday, and Maxwell. But a detailed derivation of the heat equation is less "clean", invoking assumptions about statistical ensembles over atomic particles (Williams, 1985). It is conceivable that the germ of an absolute zero temperature is implicit in these deliberations - rendering Widder's condition as the most appropriate to censure the Tychonov solution.

At any rate, an exposition of the startling nature of Tychonov's discovery and its perceived significance - ranging from serious/academic to speculative/frivolous - should go far in resolving the most hardened engineering student's contempt for the mathematician's obsession with rigor.

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Zooming into the Stem Pipeline: Post-Secondary Participation and Attrition in Mathematics

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Abstract: This paper presents results from research that investigated the participation and attrition rate of male and female candidates in two post-secondary mathematics courses (Pure Mathematics and Applied Mathematics). The data for this study consisted of the course results over five years from 2013–2017 for 15,220 candidates (N = 19,585) from 71 post-secondary educational institutions in Jamaica. They were analysed using frequencies (totals and percentages) and descriptive statistics. The data analysis revealed that, on average, over the five years and across each of the five years, approximately 18% of the students who engaged in post-secondary education opted to participate in a mathematics course. However, there was a sharp decrease in the Year 2 student participation after completing the related Year 1 course. Another key finding was that a higher percentage of males chose to undertake Applied Mathematics in Year 2 and equal proportions of male and female candidates in the other three courses. These findings suggest that initiatives are needed which improve student achievement and experience in the first year of each mathematics course which could potentially decrease student attrition across years and curb the leakage at this juncture of the STEM pipeline.

Keywords: Post-secondary, Mathematics, Participation, Attrition, Gender

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Introduction

In today's rapidly evolving world, there is an ever-increasing demand for graduates with skills and qualifications in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Murcia et al., 2020). These fields are critical in driving innovation, economic growth and addressing complex global challenges (Waite & McDonald, 2019). However, despite the growing demand, the number of individuals with STEM qualifications is still well below what is needed (Falco, 2017).

The STEM pipeline is a metaphor that was developed to depict the academic and career pathways individuals follow in STEM fields. It encompasses various educational levels starting from early childhood to primary, secondary, and post-secondary levels, then higher education and into STEM careers. One characteristic of this pipeline that has gained prominence over the past two decades is its porousness. Across successive educational levels, there appears to be a notable decrease in the number of individuals, especially women, enrolled in STEM courses (Clark Blickenstaff, 2005). One way to tackle this problem could involve boosting the number of students who complete STEM courses at different junctures along the STEM pipeline, especially where participation in these courses is optional (DeCoito, 2016; Dooley et al., 2017). The research reported in this paper focuses on the post-secondary level, which is the educational stage following compulsory high school education but preceding university. This part of the STEM pipeline has received limited scholastic attention (Rigby, 2017). This study also centres on mathematics, a key subject within STEM education (National Research Council, 2011). It aims to address the following research questions:

1. How does the candidate's participation in two post-secondary mathematics courses compare in general and by gender?
2. What is the attrition rate in general and by gender for each post-secondary mathematics course from Years 1 to 2?

Research Context

This research was undertaken in Jamaica. In this country, the post-secondary level consists of two years of study. Students who choose to pursue mathematics at this stage primarily select to complete Pure Mathematics and/or Applied Mathematics. Students take Unit 1 of the course in their first year and the second unit in their final year. Each unit comprises three modules (see Table 1).

Table 1. Pure and Applied Mathematics Content

Course	**Year**	**Units**	**Module**		
			1	**2**	**3**
Applied Mathematics	1	Statistical analysis	Collecting and describing data	Managing uncertainty	Analysing and interpreting data
	2	Mathematical applications	Discrete mathematics	Probability and distributions	Particle mechanics
Pure Mathematics	1	Algebra, geometry and calculus	Basic algebra and functions	Trigonometry, geometry and vectors	Calculus I
	2	Complex numbers, analysis and matrices	Complex numbers and calculus II	Sequences, series and approximations	Counting, matrices and differential equations

The mathematics assessment related to the two courses has internal and external components with different weightings. The external component carries the majority weight of 80% and includes two papers. Paper 01 is a compulsory multiple-choice exam worth 30% of the final grade, while Paper 02 consists of six constructed-response items and contributes 50% to the final grade. The internal school-based assessment, worth 20%, is composed of three class tests designed by the teacher and externally reviewed by the examining board.

Review of Related Literature

Post-secondary Participation in Mathematics

Following Noyes (2009), this study defines participation as the successful completion of a course of study and the subsequent undertaking of the associated examination, which may result in either a pass or fail grade. Hodgen et al. (2010) conducted a comparative analysis of post-secondary mathematics participation across 24 countries. Their findings revealed varying levels of participation in mathematics courses among these countries. In eight countries, namely the Czech Republic, Estonia, Finland, Japan, Korea, Russia, Sweden, and Taiwan, the study observed that all students (95-100%) enrolled in at least one mathematics course. This high participation rate suggests that post-secondary mathematics was compulsory in these countries. In six countries, including Canada, France, Germany, Hungary, Ireland, the USA (specifically Massachusetts), the majority of students (81-94%) engaged with mathematics courses. Four countries, namely Australia (specifically NSW), the Netherlands, New Zealand, and Singapore, reported a participation rate ranging from 51% to 80%. The participation rate in Hong Kong, Spain, and Scotland varied from 21% to 50%. Finally, in three countries, England, Wales, and Northern Ireland, only 20% of post-secondary students or fewer pursued mathematics. Hodgen et al. (2010) lamented that this participation rate was relatively low and warranted Government intervention related to policy, curricula and practice to improve it.

As it relates to gendered participation, studies conducted in various regions worldwide, including the United States, Canada, Australia, Europe, and Africa, consistently reported a gender disparity in the selection of post-secondary mathematics courses (Finnie & Childs, 2018; Hill et al., 2010; Huggins & Randell, 2007; Matthews & Pepper, 2007; Mendick, 2005; Noyes, 2009; Schneider et al., 2015). The research findings indicate that more males tend to choose these courses than females. Additionally, at this level, males generally outperform females (Boaler, Altendorff, & Kent, 2011; Noyes, 2009), even when both genders' high school mathematics achievement is similar (Boaler et al., 2011). However, a limited number of studies, such as the US and Canadian samples in Watt et al. (2006) and Card and Payne (2015), respectively, report that males do not prefer higher levels of mathematics. Mendick (2005) discusses post-secondary participation in the UK and highlights that the greater participation of males in mathematics courses becomes more pronounced as education progresses. O'Dea et al. (2018) conducted a meta-analysis of over 1.6 million students and found that this gender disparity persists "despite girls outperforming boys at school in the relevant subjects" (p. 1).

Attrition in Post-Secondary Mathematics Courses

In England, Mendick (2008) highlights the long-standing issue of a significant number of students failing in the first year of their two-year post-secondary mathematics courses. This high failure rate has consequently led to substantial attrition, resulting in many students dropping out between Year 1 and Year 2. Noyes and Sealey (2012) support these findings and further note that mathematics exhibits one of the highest attrition rates compared to other subjects, although there is notable variation between schools. Their study reports an attrition rate of 29.4% from Year 1 to Year 2 for their collected data from a specific year. It should be noted that Noyes and Sealey (2012) were unable to determine if this dropout rate extended beyond their sample; nevertheless, they concluded that there is indeed a significant problem with Year 1 dropout in mathematics.

Method

This research examined Jamaican students' post-secondary mathematics participation data from 2013 to 2017. The examination board responsible for administering these examinations provided the research data. The sample for this study consisted of candidates from 71 educational institutions, totalling 15,220 candidates, with 7,896 females and 7,324 males. For Year 1 Pure Mathematics, 71 schools provided the data, while 64 schools for Year 2. For Applied Mathematics Years 1 and 2, the sample comprised 16 and 17 schools, respectively.

The examination board administers the mathematics examinations twice a year. However, most post-secondary school students complete their exams in May/June. Therefore, the data analysis focused on this specific period. Frequencies (totals and percentages), means, and standard deviations were calculated using EXCEL 2016 and SPSS 21 to address the research questions.

Results

Research Question 1: How does the candidate's participation in two post-secondary mathematics courses compare in general and by gender?

Across the five years, there was very little change in the general and gendered percentage of candidates participating in the mathematics courses. For the present sample, the proportion of students who completed post-secondary mathematics courses for 2013-2017 was as follows: 19.9, 18.6, 17.6, 17.4, 18.2, with approximately a 1:1 female-to-male ratio (see Table 2).

Table 2. Post-secondary Mathematics Participation

Participation	2013	2014	2015	2016	2017	Average
No. of candidates who do post-secondary courses	14,758	15,811	16,703	16,887	16,117	16,055
No. of candidates who complete a post-secondary mathematics course	2,935	3,021	3,214	3,409	2,641	3,044
% of candidates who complete a post-secondary mathematics course	19.9	18.6	17.6	17.4	18.2	18.3
% of females who complete a post-secondary mathematics course	10.7	10.2	9.7	10.4	8.3	9.8

Participation	2013	2014	2015	2016	2017	Average
% of males who complete a post-secondary mathematics course	9.2	8.9	9.6	9.8	8.1	9.1

Table 3 presents the overall gendered participation as per the two mathematics courses, Pure Mathematics and Applied Mathematics. A comparison of the candidate participation by course and year shows that from 2013–2017, approximately 62% of the students selected Pure Mathematics compared to only 4% for Applied Mathematics. In Year 2, the percentages were about 32% for Pure Mathematics and 1% for Applied Mathematics. The post-secondary student participation in Applied Mathematics is significantly lower compared to Pure Mathematics, even among schools offering both subjects.

Another significant finding was the differential enrollment patterns between male and female candidates in the different mathematics courses. Specifically, a higher percentage of male students chose to undertake Applied Mathematics Year 2 than their female counterparts. This suggests a potential gender disparity in selecting advanced mathematics courses, with males showing a stronger inclination towards Applied Mathematics. On the other hand, the enrollment proportions of male and female candidates were relatively equal in the other three courses.

Table 3. Mathematics Participation per Course and Gender

Course	**Gender**	
	F (No., %)	**M (No., %)**
Applied Mathematics Year 1	329 (50.69)	320 (49.31)
Applied Mathematics Year 2	88 (40.93)	127 (59.07)
Pure Mathematics Year 1	4,875 (51.74)	4,548 (48.26)
Pure Mathematics Year 2	2,604 (52.79)	2,329 (47.21)
Total	7,896 (51.88)	7,324 (48.12)

Research Question 2: What is the attrition rate in general and by gender for each post-secondary mathematics course from Years 1 to 2?

In the case of Applied Mathematics, the participation rate for Year 2 from 2013 to 2017 was approximately one-third of the Year 1 participation. As for Pure Mathematics Year 2, the participation rate was about 50% lower than that of Year 1. Furthermore, the attrition rate in Applied Mathematics is higher for females than males, while in Pure Mathematics, the attrition rate between genders is nearly equal.

This research found that over the five-year period, from 2013-2017, the average attrition rate from Year 1 to Year 2 for Pure Mathematics, for males and females, was 50% and 48%, respectively. For Applied Mathematics, males recorded an attrition rate of 60% and females 72% by gender. These results demonstrate a substantial decrease in student participation in Year 2 courses of Applied and Pure Mathematics following the completion of Year 1. It indicates that many students who initially enrolled in mathematics courses did not progress to the advanced level.

Discussion

This research found that approximately 18.3% of students participating in post-secondary education administered by the CXC examining board opted to complete a mathematics course. This rate is low compared to international participation rates reported by Hodgen et al. (2010). Similar to the three counties, England, Wales, and Northern Ireland, that reported comparable participation rates of 20% or fewer, post-secondary mathematics participation in Jamaica is optional for students. Hodgen et al. (2010) pointed out that the issue of choice appeared to be a significant factor affecting mathematics participation rates after high school. Furthermore, Noyes and Adkins (2017) posit that end-of-high school mathematics achievement is the main contributor to post-secondary mathematics participation. This assertion may apply in the Jamaican context, where approximately half of the cohort sitting exit mathematics examinations at the end of high school do not obtain a passing grade (George, 2022). This low pass rate suggests that many students have considerable difficulty learning mathematics, so they would not be likely to continue engaging with the subject when it is no longer compulsory. The high-stakes end-of-high school mathematics examination is a requirement for students who wish to pursue further mathematics education beyond high school. The low number of students passing the mathematics examinations greatly diminishes the pool of potential candidates for post-secondary mathematics courses. Additionally, many students have a negative attitude towards and fear mathematics (Bourne, 2019; Ministry of Education, 2013). These factors, as proposed by Matthews and Pepper (2007), contribute to students' experiences with mathematics and can significantly impact their participation in post-secondary education.

The completion rates of the two post-secondary mathematics courses for males and females were nearly equal. This finding contrasts with the majority of global studies that report higher male participation in post-secondary mathematics courses (Hill et al., 2010; Matthews & Pepper, 2007; Noyes & Adkins, 2016; O'Dea et al., 2018; Schneider et al., 2015; Smith & Golding, 2018). This finding is significant as it presents a departure from global trends observed in the empirical literature, offering an example of the unique characteristics of Caribbean cohorts. Furthermore, it is noteworthy because it suggests a level of gendered participation equity that aligns with the goals pursued by international educational organisations (Smith & Golding, 2018; UNESCO, 2010, 2017).

This study also found a marked decline in the number of students who participated in Year 2 for Pure and

Applied Mathematics courses after completing the corresponding Year 1 course. This finding aligns with research conducted in the UK regarding mathematics participation during the post-16 stage (Mendick, 2005; Smith & Golding, 2017). While this consistency with previous research is notable, the author suggests that various factors, including students' career aspirations and experiences during the course, may influence this observation. Additionally, the quality of the grades obtained in Year 1 courses may play a crucial role. These grades could determine students' eligibility to progress to Year 2 or may impact their self-efficacy and confidence in pursuing more advanced related courses. Mathematics learning is hierarchical and cumulative in that new knowledge builds on existing knowledge (Babtie & Emerson, 2015). Previous mathematics achievement has been found to be predictive of future performance (Card & Payne, 2015). Therefore, a weak grade in Year 1 may indicate a limited understanding of mathematical concepts, which can potentially hinder performance in subsequent related courses. Future research endeavours could investigate the underlying reasons for the observed attrition, providing valuable insights into the phenomenon.

Conclusion

This research examined the gendered mathematics participation and attrition of students at the post-secondary educational level. Investigating participation and attrition rates at this level is crucial for addressing the decline in student engagement in STEM courses as they progress through the STEM pipeline across educational levels. Such research provides valuable insights into the current situation within different jurisdictions, helping to identify potential barriers and disparities. It also informs targeted interventions and strategies that promote equity, diversity, and inclusion in STEM education. Finally, it adds to the existing body of knowledge on the topic, expanding the international portrait of what is known in the research domain.

The outcomes of this research hold the potential to shape policy and educational initiatives aimed at enhancing the representation and retention of students, particularly female students, in post-secondary mathematics courses. By creating a supportive and inclusive learning environment, educational institutions can better equip their students with the necessary skills and knowledge to thrive in STEM fields and meet the evolving demands of the world.

Recommendations

Based on the research findings, this paper presents five recommendations, which are as follows:

1. Implement policy and practice measures to enhance mathematics achievement at the end of high school.
2. Provide increased support to Year 1 students enrolled in post-secondary mathematics courses to enhance their performance.
3. Enhance the experiences and engagement of Year 1 students in mathematics courses, which may

involve organising professional development sessions for teachers.

4. Develop policies specifically targeting post-secondary mathematics participation, outlining specific initiatives to be implemented in order to improve participation rates.
5. Regularly monitor post-secondary participation and attrition in mathematics courses and utilise these data to guide future actions.

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Different Meanings of Pure Imaginary Numbers

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Abstract: This study investigated in-service teachers' conceptualization of the pure imaginary number ib, within the Cartesian form, $a + ib$ where a and b are real numbers and i is the imaginary unit. As part of a larger design-based research study, in which a professional development (PD) program was designed to investigate five in-service teachers' conceptualization of different forms of complex numbers, we conducted pre and post written problem-solving sessions together with post PD interviews. Results showed that after PD all the participants defined i as one of the roots of the quadratic equation, $x^2 + 1 = 0$. They also could show i geometrically as a point (0,1) on the complex plane. Although all the participants mentioned operator meaning of i as a 90-degree rotation when multiplied with b; only one of them mentioned the dilation meaning of b when multiplied with i. Results suggested considering the pure imaginary part of the Cartesian form focusing on both the operator meanings of b and i is important for understanding the nature of complex numbers and the complex plane for teacher education and teacher content knowledge. These results further suggest that quantitative reasoning might lay a foundation for connecting different forms of complex numbers, including the unit, i.

Keywords: Complex numbers, teacher knowledge, quantitative reasoning.

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Introduction

At different stages of schooling, students are expected to work with and build relationships among number systems (CCSM, 2010). Understanding of complex numbers is specifically important in science, technology, engineering, and mathematics related fields (STEM). Complex numbers are particularly crucial in the learning of advanced mathematics topics such as algebra and complex analysis. They also play an important role in the learning of concepts of advanced physics such as quantum physics (Karam, 2020) and different fields of engineering including relativity, electromagnetic theory, signal processing (Atmaca, 2014), hydrodynamics and electrical circuits (Benitez et.al, 2012). Thus, a robust conception of complex numbers is expected of students both for their access to and success in STEM and other interdisciplinary fields (Anevska, Gokovska & Malcheski, 2015). Specifically, researchers stated that a complete conception of complex numbers necessitates geometrically thinking of a complex number as a point on the complex plane and as a vector (Fauconnier & Turner, 2002). Also, algebraically, "a complex number should be conceptualized as one number, i.e., the expression $a + ib$ is a single entity combining a real number and an imaginary number" (Nordlander & Nordlander, 2012, p. 633) such that they are mathematical objects in a well-defined set consisting of elements of the same kind or a particular category (Sfard, 1991). Yet, researchers argued that "Complex numbers …typically are instances of mathematical structures that seem to depend merely on formal arrangements in a system of meaningless signs, not referring to anything informal or quasi-empirical" (Glas, 1998, p. 367) such that students mostly "…cannot visualize them" and "…are also questioning the use of complex numbers in reality, and mention the difficulty in imagining what complex numbers 'stand for and really are'" (Nordlander & Nordlander 2012, p. 633). Researchers concluded that for students "…at least the imaginary unit must be visible" (p. 637) to think of any number as a complex number. Thus, they pointed to the understanding of the components of the Cartesian form meaningfully.

Specifically, Sfard (1991) further stated that the first stage for conceptualizing complex numbers is to recognize that $i = \sqrt{-1}$, in the Cartesian form. Regarding the root symbol, the radical sign $\sqrt{\ }$, Kontorovich (2018a) pointed that it "…initiates polysemy-a phenomenon in which the same concept or symbol can be interpreted in discrepant manners depending on the context in which they are used and on the curricular norms associated with the context" (p. 17). For example, $\sqrt{9}$ can be understood as equal to 3 since $y = \sqrt{x}$ is a function in Real numbers where for every x value in the domain there should be a single y value. Yet, in the field of complex numbers, $\sqrt{\ }$ is a multi-valued function such that $\sqrt{9}$ has two roots which are ±3 (Kontorovich, 2018b). In this respect, researchers argued that i should be understood as "…one of the square roots of (-1)" such that as a new discourse "…the expression $\sqrt{-1}$ is not a number no longer holds" (Nachlieli & Elbaum-Cohen, 2021, p. 5) this part needs to be developed for students and teachers.

Researchers also point to the understanding of i as a vector and a point (e.g., Karakok et al., 2015). Cognizing of i as a vector with (0,1) pointwise representation is further related with understanding the ib component of the Cartesian form, a+ib, where b is any real number on the Real number line. That is, whenever one makes sense of ib as the multiplication of i with any real number, this can lead to their "…interpreting i as a rotation of the real line through 90°" (p. 967), which yields to the formation of complex plane (Harding & Engelbrecht, 2007).

Making sense of i as an operator is further important in two significant ways. Kontorovich et al. (2021) argued for two types of relations between number sets, namely a nested and a transition relation. In the nested relation, for example, Real numbers are considered as the subset of complex numbers. The transition view rather depends on an image that complex numbers are isomorphic to Real numbers where " two sets are isomorphic if there exists a bijection between their elements that preserves a binary relationship, for instance addition and multiplication" (p.262). They further pointed that isomorphic image might resolve the aforementioned issue of thinking of $\sqrt{9}$ as 3, approaching it as a real square root function, and thinking of $\sqrt{9}$ as an element of complex numbers yielding to ±3 (Kontorovich, 2018b). This is possible as thinking of the isomorphic image might lead to the understanding that "…identically appearing words and symbols can be interpreted rather differently in different number sets" (p. 263). Thus, making sense of i as an operator acting on any real number, say b, might further allow for the understanding of the ib component of $a + ib$ such that not only one makes sense of the fact that real numbers are a subset of complex numbers but also that there is an isomorphism between the two sets. This is also possible as isomorphic and nested images of sets are complementary viewpoints rather than conflicting ideas (Kontorovich et al., 2021). This is further important as researchers argued that "…it is useful for students and teachers to be able to flexibly switch between the two images" (Kontorovich et al., 2021, p. 264).

It is in this regard that, considering mathematics teachers as key figures in the preparation of students (NCTM, 2000), who need to have a good understanding of complex numbers for their future careers especially in STEM related fields, we scrutinized specifically in-service teachers' conceptualization of i both algebraically and geometrically. With the report in this paper, we attempt at extending previous research on complex numbers by further delineating different conceptualizations of i.

Conceptual Framework

Researchers pointed that a robust conception of complex numbers include one's knowing both the algebraic and geometric representations of the Cartesian, polar and the exponential forms (See Table 1), making sense of the connections among them and the flexibility to go among these forms (Karakok et.al., 2015)

However, research has shown both students' (Çelik & Özdemir, 2011; Nordlander & Nordlander, 2012; Panaoura et al., 2006; Soto-Johnson & Troup, 2014) and prospective and in-service mathematics teachers' difficulties on complex numbers, especially making connections among different representations (Conner et al., 2007; Karakok et al., 2015; Nemirovsky et al., 2012). Therefore, researchers emphasized the simultaneous employment of algebraic and geometric aspects of complex numbers.

Table 1. Different representations of complex numbers (Karakok et.al., 2015, p.329)

Representation	Form			
	Purely imaginary i	Cartesian $(a + bi)$	Polar $r(\cos\theta + i\sin\theta)$	Exponential $re^{i\theta}$
Algebraic	$i, \sqrt{-1}, (0, 1)$	$a + bi, (a, b), z$	$r(\cos\theta + i\sin\theta), z$	$re^{i\theta}$
Geometric	A point on the complex plane, a rotation operator	A point on the complex plane, a vector with a magnitude of $\sqrt{a^2+b^2}$ and an angle of $\tan^{-1}\left(\frac{a}{b}\right)$ with the positive real axis, a rotation and dilation operator	A point on the circle centered at the origin with radius r, a vector with magnitude of r and an angle of θ with the positive real axis, a rotation and dilation operator	A vector with magnitude of r and an angle of θ with the positive real axis, a point on the circle centered at the origin with radius r, a rotation and dilation operator

Specifically, Soto-Johnson and Troup (2014) reported on mathematics major students' geometric and algebraic reasoning about complex-valued equations. Results of their study has shown that students were tended to think algebraically. Yet, when they were asked purposefully to think about geometric meaning of the equations, they could manage it. Therefore, researchers concluded that "requiring students to reason about a task both geometrically and algebraically appears to mesh these two types of reasoning" (p. 124). In addition, Nordlander and Nordlander (2012) study with engineering undergraduate and high school students showed that students "…have difficulties discerning the basic property of complex numbers, i.e., any number is a complex number" (Nordlander & Nordlander, 2012, p. 627). So, researchers concluded that for students "…at least the imaginary unit must be visible" (p. 637) to think of any number as a complex number. Similarly, Nachlieli and Elbaum-Cohen (2021) reported on a study with twelfth-grade students' mastery of complex numbers, which entailed acknowledging that "..the word number also signifies objects of the type a+ib, where a and b are real numbers, and i is one of the square roots of (-1)..." (p. 5). Results of their study showed that through questioning, even when leading, teachers' encouragement of students for thoughtful and investigative thinking might yield a shift in the discourse from real to complex numbers both algebraically and geometrically. Furthermore, Panaoura et al. (2006) found that secondary school students viewed complex numbers' algebraic and geometric representations distinctly and not as two means of representing the same number. They also claimed that this result might be due to the fact that complex numbers are introduced "…usually with little or no visual or geometric interpretation" (Panaoura et al. 2006, p. 684).

Research studies with secondary teachers (Conner et al., 2007; Karakok et al., 2015) also pointed to teachers' difficulties in conceptualization of complex numbers. Specifically, working with three secondary school mathematics teachers on their connections of Cartesian, polar, and exponential forms of complex numbers, Karakok et al. (2015) showed that one teacher had difficulty visualizing complex numbers as points on the complex plane. Similarly, once she needed to represent i as a point, "..she was hesitant whether it was located one unit up from the origin…" (p. 339). Also, another in-service teacher stated "Well, I guess just thjs letter i and anything that correlates with having i so like i+1 and multiplies of I and all that" (p. 340). So, the researchers concluded that the teacher seemed to relate the cartesian form of a complex number as an algebraic process performed on i. Similarly, two teachers in the study "…both had difficulties relating ….vector representations of the Cartesian form" (p. 345). In addition, prospective teachers did not reconnect complex numbers to the roots of quadratic equations (Conner et al., 2007).

Moreover, Nemirovsky et al. (2012) study with prospective secondary teachers showed that the classroom floor setting offered to discover the geometric meaning of addition and multiplication of complex numbers afforded prospective teachers to consider multiplying with i as a 90-degree rotation. Building on these studies, Saraç (2016) studied a prospective teacher's development of the Cartesian form of complex numbers through quantitative reasoning. Results have shown that the prospective teacher was able to conceptualize complex numbers as a single entity, as an element of a well-defined set. Particularly, she conceptualized complex numbers as the set of the roots of any quadratic equation with real coefficients. Similarly, given any complex number, a+bi, she was able to explain what a and b represented both algebraically and geometrically. She also was able to explain why and how the conjugate roots exist given a complex root of any quadratic equation. In addition, contrary to Karakok et.al. (2015) results, she was able to locate i as referring to a point, (0,1), on the complex plane (Saraç & Karagoz Akar, 2017).

All these studies point out that in-service teachers and students need to have a complete understanding of complex numbers, including the Cartesian form with a focus on algebraic and geometric meaning of the unit i. In this study, we propose that while developing teachers' conceptions of complex numbers, quantitative reasoning might provide a robust thinking process for teachers.

Thompson (1990) described quantitative reasoning as an individual's "analysis of a situation into a quantitative structure" (p. 13). From the perspective of Thompson (1994), "quantities are conceptual entities" and "a person is thinking of a quantity when he or she conceives a quality of an object in such a way that this conception entails the quality's measurability" (p. 184). We view complex numbers as the union of two quantities as directed distances derived from the analysis of a situation (a mathematical object such as quadratic functions) into a network of quantities, which are the roots and the abscissa of the vertex as distances from the origin and quantitative relationships (See for a more detailed description, Karagöz et al., in press). By quantitative relationships, we refer to the relationship between the roots and abscissa of the vertex position on the number line as a point and as a distance. It is in this regard that we scrutinized the following research question:

> How do in-service teachers conceptualize i algebraically and geometrically upon completion of a PD program focusing on quantitative reasoning?

Method

This study was part of a Teacher Development Experiment study (TDE), assuming a design-based research (DBR) approach. For the advancement of the content knowledge of complex numbers, we focused on teachers' professional development (PD). TDEs include both classroom teaching experiments and (multi) case studies

(Simon, 2000). In this paper, we presented the findings from the multi-case study focusing on teachers' existing knowledge base, upon completion of the PD. Four teaching sessions lasting between 120 and 150 minutes made up the PD. The first two sessions were about the Cartesian form of complex numbers with quadratic equations through quantitative reasoning (Saraç & Karagoz Akar, 2017), the third one on the polar form, and the last on the Euler form. As the nature of DBR investigations, the PD focused on the theory of quantitative reasoning by considering complex numbers in a quantitative structure as a union of two quantities, which are directed distances and the roots of any quadratic equation with real coefficients.

Five mathematics teachers, with two to ten years of teaching experience and a degree in secondary school mathematics teaching, participated in the study. Initially, ten teachers completed a pre-written session on complex numbers. They were asked to define quadratic functions and equations, different forms of complex numbers, and vectors algebraically and geometrically. Eight teachers were purposely selected based on the preliminary analysis of the pre-written session and on the following criteria: They knew quadratic functions and defined and expressed vectors, which were considered background knowledge. However, they did or did not state complex numbers in the cartesian, polar, and/or Euler forms and did not explain the relationship between different forms, considering the pedagogical goals (Simon, 2000). Five of these eight teachers declared their availability to attend the study.

A post-written session was held after PD was finished. Then, the researcher, who also implemented the PD to collect data about how the participants conceptualized the connections among different forms of complex numbers, carried out video-recorded semi-structured interviews. Interviews lasted between 30 min. to 45 min. Participants' written artifacts were also gathered.

For data analysis, the constant comparative method (Clement, 2000) was used. The research team collectively read the participants' written responses and transcripts of all the interviews, watching the video recordings, when necessary, in order to characterize how teachers conceptualize the complex number i algebraically and geometrically. The participants' statements in the transcripts ranging from a sentence to a whole paragraph on each interview question served as the unit of analysis. We conducted the analysis utilizing the constructs of quantitative reasoning. The analysis focused on how the teachers were making sense of the complex number i quantitatively and explaining the meaning of i as dilation and rotation operators quantitatively. We analyzed the data first for each participant and then for each question from different participants. We created narratives describing how participants conceptualized complex number i through quantitative reasoning, by comparing and extracting the similarities and differences between their thought processes.

Results

In the following sections, the results related to different conceptualizations of i such as the definition, and geometric representation, of i will be explained. Moreover, the operator meaning of i will be discussed with examples from interview data.

Different Conceptualizations of i

All the participants could define i in the post-written session. Among them, T2, T4 and T5, and T1 stated that i is one of the roots of the quadratic equation, $x^2 + 1 = 0$. In their explanations, they further stated that they take $\sqrt{-1}$ as equal to i. Only T3, defined that "i is the number which places at the point (0,1) in the imaginary axis". Similarly, all the participants but T4 could show i as a point on the complex plane as (0,1) geometrically. Rather she wrote (0, $\sqrt{-1}$) by stating that this point refers to the $\sqrt{-1}$ unit distance on the imaginary axis. We now provide data on T4' reasoning about showing i on the complex plane during the post- interview. T4 again defined i as one of the roots of the quadratic equation $x^2 + 1 = 0$. She also stated that i is the number whose square is equal to -1 and further acknowledged i as equal to $\sqrt{-1}$. Though, as her drawing showed, T4 first showed i by writing (0, $\sqrt{-\Delta}/2a$) and then by writing i and providing an example she also wrote $(3i)$ on the imaginary axis (See Figure 1):

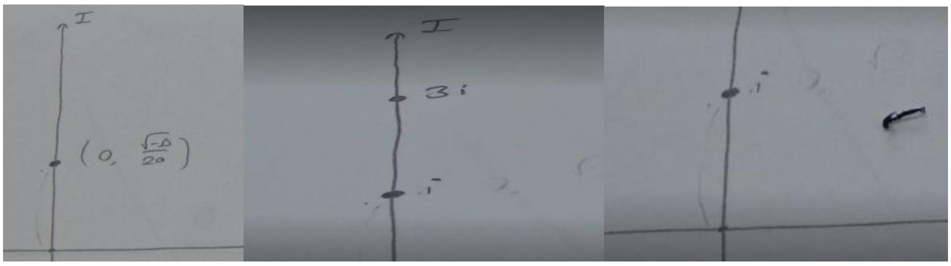


Figure 1. T4's drawing on geometric representation of i

Then hesitantly she stated whether she should use (0,3) or not. She also mentioned that i was 1 unit above the origin on the imaginary axis. Discussion continued:

R: How do you know it's 1 unit?
T4: We said square… square of it is -1, its distance is 1.
R: What does "its square is -1" mean, so how do you know it's 1 unit?
T4: Actually, for example, when I rotate this 90° (referring to what she drew on the y-axis), let this be -1. When I rotate this 90°, I am here again, -1 (marking the distance of 1 unit on the - y on the axis) becomes 1 (indicating the rotation sign again and marking a distance of 1 unit on the x-axis). Here I am actually tracing a 1unit circle.

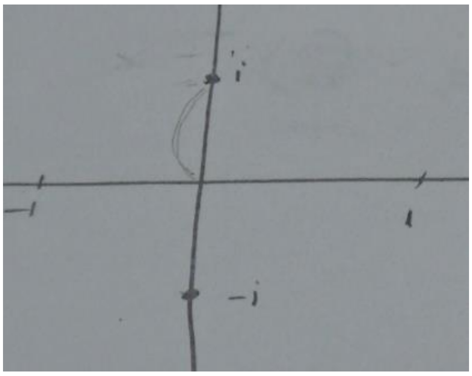


Figure 2. T4's drawing on multiplication of i

R: How do you know?

T4: We mentioned it while talking about polar representation. For example, its length, if I wanted to write this, it would be x+iy as x is 0, y in iy is 1.

R: What is y? Can you show me here where y is?

T4: This part is $(\sqrt{4ac-b^2})/2a$, when I write this as x+iy, here (referring to x) is -b/2a here (referring to y) is $(\sqrt{4ac-b^2})/2a$ so if I say i here (writing (0,i1) it becomes 1 unit.

R: You say $(\sqrt{4ac-b^2})/2a$ would be 1 unit.

T4: Huh, yes, it has become 1 unit.

R: Then what happens if you show as a point?

T4: I can't, I don't know, I can't be sure about that (0,1).

R: Why? You weren't sure about (0,3) either, were you?

T4: Yes, I wasn't sure about (0,3) either because we talked about something, for example, we said that we can say 3i and i as distance, for example, we couldn't compare them in terms of size. Yes this is 1 unit of distance (referring to the distance between i and the origin) this is 3 units of distance (referring to the distance between 3i and the origin) but when I show it as a point, I am not sure if I can write (0,3) like a coordinate.

R: And is there a contradiction between what you said and this.

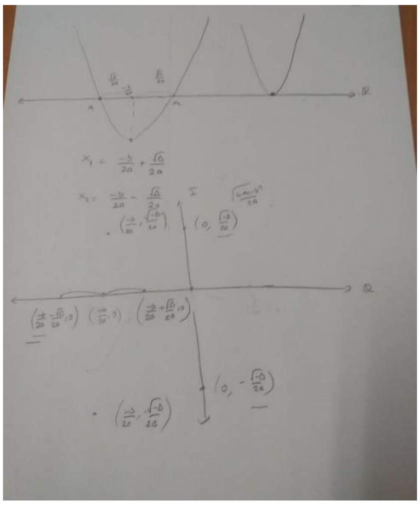


Figure 3. T4's drawing on the roots and the vertex

T4: Yes, then I can write.

R: I don't know which one you say is correct? Which one shall I believe?

T4: Here (referring to $\sqrt{(-\Delta)}/2a$) is $(\sqrt{(4ac-b^2)})/2a$ anyway

R: What was that geometrically?

T4: It was y. Then I can write (0,1), (0,3) OK.

R: Tell me again what has changed, why has it changed?

T4: I could not, we couldn't compare the size of 3i and i there. You know, as a point what we wrote in the second part is a point on the complex plane, but now it's ok.

R: What do you mean, what's okay?

T4: When I write the coordinates there, I already use real numbers. When I say x+iy there, I can write the y part (0,3) there. I just had wondered if I could write whether it is (0, 3i) but it is (0,3) yes. Now I can write this (referring to (0,3)). Let me write then (putting the points back). This is 3, this is 1, but which one of them is bigger, I can't say.

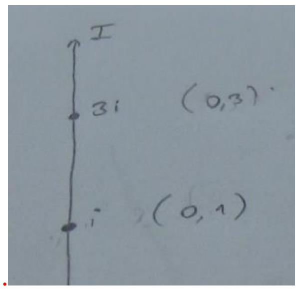


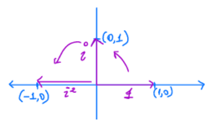
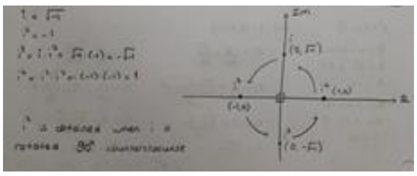
Figure 4. T4's drawing on i and $3i$

As the data indicated, T4 had difficulty in showing i as a point (0,1) on the imaginary axis. Notably, she knew that i was 1 unit above from the origin. She also knew that $3i$ was 3 units away on the imaginary axis from the origin. She knew this because as she stated, i was on the unit circle where she considered i as an operator of 90-degrees rotation counter clockwise (See Figure 2). Yet, she knew from the discussion during PD that complex numbers could not be ordered and this made her think that it might not be possible to represent i as (0,1). That is, as if when she used (0,1) or (0,3) for representing i and $3i$ respectively, she would revert back to real numbers, which could be ordered (i.e., 1 is smaller than 3). More specifically, she considered that if she had used (0,1) as could be written on R^2, this would contradict the information that the complex numbers could not be ordered. Therefore, she did not know whether she could write (0,3) to indicate $3i$. She seemed to be considering that points on the imaginary axis should be shown by imaginary symbols. However, when probed to think about her earlier drawing showing the roots on the complex plane, she recalled that complex numbers are represented by ordered pairs of real numbers. This then allowed her to show i as (0,1). These data suggested that, for T4, the polar form of complex numbers was more meaningful than the binomial form. Another important observation is that T4's explanations about comparing real and complex numbers in terms of ordering property are not legitimate when R^2 and the complex plane is considered. That is, in R^2 there is no notion of ordering either. This suggests that T4 might not have known that there is one-to-one correspondence between the ordered pairs in R^2 and complex numbers.

Meaning of i as dilation and rotation operators

As the data in Table 2 indicated, in the post-written test all the participants could explain the powers of i both algebraically and geometrically as 90 degrees rotation counterclockwise. Yet, during the interview, T1's explanations pointed to complex number bias while T5's explanations were valid. Also, T1 could mention not only the operator but also the dilation meanings of multiplication of complex numbers.

Table 2. Teachers' post test answers on the meaning of i

Multiplication with i	Teachers	Sample data
Explaining powers of i using algebraic meaning	T1, T2, T3, T4, T5	**T1** Algebraically it is $i.i = \sqrt{-1}.\sqrt{-1} = -1$ Geometrically it is the point (-1,0) on the complex plane that is to say it is on the real line. **T2** $i \cdot i = \sqrt{-1} \cdot \sqrt{-1}$ $i^2 = -1$ **T3** $i^2 = \sqrt{-1}.\sqrt{-1} = -1$ **T4** $i = \sqrt{-1}$ $i^2 = -1$ $i^3 = i.i^2 = \sqrt{-1}.(-1) = -\sqrt{-1}$ $i^4 = i^2.i^2 = (-1).(-1) = 1$ **T5** Algebraically, $i^2 = (\sqrt{-1})^2 = -1$
Explaining powers of i using operator meaning	T1, T2, T3, T4	**T2** $i \cdot i = \sqrt{-1} \cdot \sqrt{-1}$ $i^2 = -1$ i acts like a rotation operator.  **T3** $i = \sqrt{-1}$ $i^2 = \sqrt{-1}.\sqrt{-1} = -1$ Everytime we multiply i with i, a 90° rotation occurs in the positive direction.  **T4** 

We now provide data from the interviews with T5 and T1, when asked to explain how they interpreted i^2:

T5: Because i was equal to $\sqrt{-1}$. Therefore, the number we called i^2 became $\sqrt{-1}.\sqrt{-1}$. This gave us the number -1. -1 is a real number. So if we write this as a complex number, in the format $x + iy$, it becomes 0+, sorry, $-1 + 0i$. That's why I said we can show it as a number, as a point on the x-axis, at a distance of 1 unit form 0, on the left side, the negative side. So, I said directly it will be on the real axis.

Comparatively, data from T1 pointed to complex number bias:

T1: Let's write i squared (i^2) algebraically. Algebraically, it is multiplying i by i, root minus one by root minus one ($\sqrt{-1}.\sqrt{-1}$). Our rules in real numbers are valid here. We can multiply two numbers inside a single root. It becomes root one ($\sqrt{-1}$). So it's one. Um, where do we put it? The result is a real number, so we multiplied two imaginary things and the answer came out real. Then I'll show on the real.

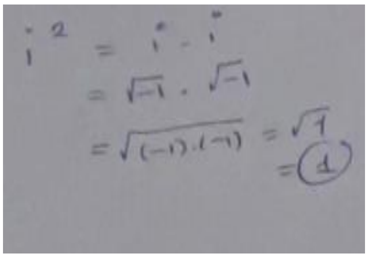


Figure 5. T1's explanation on i^2

That's here somewhere, I'm trying to make these things equal. i squared will be at (1.0). Isn't it? Yes. Because i squared is positive. I mean, I think that we cannot write i squared (i^2) under it, because it is i squared. One of its points is (1,0). One minute, i squared would be minus one, right? Smoke will come out of my head soon. One minute. I multiplied i with i, that is i squared. The i squared has to be minus one. Sorry, it won't be like this. This will be minus one.

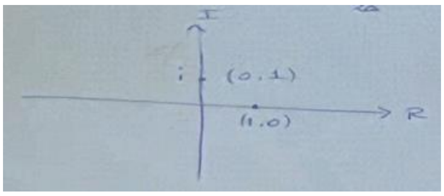


Figure 6. T1's drawing on the place of i

R: Why, how?

T1: Because I can't call it minus one squared, minus one squared $(-1)^2$). I'm saying it wrong. How can I explain that? I'm making this up now, if it was root two ($\sqrt{-2}$) and root two ($\sqrt{-2}$), it would be two. It will also be negative one since it is root minus [times] one root minus one ($\sqrt{-1}.\sqrt{-1}$). So I'm trying to explain it with that logic. Root will go. From the same number. If there are two identical numbers in the square root, that number comes out when we multiply them. This is minus one, not here, on this side (she shows it in the complex plane.) Again, it's real.

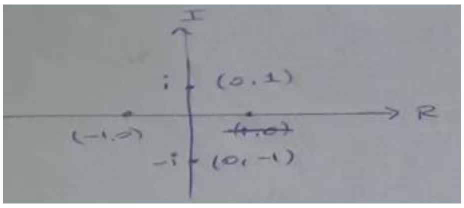


Figure 7. T1's drawing on the place of $-i$

i cubed (i3) is minus one multiplied by i, minus i, that's over there. What will it become? It becomes (0,-1). Just below this (shows the point (0,1)). Yes.

R: Okay. Can you tell me again why you changed your mind here?

T1: I changed my mind here because of this: This is not a real thing [number]. i is not a negative number. i is something like root minus one.

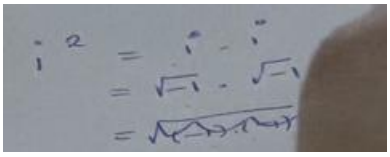
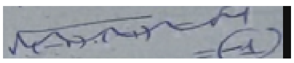


Figure 8. T1's algebraic explanation on i^2

T1: That's why I changed my mind. Because if i was the number -1, the square of -1 will come out as 1 anyway. There is no problem there. But this is defined as root -1 anyway, there is no such thing normally. But there are two expressions inside the root. Both are the same. It is like, as if the roots have canceled out each other. So it's like it turned into a square. That's why I changed my mind. 'Cause if I do this it'll be like I'm squaring -1.



T1: Then it will be as if I have defined it like this.  But it is not like that 

As the data indicated, T5 could verify that $\sqrt{-1}.\sqrt{-1}$ is equal to-1. Also, she could explain how she could write -1 as (-1,0) by pointing to the binomial form of complex numbers such that she matched $x + iy$ with $-1 + 0i$ as (-1,0). Yet, she did not explain how she knew or how she could deduce $\sqrt{-1}.\sqrt{-1}$=-1 and the researcher did not probe her further to explain her reasoning. T5's earlier explanations regarding that i is the number whose square is -1 might be the reason to write such equality. On the other hand, T1's explanations suggested that T1 considered the properties of the radicand sign in Real numbers and the complex numbers the same. Her earlier explanation and writing (See Figure 8) showed that she considered that the rule $\sqrt{a}.\sqrt{b} = \sqrt{a.b}$ in real numbers also holds for complex numbers. This pointed to a complex number bias. However, similar to all other participants, when T1 considered that i is the number whose square is -1 she realized that she made a mistake. Her explanations suggested that she considered $\sqrt{a}.\sqrt{a} = a$ also held for $a = -1$.

Before talking about i^2, T1 mentioned multiplying i with $\sqrt{-\Delta}/2a$ so the researcher asked how she made sense of it.

R: This i times $\sqrt{-\Delta}/2a$

T1: Where will it be?

R: What does it correspond to, yeah, where will that number be?

T1: On here (showing imaginary axis). It is on the imaginary axis. It depends on the value of the coefficient. So for instance, if $\sqrt{-\Delta}/2a$ is 3, I'll be pointing at $3i$. Or like I'll be pointing at $-3i$.

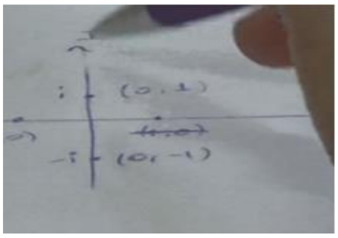


Figure 9. T1's drawing on i and $-i$

It's not a real number, but it has a real coefficient. I can say it is getting bigger or smaller according to that. Saying getting bigger or smaller may not be very accurate, as I said, because of the definition of i, it may not be like is i bigger than 3i, but we can assume that the distance is the distance to zero and place it (talking about real number times i) Since that is positive, we can place it.

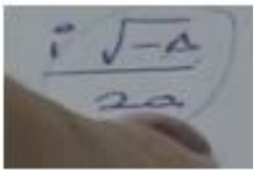
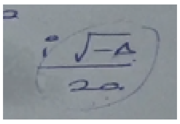


Figure 10. T1's written work on multiplication with i

R: OK. You're telling me… you say that when I multiply it with i, I can place it here (pointing to theimaginary axis). I'm asking you if you can explain √(-Δ)/2a when multiplied with i.

T1: I could not perceive the difference exactly, but I will. I multiply from here, you multiply from here (meaning multiplying from the right or left side)… and it makes a difference. Okay, just a minute. Umm, does this still exist? This (-b/2a) is zero and I'm saying this (i.(√(-Δ)/2a))…Okay. Ok. I need to put it somewhere on the axis. Because these are the i (pointing to the imaginary axis.) This (pointing to i.(√(-Δ)/2a)) I'll call it a certain coefficient of i. Because it's a coefficient.



R: OK. Alright. I am asking the same question again. What kind of number is √(-Δ)/2a? What does it mean when you multiply a real number with i? You tell me what it means when you multiply i with a real number.

T1: OK, one minute. What was it? Do I explain what happens when I multiply i with a real number? One minute. Ok. Ok. What happens when I multiply i with a real number? OK, when we multiply a real number with i, that number becomes an imaginary number…

R: I'm asking what it means. It's imaginary, on that we agree.

T1: okay, for example √(-Δ)/2a was on this line (referring to the real axis). Because it was real. When I multiply it with i, shall I say if it rotates, what shall I say? It went this way. It moved to the imaginary axis. It rotated, it rotated. It rotated, from here (meaning the real axis) to here (meaning the imaginary axis). Rotated ninety degrees, yes.

Importantly, the data showed that T1 initially interpreted the question $\sqrt{-1}\sqrt{-\Delta}/2a$ as the multiplication of i with a real number, referring to scalar multiplication rather than interpreting it as a real number multiplied with i, as rotation operator. First of all, syntactically this might make sense as the order in which the multiplication is symbolically written might have triggered this meaning. Still, T1 seemed to think that a real number acted on the $\sqrt{-1}$ which made it longer or shorter. This suggested that T1 made sense of the multiplication of i with a real number as a dilation operator. That is, she seemed to think of $\sqrt{-1}$ as the multiplicand and the $\sqrt{-\Delta}/2a$ as multiplier. This was probably possible for two reasons: First, T1 made sense of the binomial form of complex numbers as vectors. As the figure showed, she even mentioned i as a unit vector, which refers to (0,1) and she made sense of $\sqrt{-\Delta}/2a$ as the distance to the origin. Considering the location of i, she even located $3i$ three units away from the origin on the imaginary axis. Secondly, her referring to $(-b/2a)$ as being zero and her statement that $\sqrt{-\Delta}/2a$ is a real number suggested that she made sense of the dilation operator referring back to complex numbers as the roots of quadratic equations. However, as the data indicated, T1 had difficulty in thinking with i as a rotation operator. Only after the researcher has taken her attention three times, T1 could attend to the difference between i as a multiplier versus i as a multiplicand. That is, only after being prompted, she stated that i as a rotation operator, the multiplier, acts on the $\sqrt{-\Delta}/2a$, rotating it 90 degrees and locating any real number on the imaginary axis. All these data showed that T1 could reason on multiplication of i with real numbers in two ways albeit some difficulty.

Conclusion and Discussion

Results of the study showed that, upon completion of a PD study focusing on the conceptualization of different forms of complex numbers, in-service teachers developed a meaning of i both algebraically and geometrically. In addition, although all of them could mention the rotation operator meaning of i, one of them was able to consider ib pointing to both i acting on b as a 90-degrees rotation and b acting on i as a dilation operator.

Particularly, in accordance with researchers' emphasis about the conceptualization of i (Kontorovich, 2018b; Nachlieli & Elbaum-Cohen, 2021), results showed that four out of five inservice teachers defined i as one of the roots of the quadratic equation, x^2+1=0 and one teacher did not mention this. However, they also stated that they accepted √(-1) as equal to i. Such conceptualization is valid as in formal mathematics i is considered as the principal root of √(-1) (Usiskin et al., 2003). In addition, T1 specifically showed on the complex plane that she also had an awareness of "-i" as one of the roots of x^2+1=0. Still, complying with Nachlieli & Elbaum-Cohen (2021) suggestion, we propose researchers and teachers, while both teaching and doing research on different forms of complex numbers, to include a discussion about the importance of taking into consideration of i as one of the square roots of √(-1), the principal root. This might be important for both students and teachers to pay attention to the polysemy of the radical sign (Kontorovich, 2018b). This might be further important as the results showed, contrary to one teacher, T5, at first another teacher, T1, considered that the rule √a.√b=√(a.b) in real numbers also holds for complex numbers, indicating complex number bias (Kontorovich, 2018a). However, whenever she thought of i as the number whose square is -1, she could overcome her difficulty with complex number bias on her own.

Another important observation is that T4's explanations about comparing real and complex numbers in terms or ordering property is not legitimate when considering R2 and complex plane. T4 had difficulty in positioning i on the complex plane as she considered order quality within the realm of real numbers. However, in R2 ordering the elements is not possible either. This suggests that T4 might not have known that for any number pair on R2, there exists exactly one pair of numbers (a,b) on the complex plane such that there is one-to-one correspondence between the ordered pairs in R2 and complex numbers, an isomorphic structure (Kontorovich et al., 2021). Thus, we argue that both researchers and teachers might provide opportunities with learners to first establish R2 quantitatively on the part of both students and teachers (Karagoz et al., 2022). Previous research has pointed to the importance of understanding of a point as a multiplicative object (Karagoz et al., 2022; Thompson et al., 2017) that is formed from two quantities by mentally uniting "their attributes to make a new attribute that is, simultaneously, one and the other" (Thompson et al., 2017, p.96). Karagoz et al. (2022) further stated that thinking about a point on the plane, an ordered pair in the form of (a, b), as a multiplicative object as the point say, A = (a, b) can be thought of as a cognitively uniting of two quantities' magnitudes (Saldanha & Thompson, 1998; Stevens & Moore, 2017). This also aligns with Gravemeijer (2020)'s emphasis that learners should understand that each point on the Cartesian plane is a number pair signifying two connected measures. As the results of the study suggest, conceptualizing R2 in a quantitative structure might be a precursor to an understanding of isomorphism between R2 and the complex plane.

Furthermore, aligned with earlier research (Nemirovsky et al., 2012; Soto-Johnson and Troup, 2014), results showed that all the teachers could think of i as a 90-degrees rotation operator. Results also showed that this further allowed for all the teachers to think of the powers of i as points located on the complex plane. Moreover, one teacher could think of ib considering both the rotation and dilation operator meanings. That is, results suggested that she could consider i as a multiplier and b as a multiplicand and b as a multiplier and i as a multiplicand. We argue that such a dual understanding of ib needs to be further investigated. Previous research has pointed to how a classroom floor afforded the ways for pre-service teachers to make sense of multiplying with i as a rotation operator. However, how learners come to such an understanding might be further investigated with clinical studies, such as teaching experiments. In addition, as the results pointed, such understanding is one part of the coin, which also includes thinking of b as a multiplier and i as a multiplicand. Research on multiplication with rational numbers points to two types of reasoning models, namely as repeated addition and as multiplicatively. The repeated addition view is considered as limited and primitive (Fischbein et al., 1985). Similarly, Thompson and Saldanha (2003) argued that "repeated addition is a quantification technique; it is not the thing being quantified" (p. 104). On the other hand, understanding of multiplication multiplicatively requires thinking about "times as much" (Thompson & Saldanha, 2003) as the learners consider "...both the product and the factors of the product (i.e., the multiplier and the multiplicand) in relation to it" (Karagöz et al., 2022b, p.114). Further thinking about the dilation (i.e., stretching and shrinking) meaning of multiplication, we argue for extending research on multiplication with rational numbers, and doing research on understanding multiplication of i with real numbers. This is specifically important as the results in T1's explanations suggested that a dual meaning of multiplication of i with real numbers might have roots in understanding the roots of quadratic equations quantitatively in relation with vectors. Also, previous research has shown that pre-service teachers do not have a multiplicative understanding of multiplication (e.g., Karyağdı, 2022).

In this study, focused on five inservice teachers. Further research can be done to investigate students' and preservice teachers' conceptualizations of different meanings of i with a larger number of participants.

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Integrating Environmental Sciences into Regular Higher Education Curriculum to Facilitate Transition into a Sustainable Society: A Case Study

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Abstract: We live in environmentally turbulent times where issues such as freshwater scarcity, soil and air pollution, natural disasters and depletion, biodiversity loss, and infectious diseases pose a serious danger for future generations. Climate change is one of the most significant modern threats, the solution to which requires the engagement of different social branches. Every year many students complete higher education institutions in Azerbaijan. From those, only 20% engage in environmental studies. As a result, only these graduates receive education in current environmental problems and their possible solutions. To tackle this problem, the Environmental Science course was introduced at ADA university for students from all disciplines, including policymaking, economy, technology development, and science. Since the Fall of 2017, more than 2,500 students have successfully completed the course as part of their bachelor's studies. In the scope of the program which includes both theoretical and field studies, students have visited the national reserves and parks, industry facilities, received insight into current global and local policies, and unresolved problems. The students have further developed and successfully presented their projects related to environmental health and circular economy. A number of students continued their education in the field of environmental policy diplomacy and currently work for local and international environmental organizations. The aim of this initiative is to support the transition towards a global circular economy, help address the country's pollution and deforestation issues, and preserve biodiversity through engaging youth from all areas of expertise in environmental problems of our times.

Keywords: Environmental science, Education, Environmental Ethics, Public Awareness

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Introduction

Environmental health emergency

Environmental science has risen in importance in the high school and university curriculums during the last few decades due to environmental emergency. An environmental emergency refers to a sudden and severe event or situation that poses an immediate threat to the environment and may also have a significant impact on human health, property, or natural resources. These emergencies can arise from natural disasters, industrial accidents, or human activities that result in severe environmental damage. Environmental emergencies require swift and coordinated responses to mitigate the risks, minimize the damage, and protect both the environment and human well-being (Donna Rescorl et al., 1995).

Role of education in public awareness

In response to environmental emergencies, governments, international organizations, and local communities work together to mobilize resources, develop emergency response plans, and coordinate relief efforts. Prevention and preparedness are crucial elements in minimizing the impact of environmental emergencies (Tang et al., 2022). Education is a powerful tool in addressing and solving environmental problems, as it plays a crucial role in raising awareness, fostering understanding, and promoting sustainable practices. In today's world, where environmental issues are becoming increasingly urgent, equipping individuals with knowledge and skills to become environmentally conscious and responsible citizens is paramount. Education not only empowers individuals to make informed decisions and take environmentally friendly actions but also serves as a catalyst for collective action and systemic change. UNESCO has called for Education for Sustainable Development to be a core component of all education systems at all levels by 2025 (UNESCO Declares Environmental Education Must Be a Core Curriculum Component by 2025, 2021).

Education is a powerful tool in addressing and solving environmental problems, as it plays a crucial role in raising awareness, fostering understanding, and promoting sustainable practices. In today's world, where environmental issues are becoming increasingly urgent, equipping individuals with knowledge and skills to become environmentally conscious and responsible citizens is paramount. Education not only empowers individuals to make informed decisions and take environmentally friendly actions but also serves as a catalyst for collective action and systemic change (Pauw et al., 2015).

Environmental education

One of the key aspects of environmental education is raising awareness among all groups of students regardless of their major of study. By educating people about the current state of the environment, the causes and consequences of environmental problems, and the importance of biodiversity and ecosystems, individuals become more conscious of the urgent need for action. Environmental education provides a platform to communicate scientific findings, share real-world examples, and highlight the interconnectedness of environmental issues with social, economic, and cultural aspects of our lives (Ali et al., 2023)..

In addition to individual actions, education also plays a significant role in shaping policies, practices, and institutions. It equips future leaders, policymakers, and professionals with the knowledge and tools necessary to address environmental challenges effectively. By integrating environmental education into formal curricula, vocational training programs, and professional development initiatives, societies can ensure that environmental considerations are integrated into various sectors and decision-making processes (Fang et al, 2023).

Furthermore, education promotes a sense of environmental stewardship and fosters a connection with nature. It encourages individuals to appreciate the intrinsic value of the environment and recognize the need for its protection. Through hands-on experiences, outdoor activities, and environmental projects, education instills a sense of wonder and respect for the natural world, fostering a lifelong commitment to sustainable practices (Mayer et al., 2004).

Problem statement

The aim of this study is to promote environmental education as a core curriculum component for all students. Education, encompassing formal learning, public awareness, and training, should be acknowledged as a transformative process that empowers individuals and societies to unlock their maximum capabilities. Its significance lies in promoting sustainable development and enhancing people's abilities to tackle environmental and developmental challenges. Historically, education played a secondary role in addressing environmental and developmental issues, but its importance has grown significantly. Education possesses the potential to shape people's attitudes and behaviors towards their surroundings. Environmental education specifically emphasizes the acquisition of knowledge, skills, and attitudes necessary to effectively address and solve environmental problems.

Method

For this study, statistical data on the overall number of students and the number of students enrolled in pure environmental majors were collected and evaluated. The data collection process involved accessing relevant databases and records from educational institutions to obtain accurate and up-to-date information. The collected data were then organized and analyzed using statistical techniques to gain insights into the enrollment trends and the proportion of students engaged in pure environmental majors.

In order to assess the level of awareness, actionability, and career prospects among students after attending environmental science classes, a comprehensive survey was developed. The survey targeted students that complete the ADA University Introduction to Environmental Science class from diverse educational backgrounds (political sciences, international relation, law, business, etc.). The survey aimed to gather valuable insights into the knowledge and understanding gained by students during their environmental science education. The awareness of students was evaluated to gauge their understanding of key environmental issues, such as climate change, pollution, and sustainability. Furthermore, the actionability of students was assessed to determine whether they felt empowered to take individual and collective actions to address these challenges. Lastly, the survey explored career perspectives to shed light on students' aspirations and potential paths within the field of environmental science, promoting informed decision-making and future opportunities. The development of this survey aimed to gain valuable feedback and enhance the effectiveness of the environmental science curriculum, ultimately fostering a generation of environmentally conscious and proactive individuals.

The questions were created in the Google Survey form and the link was sent to students via Blackboard system. The participants do not need to provide their email address or their name. This makes it easier for them to access the form through any device (computer or phone). The questionnaire consists of 12 multiple choice questions and one open question. The responses included five options: “Strongly disagree, Disagree, Neutral, Agree, and Strongly agree.”

Table 1. The questions used in the survey

#	Question
1	I understand modern environmental problems better than before
2	I feel more engaged in the modern environmental issues
3	I want to find ways to take action against environmental issues more that before I took the class
4	I feel more helpless against environmental problems
5	Since taking the class, I have taken steps to counter environmental problems (even tiny steps count!)
6	Please list the steps or actions you have taken to counter environmental problems (even small steps, like sharing facts with friends and reducing plastic use, count!) Otherwise, leave empty
7	Since taking the class, I wish I behaved more sustainably
8	The class has prompted me to consider integrating environmental questions into my career plans
9	Since taking the class, I feel more equipped to take action against environmental problems
10	I have decided to link my future career with environmental questions
11	I believe the class is useful to people from any career path
12	I believe introductory environmental classes should be mandatory to all high school and university students

Results

Statistical data results

In Azerbaijan, during the period of 2021 to 2022, a total of 36,448 students successfully completed their bachelor’s degrees. While this demonstrates the dedication and hard work of these students, it is notable that only a small fraction of them, around 1,000 students per year, chose to pursue studies specifically focused on the environment.

ADA Case Study: Introduction to Environmental Science Course

ADA university introduced the Environmental Science Course for students from all disciplines, including policymaking, economy, technology development, and science. Since the Fall of 2017 more than 2,500 students have successfully completed the course as part of their bachelor's studies. The program includes both theoretical and field studies. In addition, the study of environmental ethics is of paramount importance for students as if employes a sense of moral responsibility, fosters an understanding of environmental issues, and equip them with necessary knowledge and skills needed to address environmental challenges. To shape the next generation of environmentally conscious citizens and professionals, and increased environmental awareness has led ADA University opened a course of Environmental Ethics within the scope of General Education Program. Each academic year around 600 students take this course as the university core course.

Results of survey

Through the analysis of survey responses, compelling evidence emerged that confirmed the positive outcomes of environmental science education. The results indicated that a significant majority of students experienced a substantial increase in their understanding of key environmental concepts and challenges, such as climate change, biodiversity loss, and sustainable practices (Figure 1).

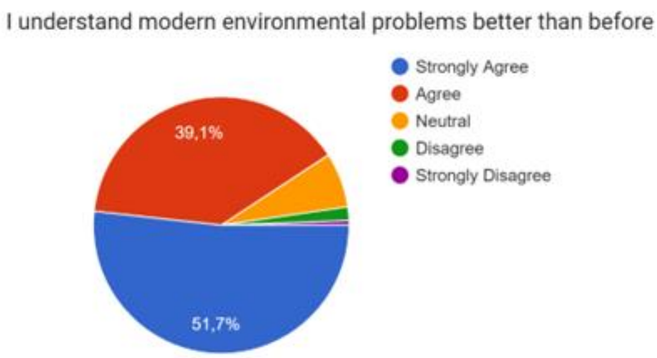

Figure 1. Survey result on Awareness Increase

Furthermore, the survey revealed notable shifts in students' attitudes towards environmental conservation, with an enhanced sense of personal responsibility in adopting eco-friendly behaviors (Figure 2). Importantly, the findings demonstrated that the environmental science classes were highly engaging, informative, and relevant to students' everyday lives.

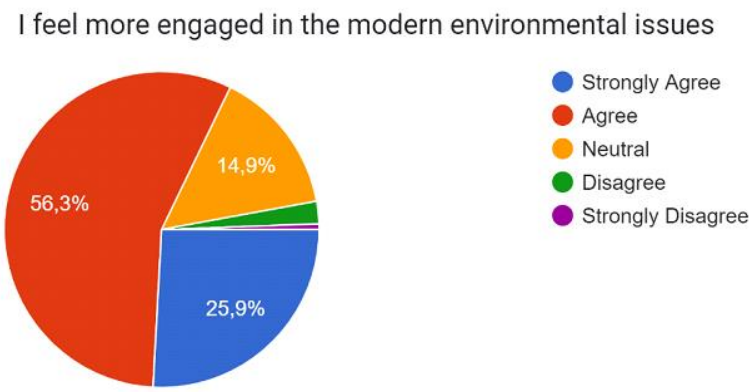

Figure 2. Students' Engagement in the modern environmental issues

More than 86.8% of participants agreed and strongly agreed that the Introduction into Environmental Sciences (IES) classes are useful to students from any career path, and only 3.5% of responders disagreed and strongly disagreed. Most students (85%) participated in the survey agreed that IES classes should be mandatory for all high school and university students. More than 80% of participants indicated that feel more engaged in the modern environmental issues.

This research provides valuable insights into the transformative potential of environmental science education, empowering students from various backgrounds to become active and informed environmental stewards (Figure 3).

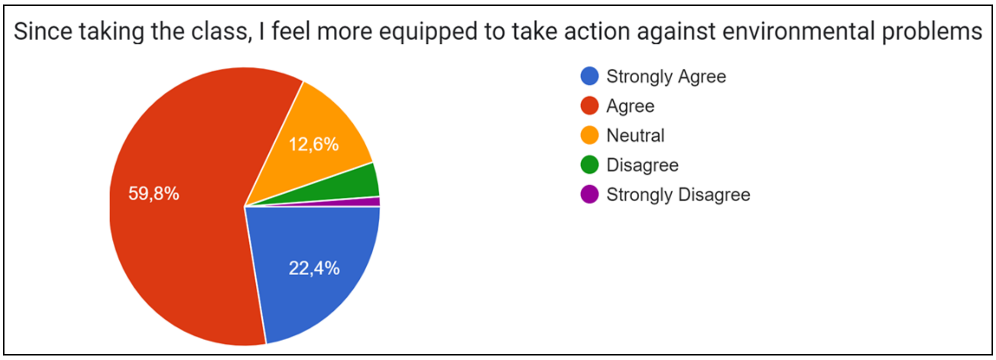

Figure 3. Knowledge capacity enhancement

Around 65% of students were prompted to consider integrating environmental questions into their career plans and besides that more than 30% of responders decided to link their future career with environmental questions (Figures 4 and 5).

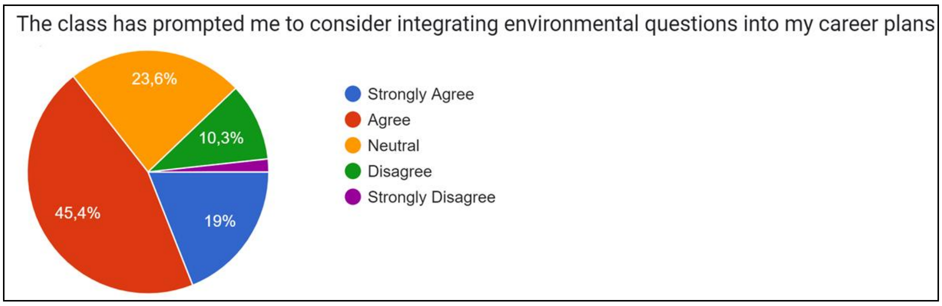

Figure 4. Impact of classes on the career plans

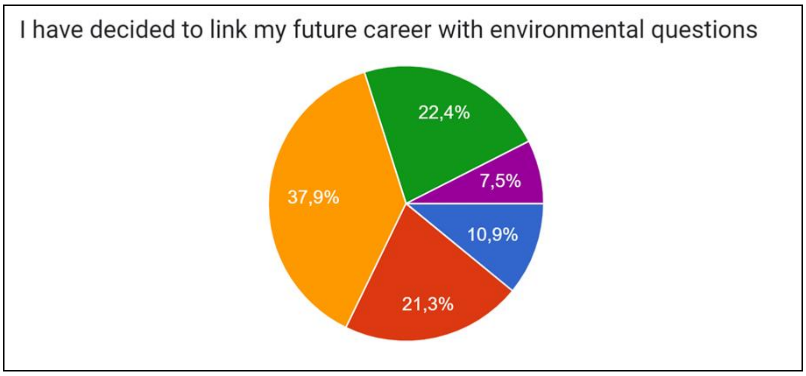

Figure 5. Linkage of the future career with environmental aspects

According to the survey, 90.8% of participants mentioned that they started understanding modern environmental problems better than before. In addition, more than 50% of students reported each of the following emotions: sad, anxious, angry, powerless, helpless, and guilty consistent with other publications (Hikman, 2021).

Most participants (82.2%) stated that feel more equipped to take actions against environmental problems, which shows that understanding and introduction into practical applications increased self-belief. Around 80% of participants reported feeling more responsibility towards climate issues. According to the survey, more than 70% reported to have taken actions regarding environmental issues (Figure 6).

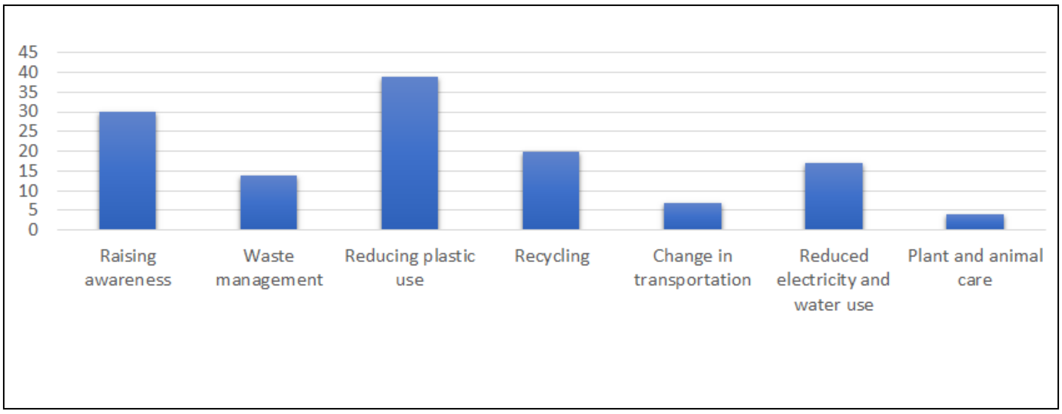

Figure 6. Actions reported by students.

Following the completion of environmental science classes, many students showcased their success through impactful projects. These projects reflected their newfound knowledge and skills acquired during their coursework. One notable project involved the design and implementation of a community recycling program, which significantly reduced waste and promoted sustainable practices in the local area. Another student undertook a research project on the effects of pollution on nearby water bodies, leading to important findings that highlighted the need for stricter environmental regulations.

Additionally, some students-initiated awareness campaigns, organizing events and workshops to educate their peers and the wider community about environmental conservation. These successful projects exemplify the practical application of classroom teachings and demonstrate how students can contribute positively to addressing environmental challenges.

Such accomplishments further highlight the tangible benefits of environmental science courses in empowering students to become proactive agents of change in their communities. These are some examples of the successful projects: Reuse for Youth, Reducing plastic usage; Caspian Sea Beach Cleaning Project; "Eat or Feed" decrease food waste and promote sustainability by reusing leftover food; "EcoPaws" increases public awareness about the negative effects of food waste and many others.

To provide ADA students with more comprehensive approaches to practical segments of the local environmental issues, the university cooperates with the local and international companies. With cooperation of the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan and GIZ (The Branch of German Federal Ministry for Economic Cooperation and Development) the university organizes study trips to national parks to enhance students` projects on the environmental issues. About 20 ADA students' effective environmental initiatives submit applications for the Haji Zeynalabdin Taghiyev Award, the highest award of the university for social projects.

Discussion

Empowering individuals is another crucial aspect of environmental education. Through education, individuals gain a sense of agency and become aware of their role as active participants in environmental conservation. They learn about sustainable practices, such as reducing waste, conserving energy, and adopting eco-friendly lifestyles. Education empowers individuals to make informed choices and take action to mitigate environmental degradation in their daily lives. Additionally, education equips individuals with the skills necessary to advocate for policy changes and implement effective environmental initiatives at local, national, and international levels.
Furthermore, education plays a pivotal role in shaping policies and practices related to environmental protection. Through research, analysis, and informed decision-making, policymakers can develop effective strategies to address environmental challenges. Educational institutions, in collaboration with government bodies and non-governmental organizations, can contribute to the formulation of environmentally conscious policies and

provide the necessary expertise for their implementation. By integrating environmental education into school curricula, policymakers can ensure that future generations are equipped with the knowledge and skills needed to navigate environmental complexities. As we strive to create a sustainable future, investing in comprehensive and inclusive environmental education becomes crucial. It is essential to reach individuals from diverse backgrounds and communities, ensuring equal access to environmental education regardless of socioeconomic status or geographic location. By promoting inclusivity, we can cultivate a sense of global environmental responsibility and foster collaboration across borders.

Conclusion

In conclusion, education serves as a powerful tool in solving environmental problems and promoting environmental awareness on a global scale. The role of education goes beyond simply imparting knowledge; it plays a vital role in shaping individuals' attitudes and behaviors towards the environment. By raising awareness about pressing environmental issues, such as climate change, deforestation, and pollution, education enables individuals to comprehend the magnitude and complexity of these challenges. Moreover, environmental education fosters the development of critical thinking skills, enabling individuals to analyze environmental problems from multiple perspectives and propose innovative solutions.

In summary, education is a powerful catalyst for change in the face of environmental challenges. By raising awareness, developing critical thinking skills, empowering individuals, and shaping policies and practices, environmental education plays a fundamental role in addressing urgent environmental issues. It equips individuals with the knowledge, values, and skills needed to protect and preserve our planet for generations to come. Therefore, embracing and investing in comprehensive environmental education is a crucial step towards building a sustainable and resilient future for all.

Recommendations

Environmental courses have become increasingly vital in today's world as we face pressing challenges related to sustainability, climate change, and conservation. These courses provide students with a comprehensive understanding of the environment, its interconnected systems, and the human impact upon them. Currently different environmental courses are thought in different universities in Azerbaijan: Baku State University, Azerbaijan State Economic University, Azerbaijan State Agriculture University, Azerbaijan Technology University, Mingachevir State University, Lankaran State University, Sumgait State University, West Caspian University, “Odlar Yurdu” University.

With the urgency to address environmental issues and create a sustainable future, educational institutions have incorporated a diverse range of environmental courses into their curricula. It will aid promoting social and economic well-being while minimizing harm to the environment, and gain insights into the potential benefits and challenges of implementing sustainable practices at individual, community, and global levels. In this regards, here are the following recommendations for the introduction of environmental classes to all students:

- Curriculum Integration: It is recommended to integrate environmental education into various subjects across the curriculum, including science, social studies, and the arts. This interdisciplinary approach will provide students with a holistic understanding of environmental issues and their interconnectedness with other disciplines.

- Teacher Training and Professional Development: Comprehensive teacher training programs and ongoing professional development opportunities should be provided to educators. This will equip them with the necessary knowledge and pedagogical skills to effectively teach environmental concepts. Emphasis should be placed on innovative teaching methodologies, hands-on learning experiences, and the use of technology to enhance engagement and understanding.

- Practical Experiences: Incorporating practical experiences such as field trips, outdoor activities, and hands-on experiments is highly recommended. These experiences will enhance students' engagement and understanding of environmental issues by allowing them to observe and interact with the natural environment firsthand.

- Community Engagement: Collaboration with local communities, environmental organizations, and experts is essential. This collaboration will provide students with opportunities for real-world application of their knowledge, engaging them in community projects, environmental restoration initiatives, and sustainability campaigns.

- Global Perspectives: Introducing global perspectives on environmental issues is crucial. Incorporating case studies and discussions on environmental issues from different regions of the world will broaden students' understanding of the interconnected nature of environmental challenges and the importance of global cooperation.

- Assessment and Evaluation: Developing appropriate assessment methods to evaluate students' knowledge, attitudes, and behaviors related to the environment is recommended. Assessments should go beyond traditional exams and include performance-based tasks, project-based assessments, and portfolios that reflect students' understanding and application of environmental concepts.

- Long-Term Commitment: It is important to consider environmental education as an ongoing and long-term commitment rather than a one-time initiative. Continuous evaluation, feedback, and improvement of environmental education programs will ensure their effectiveness and relevance over time.

Implementing these recommendations will establish a solid foundation for fostering environmental literacy among students and empower them to become active and responsible stewards of the environment. By integrating environmental classes into all students' education, we can cultivate a generation equipped with the knowledge, skills, and values necessary to address environmental challenges and create a sustainable future.

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Little Miss Strange: Online Education for Empowering Women from Under-Represented Groups

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Abstract: In many countries, opportunities for higher education are reduced for some under-represented groups in society. One such group are young women from rural and underdeveloped areas who due to traditional, patriarchal lifestyles have much less chance to go to college and get education that their peers from urban areas have much more access to. Online education opens doors for these women, but they still need support and guidance. WINnovators, a 3-year EU Erasmus+ project started in late 2021, has made steps towards providing such support and guidance. It focuses on providing online learning content in different areas of STEM/STEAM and aims at encouraging young women from rural areas to go through such content, develop their entrepreneurial skills, and possibly come up with ideas of how to start their own businesses. Of course, this vision largely contradicts traditional lifestyles. Still, it creates some chance for at least partial leveling with other groups in society. To provide guidance to these women, university students guide them in using the online learning content and taking the learning challenges that eventually lead to raising their awareness of how to break on through to the other side. The paper explains this process and illustrates it by a case study.

Keywords: Online education, Women, Under-represented groups.

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Introduction

By under-represented social groups, researchers and social workers usually mean nondominant groups such as people of color, people with disabilities, people with a lower socioeconomic status, LGBTQIA+ people, ethnic and/or religious minorities, elderly people, women, immigrants, homeless people, low-income earners, single parents, first nations / indigenous people, and the like (Drew, 2023; Hamlet, 2017). Unfortunately, such marginalized groups often have limited representation and voice in education, politics, and decision-making processes and bodies in society. This lack of representation in society has real impacts on the lives of those affected, because partial or complete exclusion of marginalized groups from conversations and decision-making processes puts them at risk for being oppressed and having policies made *about* rather than *for* them (Ezorsky, 2018). Likewise, these groups often suffer from various forms of discrimination – from taste and statistical discrimination, to institutional discrimination (which can be immaterial, but hard-hitting), to various forms of everyday interpersonal discrimination (Small & Pager, 2020). All these types of discrimination can be highly consequential, although sometimes actors do not perceive clearly that they have experienced discrimination.

The research presented in this paper focuses on a specific under-represented group: young women from largely undeveloped and usually rural areas, where traditional and often patriarchal lifestyles still prevail. Due to hard economic, financial, and social conditions, these women often stay short of opportunities for proper education. It is long known that living in a city typically offers greater access to education and wider employment opportunities (Azcona, et al., 2019). In the case of young women, it also typically means greater independence, lower fertility rates, and higher gender equity. Still, moving from rural areas to a city can be difficult for young women, because of family, financial, and other reasons.

The *WINnovators project (Boosting young women's entrepreneurial spirit and skills to become the women innovators of the future)*, funded by the EU Erasmus+ program (Project No. 2021-1-EE01-KA220-HED-000032081), concentrates on these marginalized women and develops free online courses for them to help them get informally educated and possibly start their own businesses. Preliminary studies of the project participants have shown that in many countries young women from underdeveloped areas can have great ideas of starting and running businesses, but are lacking skills and entrepreneurial approach to put these ideas to life. Note that boosting entrepreneurship among some of the targeted young women does not necessarily mean changing their lifestyles completely – online education and online entrepreneurship can be initially run as a side activity, with minimum costs and moderate effort. On the other hand, to some of them this can be a great door opener for improving their living in the future.

The next section provides more detail about the WINnovators project. The rest of the paper presents a case study of running online courses for under-represented young women. A number of these courses are developed and uploaded on a dedicated online platform, called the WINnovators platform.

The WINnovators Project

WINnovators (https://www.winnovators.eu/) is a three-year project in the area of capacity building in the digital, entrepreneurial, STEM/STEAM innovation and sustainability fields, for the benefit of young women in rural areas and outskirts regions, higher education students, and teachers. The project is conceived as a series of activities to create suitable online teaching and training materials that encourage innovation, critical thinking and problem solving using STEM/STEAM knowledge, i.e. knowledge from science (S), technology (T), engineering (E), art (A) and mathematics (M) (White, 2014). The young women it targets are envisioned to be between 19 and 29 years old and facing socio-economic difficulties in applying to get educated in high-quality educational institutions (Radenkovic et al., 2022).

The partners in the project consortium include institutions from five European countries – Estonia, Serbia, Slovenia, Romania and Italy. The project activities are designed to also involve stakeholders other than the targeted young women. These other stakeholders and their roles in the project are:

- university teachers – experts from different fields (pedagogy, social sciences, computer science, information systems, finance, marketing, management, etc.) with skills in creating online courses
- university students – predominantly female students who mentor targeted young women in their activities and help them come up with innovative, feasible, and sustainable business ideas
- education management bodies and policy makers in the partner countries – individuals and organizations responsible for advancing educational regulations to enable disadvantaged individuals to get access to high-quality education and overcome geographical, social, financial, and other obstacles on that path
- educational associations, networks, and training and research centers – organizations with large lists of contacts that provide knowledge transfer to targeted learners and encourage and incentivize the learners to develop their entrepreneurial skills
- relevant SMEs and technology transfer consultants – IT, business, and educational technology companies with trained and skilled employees that support technical, innovation, and business aspects of the project

The synergy of these stakeholders has resulted in creating:

- a new online platform – the WINnovators platform – an interactive online working space that stores all learning content for the targeted learners and enables detailed online interaction between the learners, their student mentors, and the teachers
- a gamified support for learners and their learning activities on the WINnovators platform – each successful completion of a learning activity or a challenge is awarded by an appropriate digital badge, thus increasing the learners motivation and enabling them to demonstrate their newly acquired skills to

third parties online

- an open collection of best training practices – the collection was initially created by the pedagogical experts from the project, and is regularly updated with new experiences with the actual learners
- a collection of recommended policies – these suggest valuable measures to policy makers in order to tackle the lack of opportunities for under-represented young women in terms of getting better education and starting and running their own business

Methods

In practice, the WINnovators project works with under-represented young women as follows:

- in three partner countries – Estonia, Slovenia, and Serbia – relevant project participants promote the WINnovators opportunities among targeted young women and assemble the interested ones to join the courses and work together with the project team to get educated in different STEM/STEAM topics; these country-based learning cases come in cycles, each cycle taking several months
- the learners get in touch with the WINnovators teachers and students from their respective countries and get guidance in joining and using the WINnovators platform; to do that and start taking courses and challenges from the platform, they only need Internet connection and can access the platform using their phones (the platform is optimized for phone access)
- once the learners are familiarized with the platform, they start taking courses and challenges they select from all of the courses and challenges uploaded on the WINnovators platform; each learner is assigned a student mentor as the first contact person to get in touch with whenever it's necessary
- during the learning phase, all learners are encouraged to come up with their own ideas for starting a business; examples of such ideas are starting agro-tourism on a farm, collecting and selling medicinal plants, selling specific home-made products online, providing guidance to hiking groups and nature lovers, and the like
- those who don't come up with their own ideas for starting a business or an innovative activity get help from their mentoring students and teachers in one or more brainstorming, motivating online sessions
- student mentors track all of their students' activities online and through direct interaction with them, thus collecting data about all relevant activities in each cycle
- student mentors and teachers award appropriate badges to learners as tokens of recognition for their learning attainments
- in the end of the cycle, the project team analyzes the data collected during the cycle activities and spots weak points and makes improvements for the next cycle accordingly

In the last phase of the project, the accumulated collection of best training practices and the collection of recommendations to education policy makers will be presented to policy-maker representatives from each of the WINnovators partner countries. This event will include representatives of all types of the WINnovators project stakeholders (see the previous section). The project dissemination among policy-makers in each partner country, in social media, and through numerous other dissemination activities is a continuous activity, running from the very beginning of the project. In addition, demographic expertise and different women associations are consulted and deployed whenever necessary in order to target potential learners in the best possible way (the results of this process are explained in the next section).

At the time of writing this paper, the first cycle of working with groups of under-represented young women – the targeted learners – is ongoing. The approach to building teams (learners + student mentors) slightly differs from one partner country to another, but in general all learners have their student mentors to guide them through the process. There are country-based weekly online meetings for all the learners, the student mentors, and the teachers, to discuss the learners progress, to enable the learners to reflect on their own progress relevant to that of the other learners, and to share experiences.

Who Is Little Miss Strange, Actually?

Research shows a great statistical variety when it comes to women running their own businesses. To an extent, this is due to the level of development of the country and/or geographic region where the statistics are taken. For example, 42% of all businesses in the USA are owned by women (33% in Europe), and, somewhat paradoxically, less-populated cities and states have more women-owned businesses that are successful in terms of revenue and employment (Dorn, 2023).

Most women business owners there are Gen X women (born between 1965 and 1980), about 69% of all female business owners, followed by boomers (born between 1946 and 1964), about 19%. In Latin America and the Caribbean, 50% of SMEs have at least one woman as one of their principal owners, but only 23% so in The Middle East and North Africa, and only 18% in South Asia. For example, among rural small business owners in India, only 8% are women, although there are 38% women solopreneurs in rural areas there (Naseer, 2022); women solopreneurs refer to individual women running their home-based, non-farm business.

Also, most of these women entrepreneurs in India (58%) were in the age range of 20-30 when they first started out. Their businesses are typically necessity-driven, rather than innovation-driven (which also holds for some African countries, e.g. Egypt and Angola). However, another recent study, also from Africa (Burundi) shows that women entrepreneurs often engage in their businesses out of self-satisfaction, not out of necessities like family and/or social crisis, are typically self-funded (e.g. from livestock ownership), and that their businesses bring life improvement to 75% of such women (Kabagerayo et al., 2022).

What is the situation to this end in Serbia? The WINnovators case study presented in the rest of the paper refers to education of young women from rural areas and outskirts regions in Serbia, thus it is of interest to have at least a big picture about the situation there. Note that the data from the recent census (2022) are still not publicly available, hence statistics are incomplete.

Still, it is known among demographers that rural settlements in Serbia are characterized by intensive depopulation due to emigration and negative natural growth, resulting in an advanced demographic age. The median age of the population of Serbia is now 43.8 years, 45.2 for women (from the yet unpublished data from the latest census). Out of all women living in rural and outskirt areas, only about 10% are in the age group 20-30, which is about the relevant age group for the WINnovators project.

An earlier study (Babovic, 2012) has identified that the vast majority of women entrepreneurs lived in urban settlements (82.2%), that trade was their dominating industry (46.8%), that only about 12.7% of them belonged to the age group 19-29, and that about 66% of them had degrees only from secondary education establishments. An encouraging figure from that study indicates that 38.2% of women entrepreneurs had started their businesses after coming up with a promising business idea they wanted to pursue, and an additional 20% of them wanted to take on new challenges. However, 58% of their initiatives have been necessity-driven, rather than innovation-driven. More than 75% of women entrepreneurs from that study have declared that they had consultancy and guidance only from family members and friends. 43.2% of these women thought that further education was essential for their businesses, and an additional 35.5% thought that it was important, although not essential. A vast majority of them (72.3%) have never taken any additional course.

Interestingly, the same authors have repeated their study ten years later (Babovic & Stevic, 2023). Key findings from this new study indicate that there are many "new" women entrepreneurs in Serbia (those who have started their businesses during the last decade). Their profile has changed to an extent over the 10-year period – they are on average 4-5 years older (46.3 years) than in the first study (41.9 years), there are much less of them in the age group 19-29 (only 4.5%, as opposed to the 12.7% in the first study), and they are much less in the trade sector than before (24.2%) although it is still their dominating sector. However, most of them still run micro businesses in urban areas. Likewise, women entrepreneurs do not show interest in additional education and training, and only a small proportion of them innovate and report that innovation has proven to be the key to success.

Recent statistics confirm stereotypes about women in Serbia: they work in the household twice as much as men, regardless of whether they are employed or not (SORS, 2020). This unpaid work is referred to as "the second shift" for women. There are slightly more than 30% of women, typically self-employed, who work in agriculture and for whom it is reasonable to assume that they live in rural areas. The proportion of self-employed women who work in services in Serbia is much higher, about 65%. Recent data about the exact entrepreneurial activities of women in Serbia are still incomplete and imprecise; the proportions are expected to be different with regard to those from the previous census (2011), but until they become officially available one can only assume the exact figures.

So, where do the WINnovators project participants find the targeted under-represented young women to offer them free educational services through the WINnovators platform? The metaphor from the paper title and from the title of this section, Little Miss Strange, is not a coincidence. There are very few marginalized young women in rural, depopulated areas, who would simultaneously take an educational journey on the WINnovators platform. Even if they did, it might be considered strange in their local communities, given the hardship of living the life they do, with very little time for anything else but the family, household, and other duties.

In reality, many young rural women all over the world increasingly move or have already moved to urban areas, often together with their families. True, in underdeveloped countries they are often still denied the same educational benefits and opportunities that cities offer to men, especially if they can only afford living in urban slums (Azcona, et al., 2019). Yet, the "urban calling" there echoes a little stronger. The WINnovators participants from Serbia have managed to find some of their Little Miss Strange women in these communities. Another group has been identified in rural settlements close to larger cities, where there are young women who do not want to emigrate to cities. Thus contrary to the initial vision of the WINnovators participants from Serbia, the demographic reality has indicated that the targeted learners do not have to be reduced only to villages with scarce demographic potential, but also to peripheric smaller urban settlements.

Results

A necessary prerequisite for all learning activities in the WINnovators project was to develop the WINnovators platform first. The platform has been developed and tested by the project participants during the first year of the project activities. All learning materials are uploaded there and much of the interaction between the project stakeholders run through the platform.

Two cycles of learning activities with different groups of under-represented young women have been envisioned in the project: the pilot cycle, and the first regular cycle. The pilot cycle has been envisioned much as a regular cycle, with an additional objective of getting a feeling how everything will work in practice, with learners of different backgrounds. At the time of writing this paper, the pilot cycle is still ongoing.

All technical and practical deficiencies and weaknesses spotted during the pilot cycle have to be reported and analyzed by the project team and eliminated or at least mitigated before the first regular cycle. After the end of the project, the WINnovators partners intend to continue with running regular cycles periodically.

The WINnovators Platform

When a user logs on to the WINnovators platform, their personalized starting page looks as the one shown in Figure 1. The Teams tab takes the user to the list of teams of learners and students that work together on the platform, Figure 2. All teachers, learners, and student members can check out all ongoing activities in all teams, Figure 3.

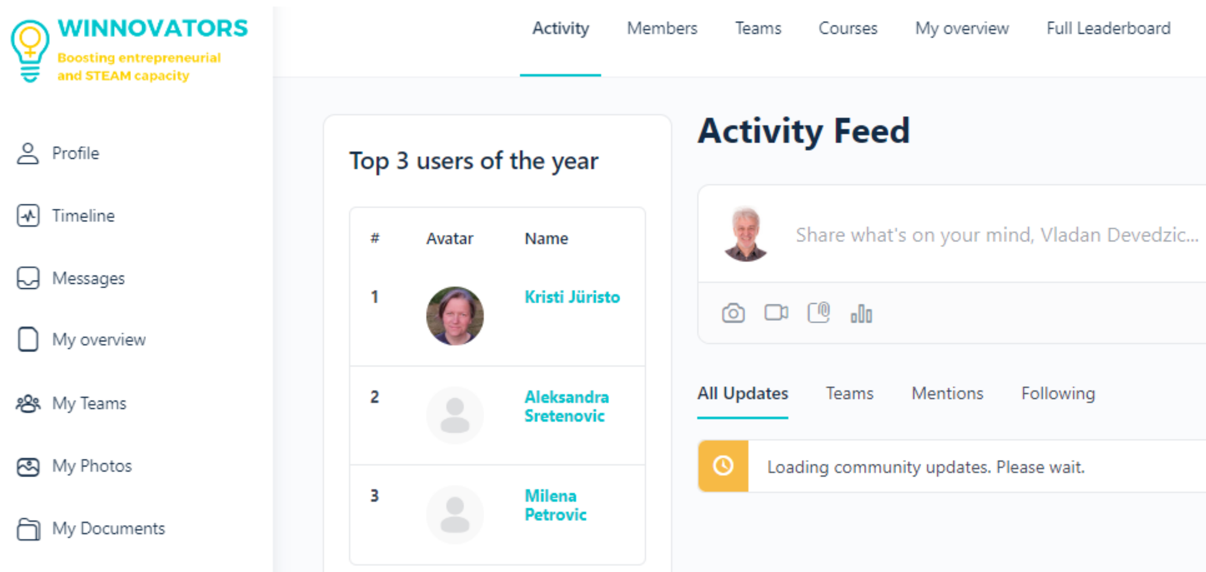

Figure 1. Part of the Home Page of the WINnovators Platform (Personalized for a Specific User)

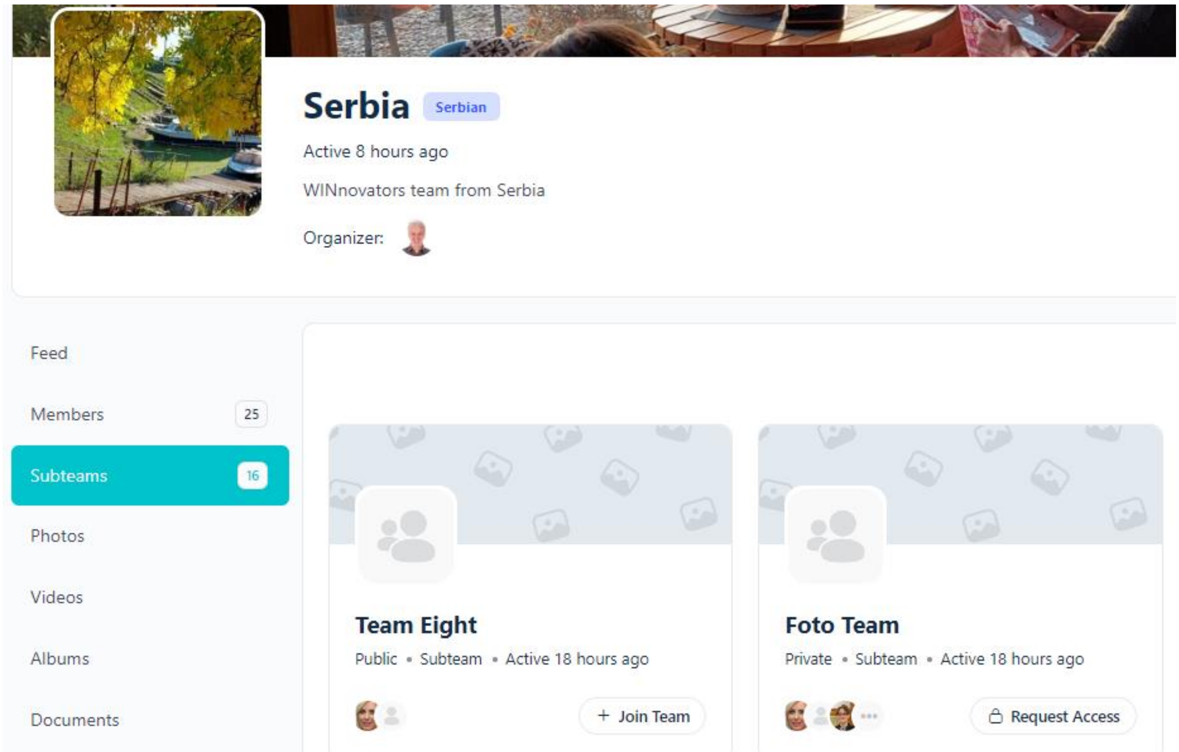

Figure 2. Some of the Teams working on the WINnovators Platform

The Courses

The Courses tab shows *groups* of courses (modules) for learners to select from, Figure 4. There are General Learning Resources, aka beginner-level courses to take first, Figure 5 (left). They will prepare the learners for advanced-level courses, or Challenges Figure 5 (right). A notable difference between the General Resources and

Challenges is that Challenges assume that the learner will *develop* and/or *create* something in order to complete the course, whereas the assessment activities pertaining to the courses in the General Resources category are not that demanding. Note that Figure 5 shows only part of the courses for learners to select from; in reality there are 19 courses in the General Resources category, and 7 courses in the Challenges category. There is no restriction in terms of how many courses a learner can take and in what order, since all of their activities are monitored by their respective student mentors and all their attainments are awarded by specific badges.

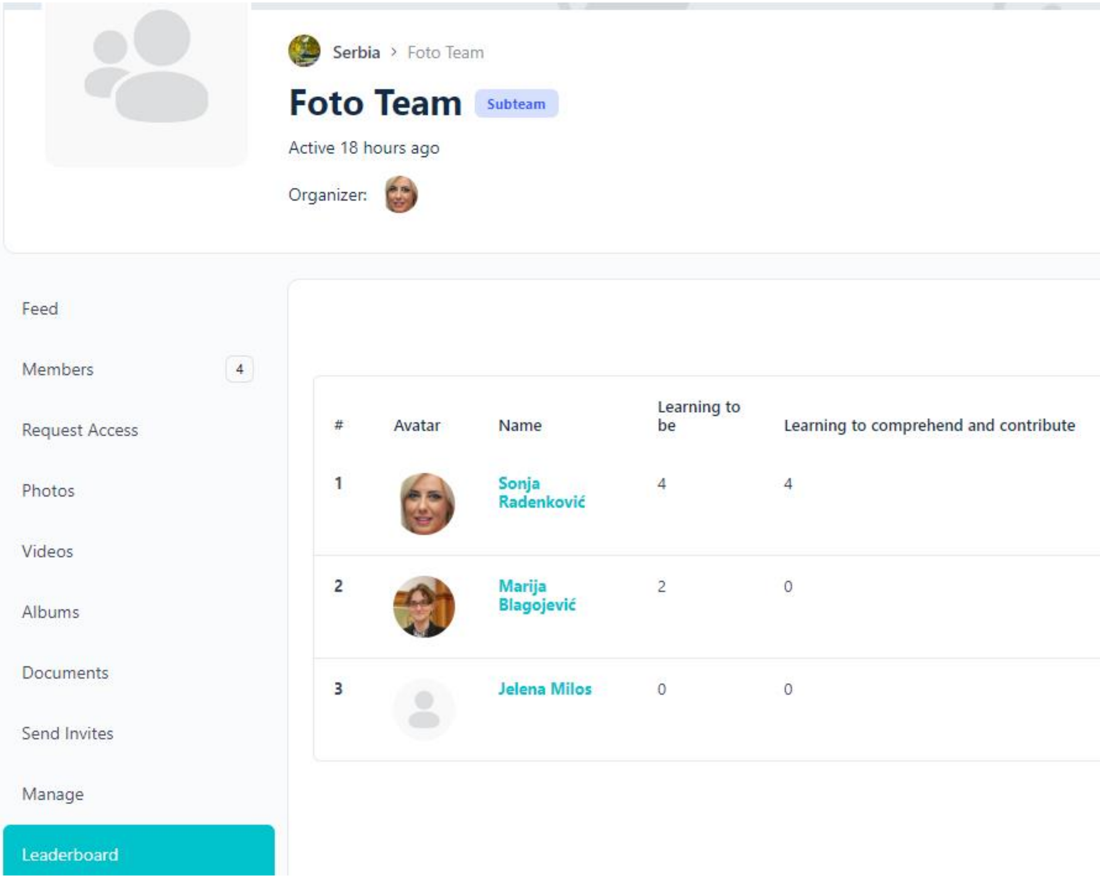

Figure 3. A Specific Team

All courses are organized in suitable multimedia lessons, Figures 6 and 7, followed by exercises and assessments. The learners can always ask their student mentors for guidance during their learning. However, they are expected to complete the assignments on their own.

The pilot cycle

The pilot cycle in Serbia has started with 18 teams – 18 young women and their 18 student mentors. Each young woman has got her mentor, and the teachers from the Serbian team have taken the coordinating roles. Over time, 3 young women have dropped out. The remaining 15 teams have continued to work and the teachers have organized weekly 1-hour online meetings with all the teams to share ideas and report difficulties with using the platform. These online meetings have proven to be useful both for the learners and their mentors, as well as for the project team members who get familiarized with real-world situations that arise during the process and can then start actions to improve the platform, the courses, the interactions, and the overall process.

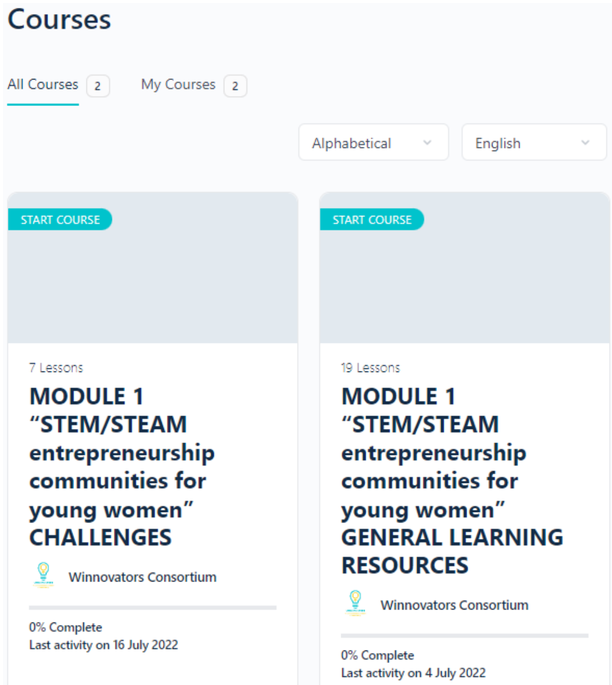

Figure 4. Groups of Courses on the WINnovators platform

Figure 5. Some of the WINnovators Courses – General Resources (Left) and Challenges (Right)

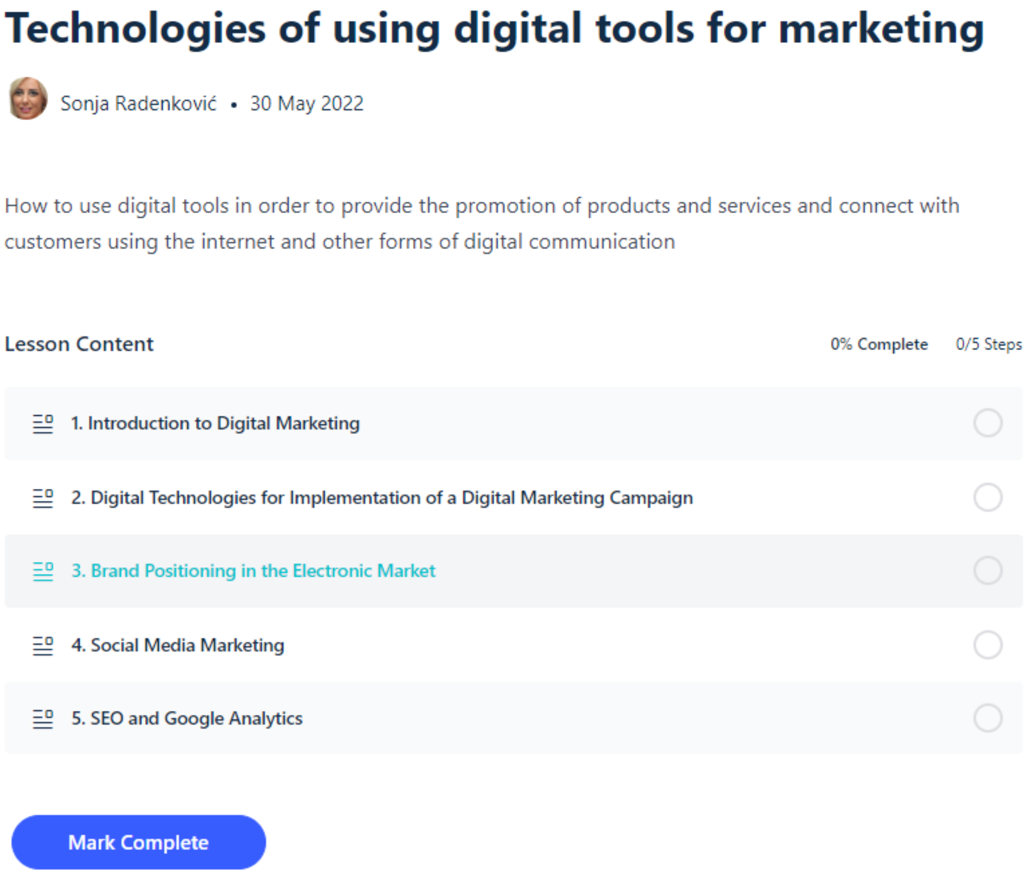

Figure 6. A Lesson from the *Technologies of Using Digital Tools for Marketing* Course

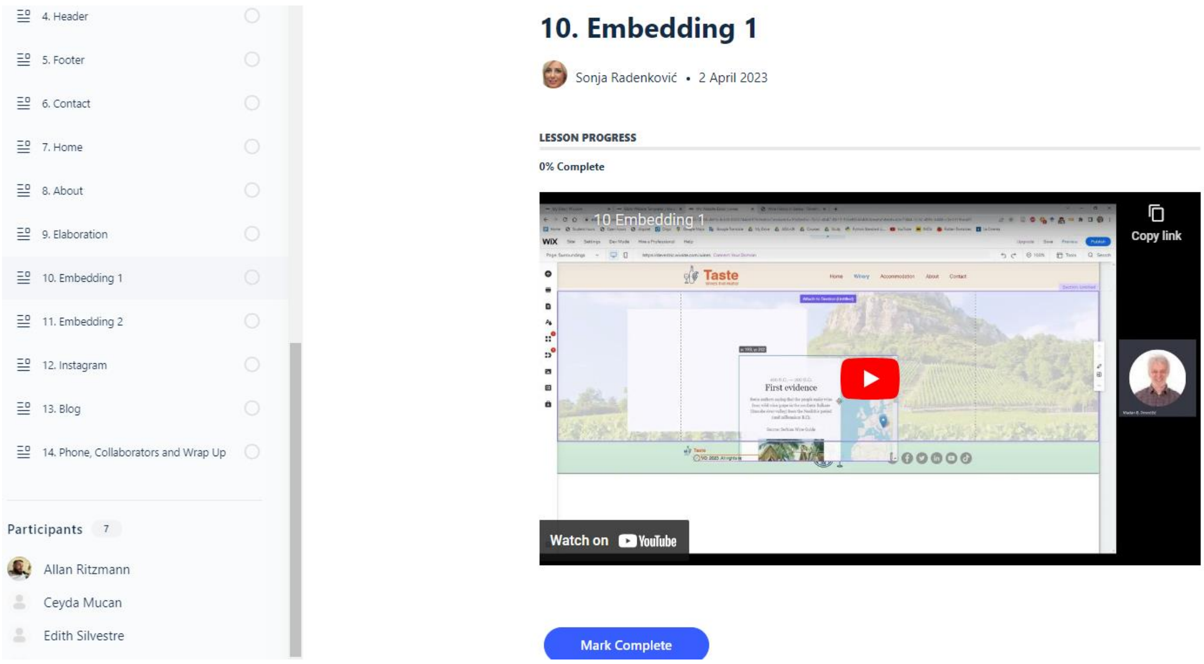

Figure 7. A Lesson from the *Introduction to Web Development* Course

See (Blagojevic et al., 2023) for more details about the courses on the WINnovators platform.

Several useful observations have been made since the beginning of the pilot cycle:

- There is a great variety in the ideas that the teams are developing. Examples include wool processing, collecting and selling medicinal plants, caretaking about elderly people, catering, guiding hiking tours, landscape photography, holistic massage, gardening, craft beer brewery, culinary business, etc.

- The most popular course from the General Learning Resource group is *From idea to business*. The major objective of this course is to learn how to efficiently create the business plan for implementing a business idea and putting it to life. Many learners have already come up with drafts of their business plans. Their mentors and teachers are helping them and encouraging them to complete the plans.
- Most teams work in small steps and do not rush to jump to more advanced topics. Half the way through the cycle, no challenges have been attempted by the teams yet.

- Initial explanations have been necessary. Upon successful registration on the WINnovators platform, the learners have seen a number of courses and have reported that many of them looked appealing and that they were ready to take more than one. Still, in what order to take them? Obviously, the optimal order may be different for different learners, depending on their prior knowledge, their interests, and their ambitions. Thus the student mentors and the teachers have suggested to them what the optimal learning path might be in each specific case.

- The effort the learners put in the learning process varies, depending on their specific private situation, prior education level, and learning objectives. This has resulted in variations in the learning pace from the very beginning. For example, while some of the learners are making slow progress through the learning materials and do not communicate with their student mentors frequently, others have already completed more than one course and have elaborated their business ideas to the point that they plan to apply for funding with different funding agencies to start up their business.

Discussion and the Lessons Learned (So Far)

It is important to understand that the process of attracting young marginalized women to join the WINnovators process and take courses is not always smooth. When the project contacts them, their reactions are different. Some accept the offer immediately, as soon as they learn that the courses are free. Others are reluctant and hesitate joining the teams. The best practice so far has been to approach them through personal contacts ("A friend of a friend").

The same goes for students (mentors). The initial vision of altruistic students who want to help just like that has dissolved quickly. It took some time for the project team to realize that many students have a different idea in mind – "What's in there for me?" The reason is that they are either too busy with their regular duties at the university, or they simply want to keep their time for themselves. The solution to this problem has been found in selecting the students through personal contacts (again), in offering them to join in order to start and run their own small research projects (this has attracted some students of social sciences, especially PhD students), and in arranging with the university management for these students to complete their mandatory internship and earn credits for their work in teams with young women.

Several young women who have joined the pilot cycle obviously did have some vague business ideas already, but have typically lacked experience and skills to put them to life. They have welcomed the idea of having mentors with whom they can further develop their own innovative business approaches, since in their local communities they did not have skilled partners to engage with them in articulating and accelerating their ideas.

An interesting finding from the pilot cycle is that having children did not seem to be a constraint for young women in their ambition to start their own business. Contrary to the popular belief that under-represented young women with children lack interest in getting proper training and that they focus on their family duties only, several young women from the pilot study have completely different mindsets. Possible constraints that they experience in their local communities are of different nature (financial, lack of opportunities, and the like), but their readiness to start and run a business alongside of raising children is evident.

Conclusions

The WINnovators project tries to increase opportunities for under-representing young women to gain new experience and knowledge, as well as to test their own business capacity. Grasping new opportunities for self-accomplishment outside of narrow local mindsets and conservative lifestyles, critically assessing processes of change in the society, and building sustainable alternative futures through improving their own lives is seen as an important move in the lives of these women.

To this end, the project offers online training opportunities for marginalized young women, in several STEM/STEAM fields, with the common objective of giving them a better starting point and incentives to start up and run their own business. The case study presented in the paper – the one related to the ongoing pilot study in Serbia – shows that in spite of initial difficulties such opportunities are welcome among such women. They are ready to put effort in getting an appropriate training and at least partially compensate for the lack of educational opportunities that their luckier peers have when they live in different local communities.

However, to sustain the process of training these young women in the long run (beyond the pilot cycle) it is important to have a clear idea of the demographic picture in the country/region where the training is running. Depopulation is present in rural areas in many countries. Under-represented young women and their families today very often live in towns and in the outskirts of cities, where lifestyles are considerably different from those in villages. *These* young women should be targeted in the future developments of the WINnovators project and in providing training for them after the project ends.

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Building Career Skills in Computer Science Students through Design Thinking Hackathons

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Astract: Career development is an important aspect of every young person's life as it helps them identify their skills, interests and goals and find the right career path for themselves. Career skills are a broad range of competencies and abilities that are necessary for success in the workplace. Developing them through education, training and experience can help students identify them and achieve their career goals. Design thinking is a powerful approach for this purpose. With its components-problem solving, innovation and creativity, collaboration and teamwork, iterative approaches, and empathy-design thinking can help students develop the skills they need to succeed in a wide range of professional fields. The specificity of the hackathon as a form of organization further contributes to building these essential skills that are directly related to students' career development. This paper explores the possibilities of forming career skills in students through design thinking hackathons.

Keywords: career skills, design thinking, hackathon, problem solving, empathy, innovation, collaboration and teamwork, iterative approach

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Introduction

Career skills are a broad range of competencies and abilities that are necessary for success in the workplace. Teamwork and collaboration skills, problem solving, effective communication, creative thinking and creativity, resilience, emotion regulation, self-awareness, work organisation and time management skills, initiative, presentation and technical skills, among others, have been identified as leading career skills (LinkedIn 2023, Indeed 2022). "Future-proof occupations will require communication, managing people, creativity, and specialized knowledge."(Guffey & Loewy, 2023) Developing career skills through education, training, and experience helps to achieve the professional goals one has set for oneself and one's career advancement. The design thinking method can be successfully applied to this purpose as its core elements are problem solving, innovation and creativity, collaboration and teamwork, iterative approach and empathy.Design Thinking as a "way of thinking" in the sciences goes back to 1969 (Simon, 1996), and as a method of creative action it was discussed by Peter Rowe's book Design Thinking (Rowe, 1987), as noted by Val E. et al (Val E. et al., 2017), while its meaning was expanded by Richard Buchanan (1992), Tim Brown (2009) and Roger Martin (2009), to name a few.

Design thinking is a leading methodology for creative problem solving and innovation. It integrates creativity and imagination with analytical thinking and combinativity. It is based on convergent, divergent and lateral thinking and leads to ideas, concepts, solutions, products, articles, etc. that are unique and innovative. Tim Brown, CEO and President of IDEO, defines design thinking as "a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success."(Brown, T., n.d.) It achieves creative problem solving that is rooted in people's curiosity and creative confidence in their ability to change and improve the environment around them. Design thinking does not focus on the problem, but on finding creative solutions, the selection of which is determined by the people for whom the solution is intended. Empathy and putting the person with their experiences at the centre are hallmarks of design thinking. Tim Brown defines design thinking as "a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (Brown 2008).

In the context of developing students' career skills, design thinking appears to be a compatible and valuable approach and can be successfully applied to achieve this goal.

Design thinking is a process-oriented approach to problem solving that emphasizes creativity and innovation as key elements in the search for solutions and emphasizes continuous improvement and refinement of those solutions. This is user-centred thinking, requiring collaboration and teamwork. Therefore, using design thinking techniques, students learn to approach problems systematically, work in teams, communicate effectively, share ideas, and use their strengths to achieve a common goal. They understand the perspective of the end users and build empathy and empathy as key focuses in problem solving. By considering the needs of end users, students find effective solutions to real-world problems. Thinking outside the box, they generate out-of-the-box ideas, develop innovative products and articles. And applying an iterative approach enables them to test and refine their ideas and concepts based on feedback and data, leading to more effective and efficient solutions. More inspiration and insights on the use of different techniques and approaches for applying design thinking in different domains can be drawn from, for example, (Lewrick, M. et al., 2018) A methodological framework on implementing design thinking principles in the context of Experimental Robotics classes is elaborated in (Tramonti, 2023).

Training through competitions has specific features that distinguish it from classical organisational forms of training and is an effective way to develop skills in various areas, including career skills.

In competitions, participants are usually grouped into groups, teams or squads. As a result, collaboration and teamwork skills are built, which is especially valuable in fields where cooperation is an essential component of success. Team members usually have different backgrounds, interests and experiences. This contributes to generating diverse ideas, considering different perspectives and creating innovative solutions, and to the participants themselves broadening their views, perceptions and understandings. Competitions are highly motivating for participants as they have a clearly defined objective with a specific end result and a competitive nature, which is a prerequisite for greater interest and engagement and can lead to more effective learning. Competitions offer students the opportunity to apply their skills in real-life scenarios. This practical experience enables them to better understand the practical applications of the skills they are developing. Competitions are often structured with time constraints, which can help participants develop time management skills and learn to work effectively under pressure. Competitions include feedback and evaluation from a panel of judges and referees. In this way, participants discover areas for improvement and hone their skills through constructive criticism. In the context of career development, competitions provide valuable networking opportunities where participants build relationships with other professionals in the same field and contacts and future career opportunities are created.

A suitable form of organisation that has the characteristics of a competition, and is compatible with the "design thinking" method is the hackathon. The term was coined in 1999 when the first event was held with 10 participants (Wood, 2013, OpenBSD, n.d.). Although hackathon traditionally comes from the software sector, but today it is a term that is associated with problem solving in general, not limited to software programming (Cornelissen, 2020). Hackathons are events aimed at finding creative solutions to problems that are not possible in everyday office life. A hallmark of a hackathon is that the solution is found in a short period of time, e.g. 24 or 48 hours, teams often work unconventionally and without long breaks. At the end of the hackathon there is a completed prototype. The hackathon starts with one or more problems and usually follows a specific theme. There is also an option where participants are given the freedom to choose the problem they want to solve. First suggestions and ideas can be shared before participants start working in groups on the problem. Classically, groups include about five people, who are ideally interdisciplinary. The working phase of the hackathon itself can last from a few hours to several days. The final part is a presentation of the resulting final product to each group. In some hackathons, winners are selected and prizes are awarded. In the context of career skills, hackathons provide opportunities to meet new people, make useful contacts, and meet potential employers. Some best practices in running them are provided in (Accept Mission, n.d.; Hackathon, 2021).

Relative to an educational setting, hackathon and design thinking have multiple intersections that directly correspond to building career skills in learners. Design thinking hackathons require students to solve complex problems in a short period of time by using innovative approaches, analyzing information, developing creative ideas, and testing and refining their solutions in real time based on feedback and data. The problems posed are often related to real-world scenarios and the solution finding is user-centric. Working on real-world problems gives students real insight into how to work in a professional environment. Asking problems that require design thinking and searching for solutions in a hackathon setting puts students in situations that are analogous and close to real-world situations. The time pressure, while stressful, forms in them the skills to concentrate as much as possible and sort out the essential from the unimportant details. Design thinking hackathons require students to think outside the box, generate innovative ideas and explore alternative solutions. As a result, they develop their creativity, which is a key competency and a prerequisite for professional advancement. Hackathon and design thinking are based on teamwork, which involves effective communication, sharing ideas, understanding others' perspectives, and using their personal abilities and knowledge to achieve a common goal. In this way, students form collaborative and teamwork skills that are essential for fields in which effective teamwork is critical to success. Design Thinking Hackathons require students to present their ideas to a panel of judges and audiences, thereby developing the communication and presentation skills necessary for their future success in multiple professional fields.

The possibility of developing students' career skills through design thinking is explored in a two-day hackathon with 2nd, 3rd and 4th year students studying Computer Science. The hackathon took place at the end of the PARAMETRIC AND GENERATIVE DESIGN course. The students had to develop a high-tech cyber-physical product. The students were divided into teams of four members. The teams were formed by testing with Belbin's questionnaire (Belbin, n.d.). At the start of the hackathon, the students were briefed on the regulations and conditions of the hackathon and were provided with talking points, keywords and an algorithm to follow in the form of the following guidelines. The jury was composed of IT professionals with experience in startups and in judging hackathons, so the experience was completely authentic.

Directions

HACKATHON ON PARAMETRIC AND GENERATIVE DESIGN. SOFTWARE PACKAGES FOR 3D MODELLING OF CYBER-PHYSICAL SYSTEMS

25.03.2023г.

Topic /Problem to be solved/ : To develop a conceptual design of a high-tech cyber-physical product.

Note 1 : A cyber-physical system is generally such a system that includes a mechanical part, a software part, sensors, actuator units and communication channels.

Areas:

Topics and areas in which your project can be:

- Ecology and microclimate

- Urbanisation and urban environment
- Sustainability, green technologies and renewables
- Conservation of natural resources and climate
- Transport, mobility, logistics
- Health, sport and medicine
- Interactive systems with AR, VR, ML , AI ...
- Environment and water conservation
- Pollution
- Poverty
- Behaviour modelling systems and new skills development
- Systems and platforms for innovative and interactive education and pedagogical systems
- Agri-culture and livestock production

Key methods and approaches to project development:

- Design thinking

Requirements and reference points

- Regarding the project:

- Problem globality
- Scope of application - problems and challenges
- Target group
- Steps to generate the innovative ideas
- Analysis of current solutions - benchmarking and competition /in deep tech, high tech and innovation areas/
- Product - concept and future steps for upgrade/ upgrade/

- In terms of product:

- Product purpose
- Product innovation
- Components building the product/ actuators, sensors, network devices, etc./
- Operating principle of the product
- Ways of handling the product and its components / ergonomics, maintainability of the product, serviceability, safety, serviceability /
- Materials, composition and colour of the product
- Artistic and aesthetic shaping
- Communication design elements carrying information
- Psychophysiological indicators
- Social impact of the product

- Parameters of the product in the context of the age and socio-cultural characteristics of the potential users / children, adolescents, adults, people with physical problems and deficiencies; parents, company employees, etc./

- Norms, standards and certificates related to the product
- Legal protection of the product
- Market niche

- In terms of presentation:

The project presentation should contain:

- 3D modelled physical part of the product / cyber-physical device/.
- Basic simulation in Thinkercad of the main components of the product with the accompanying software.
- Description of algorithms, flowcharts and how to interact with the product.
- Product interface concept in Figma platform
- Start-up business model based on business canvas

Evaluation criteria:

- Independent finding and processing of information
- Generation of non-standard ideas
- Proposing original solutions
- Breaking out of the usual linear way of thinking
- Examining the problem from different perspectives
- Identifying areas where improvements can be made in the context of users
- Understanding user needs and preferences
- Create products that prioritise user needs and preferences
- Drawing conclusions and inferences
- Analysis and synthesis skills

The study of the students' career skills was carried out by means of an assessment questionnaire, which included 23 questions relating to the following career skills: teamwork and collaboration, problem solving, creativity, empathy and organisation /work organisation and time management/. The questionnaire is attached in Appendix 1 of the article. The survey was conducted twice - at the beginning and after the hackathon.

The results obtained from the survey of students with the career skills assessment questionnaire are summarized in Table 1 and presented graphically in Figure 1 and Figure 2.

Table No. 1: Survey of career skills of students

Career skills	Follow-up survey			Baseline survey		
	Low Level, %	Medium Level, %	High Level, %	Low Level, %	Medium Level, %	High Level, %
	27	40	33	8	45	47
Teamwork and cooperation	42	35	23	22	40	38
Problem solving	60	35	15	22	43	35
Creativity	51	37	12	25	46	29
Organization	44	42	14	21	48	31

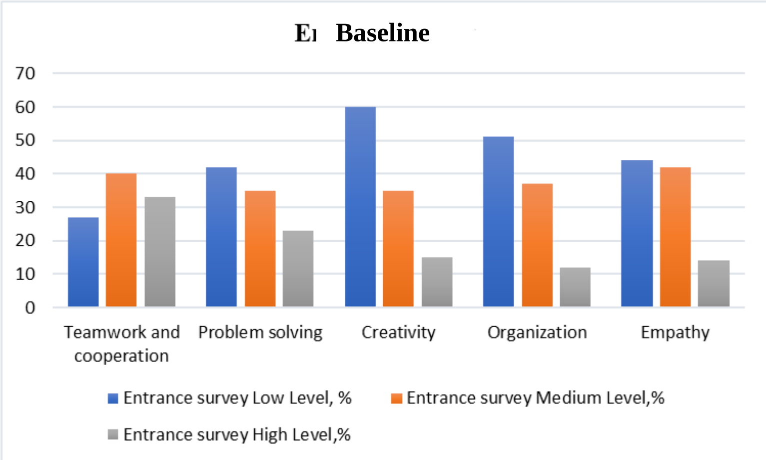

Fig. №1: Results of the entrance survey

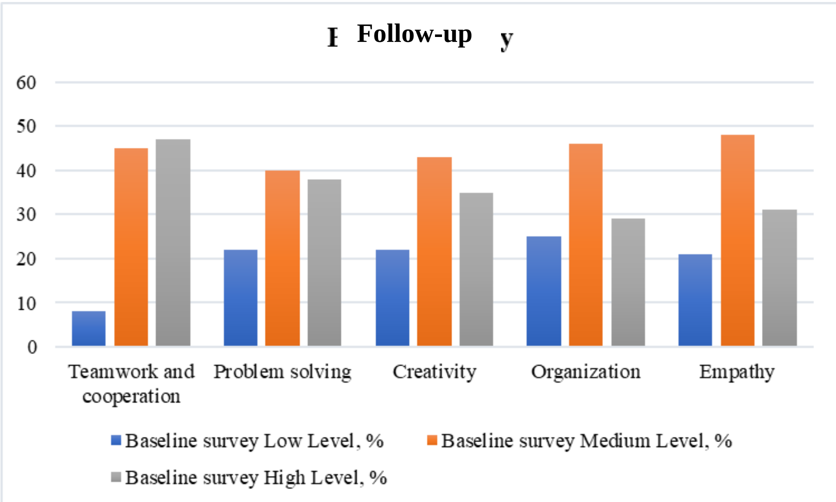

Fig. №2: Results of the baseline survey

The results of the entrance survey show that in terms of problem solving, teamwork and collaboration skills, the highest percentage of students with an average level of manifestation. In terms of creative thinking skills, organization and empathy, students with a high level of manifestation were significantly less than those with a medium and low level of manifestation. The largest difference in the percentage of students with high and low level of manifestation was in the skill of creative thinking.

From the results obtained with the baseline survey, it was found that after the design thinking hackathon, the percentage of students with high and medium level of manifestation increased in all the skills studied - teamwork and collaboration, problem solving, creativity, empathy, and organization. The greatest positive change was in the skills of creative thinking, organization, and empathy. The highest percentage of students with high levels of manifestation was in teamwork and collaboration skills.

The results thus suggest that design thinking hackathons contribute to students' formation of career skills and the acquisition of experiences that will be useful to them in a wide range of personal and professional contexts.

After the completion of the hackathon, an exit survey of the participants was conducted in order to explore their opinion on the training and to obtain "feedback" on the following aspects related to the formation of career skills in the process of this training:

- Self-awareness
- Problem solving
- Career guidance - career field, organisation and nature of work

The exit questionnaire is attached in Appendix 2 of the paper.

The results obtained from the students' exit survey are summarized in Table №2.

№	Exit survey response	answer	
		yes	no
1.	Was the hackathon an enjoyable experience for you?	97%	3%
2.	Would you participate in such a hackathon again?	95%	5%
3.	Did the hackathon give you new starting points when looking for solutions?	92%	8%
4.	Did the hackathon change your interests in any way?	73%	27%
5.	Did the hackathon influence the way you think about finding solutions?	94%	6%
6.	Did the hackathon increase your problem solving skills?	92%	8%
7.	Would you like similar hackathons to be held in other subjects?	95%	5%
8.	Did the hackathon influence your idea of what you would like to do professionally	75%	25%
9.	Did the hackathon require a high level of attention, commitment and concentration from you?	98%	2%
10.	Has learning about the design thinking method changed your approach to problem solving in the future?	95%	5%
11.	Will it be easier for you to find solutions to a problem in the future?	92%	8%
12.	Did you discover any new aspects when looking for solutions to a problem?	95%	5%
13.	Did you feel satisfied with your participation in the project?	95%	%
14.	Were you surprised at yourself for successfully completing the project tasks?	89%	11%
15	Did the project work bring you pleasant emotions?	97%	3%
16.	Would you choose a profession related to the same field as the project you developed?	81%	19%
17.	Would you choose a profession with a similar nature of work?	89%	11%
18.	Would you be comfortable with your future profession having a similar work format	88%	12%
19.	Did the hackathon increase your self-confidence	80%	20%
20.	Would you engage in activities requiring similar work dynamics?	86%	14%
21.	Did the hackathon change your self-image in any way?	78%	22%

Figure 3 shows the results of the questions related to the students' opinion on the training /question 1, question 2, question 7, question 9, question 15/.

The results show that the training conducted through design thinking hackathon is highly approved by the students. Over 95% of them rated the conducted hackathon as an enjoyable experience which increased their engagement, interest, attention and concentration. They indicated that they would like to organize other courses and would participate again.

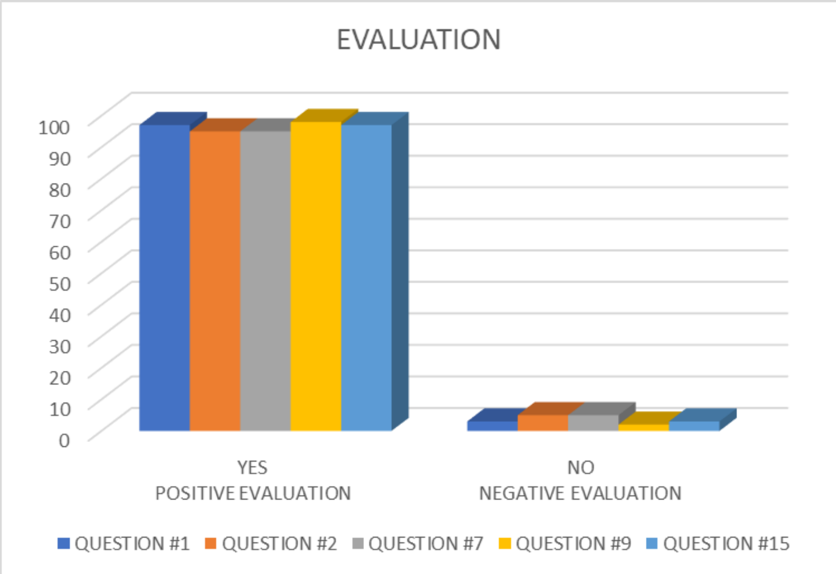

Figure №3 Exit survey - evaluation of the training

Figure 4 presents the responses to the questions related to the students' self-assessment of their problem-solving skills during the hackathon /question 3, question 5, question 6, question 10, question 11, question 12/.

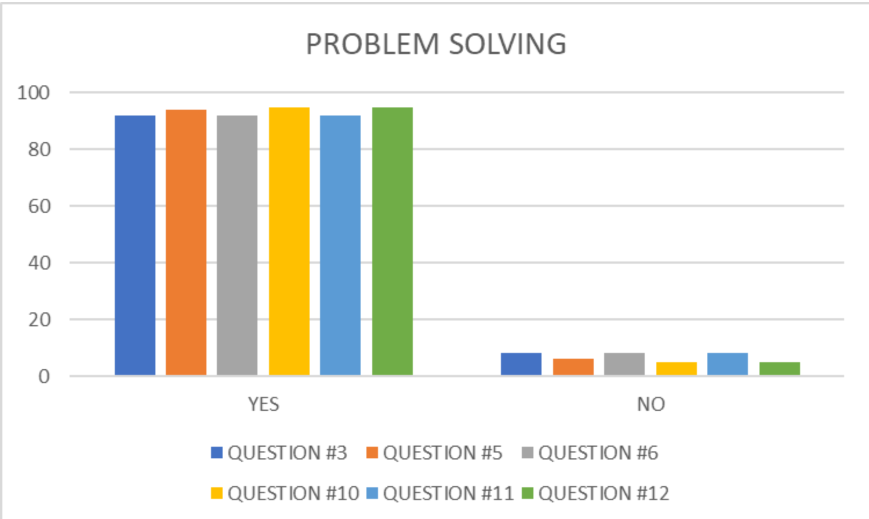

Figure 4: Output survey - problem solving

Between 92% and 95% of the students indicated that the design thinking hackathon helped them to discover new aspects and gave them new starting points in their search for solutions, changed their way of thinking and their approach to problem solving, thus contributing to the enhancement of these skills.

The exit survey also explored the possibility of using a design thinking hackathon to increase students' self-awareness as an important aspect of career skills. Figure 5 presents the results of this study.

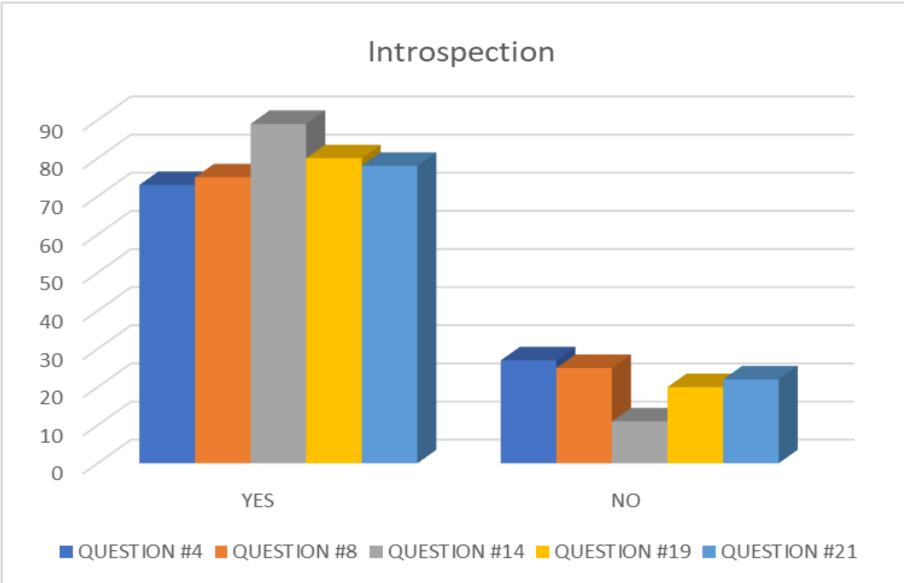

Figure 5: Output questionnaire - self-knowledge /Introspection/

Over 80% of the students indicated that as a result of their project work during the hackathon, they had increased their self-confidence, discovered new interests, and changed their perception of themselves and what they would like to do. This gives reason to believe that training through design thinking hackathons contributes to increasing the level of self-knowledge of students.

The design thinking hackathon in many aspects resembles the real working environment in a number of professional fields. Therefore, the exit survey includes questions to explore students' opinions about such a work organization/question #13, question #16, question #17, question #18, question #20/. The responses to these questions are presented in Figure 6.

Between 86% and 89% of students indicated that they liked this type of dynamic and nature and would like their future work to have a similar format. 95% of the students stated that they felt satisfaction from participating in the hackathon and working on the project.

The results obtained give reason to believe that the hackathon was useful in terms of the nature, dynamics and organization of work and helps in the career guidance of students. By linking the training with such a format, which is close to the modern real working atmosphere, they successfully developed their career skills.

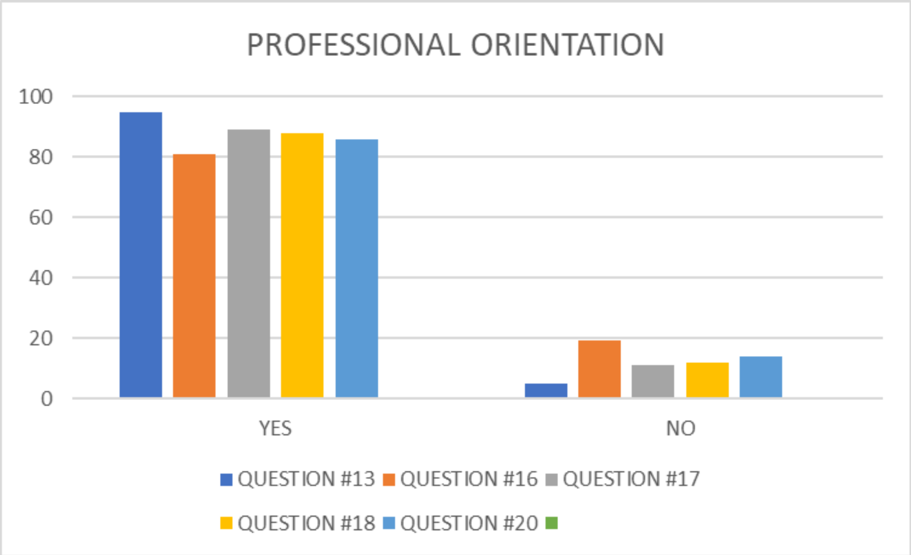

Figure №6 exit survey - career guidance

Conclusion

In the process of conducting design thinking hackathons, students generate multiple ideas and explore a wide range of possibilities; think systematically; evaluate and analyze proposed solutions to determine which ones are most feasible and effective; design products that are oriented to the needs and preferences of potential users and thus build empathy and empathy; reflect on their progress and their own mindset; avoid conflict and manage their emotions; maintain engagement and motivation regardless of emergent Therefore, design thinking hackathons appear to be an effective way to develop valuable career skills and experiences in students that will contribute to their future professional development.

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Appendix 1. SURVEY

To assess career skills

Instructions: The proposed questionnaire contains statements, each of which has five possible response levels - never, rarely, sometimes, often and always. Choose the one that you feel applies most to you. There is no right or wrong answer, so be as honest as possible.

1. I am always on time and rarely miss deadlines
2. When I make a decision, other people's feelings about it don't concern me.
3. When I start to do something, I try to finish it without distraction
4. I can be counted on when there is work to be done
5. I step back to see the big picture before I try to analyze a problem
6. I think creatively and offer solutions that others have not thought of
7. When more people think about an issue better solutions are found
8. I understand how my role fits into a larger team
9. I prefer to work on a task by myself rather than explaining to others what needs to be done
10. When there is a common task to solve, I can work with anyone as long as they are helpful.
11. When solving a problem, I freely exchange information with others
12. I feel the need to learn about new and unfamiliar things
13. If a particular job is unfamiliar to me, but I enjoy it, I desire to learn everything about it in order to achieve excellence
14. I think that implementing my ideas can lead to progress in a particular field
15. When searching for solutions to a problem, I point out the logic of my point of view and its advantages
16. I prefer to leave the responsibility for solving a problem to others
17. People who surround me strongly influence my mood.
18. I take my friends' problems to heart.
19. I regularly write to-do lists and check off those that are completed
20. I get very excited if I need to tell people unpleasant news.
21. I can communicate positively in difficult or challenging situations
22. I get upset at the sight of a suffering animal.
23. The helplessness of old people depresses me.

Appendix 2. EXIT SURVEY

The proposed survey explores psychological aspects of learning through hackathons for design thinking. The questionnaire contains 21 questions to be answered with YES or NO. Choose the answer that most applies to you.

1. Was the hackathon an enjoyable experience for you?
2. Would you participate in a similar hackathon again?
3. Did the hackathon give you new starting points when looking for solutions?
4. Did the hackathon change your interests in any way?
5. Did the hackathon influence the way you think about finding solutions?
6. Did the hackathon increase your problem solving skills?
7. Would you like to see similar hackathons conducted in other academic disciplines?
8. Did the hackathon influence your idea of what you would like to do professionally?
9. Did the hackathon you conducted require a high level of attention, commitment and concentration?
10. Did learning about the design thinking method change your approach to problem solving in the future?
11. Will it be easier for you to find solutions to a problem in the future?
12. Did you discover new aspects when searching for solutions to a problem that arose?
13. Did you feel satisfied by participating in the project?
14. Were you surprised at yourself for successfully completing the project tasks?
15 Did the project work bring you pleasant emotions?
16. Would you choose a profession related to the same field as the project you developed?
17. Would you choose a profession with a similar nature of work?
18. Would you be comfortable with your future profession having a similar format of work?
19. Did the hackathon increase your self-confidence?
20. Would you engage in activities requiring similar work dynamics?
21. Did the hackathon change your self-image in any way?

Researching the Possibilities for the Formation of Communication Skills and Dialogicity in The Process of Training in Technical Disciplines through Teamwork on Projects

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Abstract: Communication skills and dialogue are key competencies of the 21st century and a condition for successful implementation and personal development in general. This requires their formation to be the subject of purposeful educational activity. At the same time, their implementation in the learning process is a complex and difficult task, requiring a change in learning models, teaching competencies, and the organization of learning. The present report examines the possibilities of forming skills for effective communication and dialogicity in high school students in the process of training in technical disciplines through teamwork on projects

Keywords: communication skills, dialogicity, team, team roles

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Introduction

Communication skills and dialogicity

In its social aspect, communication is seen as a dynamic process involving the exchange of information, mutual perception and understanding, interaction and mutual influence between people. One of the most famous psychological interpretations of the need for social communication is that of the American psychologist William Schutz, presented in his theory of the basic interpersonal orientation of the individual. According to Schutz, the need for other people is determined by three main primary human needs: inclusion, attachment and control. Based on them, a person's interpersonal behavior can have different manifestations. Depending on inclusion, which is seen as people's need to be in a group, a person can have oversocial, social, and undersocial behavior. According to the need for attachment, it can be depersonalized, hyperpersonal, or personal, and according to the need for control, a person's behavior manifests itself as giving up, autocratic, or democratic. Each of these needs manifests itself in individual behavior in a different way and with different intensity depending on the point of view. One of these perspectives is related to the Other-Self perspective and encompasses what one expects from others, and the second perspective is related to the Self-Other perspective and includes what a person would like to do in relation to others. According to Schutz, childhood experiences have a determining role in the realization of these needs later in adulthood.

Every interpersonal communication contains a theme, a message of interaction and motives for exerting control. The theme may be clear and specific, but sometimes it is implicit or not fully relevant to the communication. The message reflects the interaction, seeking to build and strengthen it. Motives are related to feelings, which play an important role in communication. Sometimes they remain hidden, in other cases they subtly accompany it, and in others communication is completely dependent on them.In the process of interpersonal communication, each of the participants is involved with verbal and non-verbal signals. Verbal communication is done through speech. Good verbal communication requires the skill of free expression, richness of speech, compliance with literary legal speech rules, expressed in correct pronunciation, appropriate intonation and pace of speech, "color", strength and timbre of the voice. In order to communicate effectively, a person must have a sufficient vocabulary, be able to formulate his thoughts correctly, be able to express himself clearly and convincingly, and convey information in a way that makes it understandable to different people. In the process of communication, in parallel with his speech (verbal) behavior, each person implements a whole system of non-verbal (non-verbal) messages. The term "non-verbal communication" includes everything that is communicated in the process of communication without the use of words. It is realized by means of non-verbal signs and signals. Some of them are innate, and others are acquired through upbringing and education and through the ethno-cultural characteristics of the environment in which a person grows up. And while verbal communication refers to signals that are received by hearing, non-verbal messages are received with the participation of all human senses - mainly sight, but also smell, touch, hearing. In addition, nonverbal communication is more direct, more general, and more spontaneous than verbal communication. Therefore, it is strongly present in some social psychological mechanisms, such as suggestion, persuasion, imitation. Non-verbal communication is related to feelings and emotions. Some of it comes from the subconscious and is much less subject to conscious interpretation and observation. As a result, decoding and responding to nonverbal messages becomes much more automatic and partly unconscious compared to making sense of verbal messages. Some of the nonverbal messages can be controlled, but others happen completely automatically, making them much more effective in conveying information about attitudes and feelings than speech. Through them, the real emotions, attitudes and motives of the communicator are revealed much more easily.

To summarize, the most common errors in communication are related to inconsistency between verbal information and non-verbal signals and signs, insincerity, exaggeration and distortion of facts, escape or diversion from the topic of conversation, failure to listen, use of slang and dialect words, "labeling", selective listening and misinterpretation of information, lack of feedback from the listener, nonverbal rejection, inability to control nonverbal communication, etc. The ability to communicate effectively verbally and non-verbally is expressed in approximately equal levels of eye contact, direct eye contact, displays of warmth, trust, security, positive feelings and emotions. It is desirable that the posture is relaxed and that the body is slightly bent forward in dialogic forms of communication. Positively coloured gestures, a clear and sufficiently high voice, rich and nuanced intonation, the appropriate pace of speech, respect for personal space taking into account its ethnic and social parameters are part of the indispensable elements of effective communication. The success of people's communicative relationships depends to a large extent on how well they are able to listen and how well they are able to adapt their communication style. And while these are culturally determined and in no small part determined by the upbringing, values and education of the individual the universal rule for all cultures is politeness.

A mandatory element of good communication is dialogicity. In the process of teamwork or other joint activity of people, the ability to conduct dialogue, as part of communication skills, is a mandatory condition for achieving the set goals. The dialog has a number of features. It has a strong situational conditioning and is distinguished by dynamics expressed in a continuous change of the communicative roles "speaker - listener" of the interlocutors. Since speaking and listening are mutually conditioned, the effectiveness of the dialogue as a whole depends on their synchronization. Dialogic communication has a spontaneous character and provides an opportunity to use non-linguistic means, which gives expressiveness and specificity to its structure. It implies the activity of all its participants and requires joint discussion of information and making a common decision. It is aimed not only at the subject of communication, but also at the participants themselves, allowing for a certain versatility, expressed in a transition from one topic to another and subjectivity in the assessment. Dialogic behavior is related to recognizing the interlocutor's right to his own point of view, showing empathy, mutual respect and tolerance, an attitude of partnership, listening to the interlocutor, criticality and self-criticism, the ability to overcome disagreements, etc.

2- Psychological-pedagogical features of high school students in the context of the formation of communication skills

The high school stage of education covers the age of 16. up to 18 This is the final stage in the transition to adulthood and is usually referred to as adolescence or adolescence. In this period, the aspiration of adolescents is to express their individuality, to be original. The need for independence and communication are important features of this age period. There is an aspiration and assertion of personal choice regarding one's own behavior, desires, interests, activities and pursuits. Adequate self-esteem, high moral requirements, need for independence and activity in responsible spheres of public life. At this age, the student's intellectual activity is accompanied by a clearly expressed will, richer needs and interests, "mastery of thought", "new quality of thinking", creative imagination. As a result of the accumulated knowledge, the students acquire the skills to think much more fully, developed and original, to convincingly express and defend their point of view. In the educational activity, students pay more attention to independent work, discussions, discussions, counseling and cooperation. Their social self- determination is part of the motivation to learn. A psychological center in thoughts and feelings is the choice of profession. Therefore, the interest in learning and learning correct social-communicative models for professional realization is increasing.

3- Socio-communicative features of team organization at work

The idea of teamwork of people is based on the principle of synergy, according to which the energy of a system is greater than the energies of the elements participating in it.

The main characteristics of each team are related to its goals and structure (size, role differentiation and composition of the team), with the status of its individual members, including the leader, with group dynamics, identity, cohesion and motivation, with the socio-psychological climate, communications and interpersonal interaction. The team does not have a strictly hierarchical - structured organization of work. All its members participate in the decision-making process. In the process of teamwork, each member usually has one main task, but may also perform additional ones.

Team members complement each other in terms of their knowledge and skills.

Distinctive characteristics of teamwork are: partnership behavior, mutual respect and personal integration, equal participation of everyone in discussions about the methods, content and goals of the work and its implementation. Team organizational approach is related to good interpersonal relations and understanding. Team members maintain a harmonious relationship with each other. Everyone contributes to ensuring a positive working environment and an atmosphere of trust by listening to each other, giving and receiving open feedback, exercising and accepting constructive criticism, self-affirmation, tolerance and willingness to compromise, openness and responsiveness. An important prerequisite for the success of teamwork is team cohesion, expressed in similarity between group members and close individual values and attitudes, desire to be together, striving to like each other. The factors that most strongly determine the effectiveness of a team are the clearly formulated goals and tasks, the degree of satisfaction with the work performed and with the group interaction, the working conditions and the availability of sufficient resources at the disposal of the team, the socio-psychological climate and interpersonal relationships, the fair and stimulating assessment, everyone's personal commitment. The degree to which a team realizes the set goals and achieves specific measurable results is defined by the term team effectiveness. It also includes the satisfaction that team members experience in the teamwork process. Effective teams are distinguished by clear goals, high motivation and competence to achieve them, skills to deal with difficult and conflict situations, goodwill, cooperation, support, clear rules and norms, a good leader, etc.

4- Types of team roles

In order to build a good team, it is necessary that its members possess specific behaviors called team roles. In team role theory author Dr. Meredin Belvin defines it as "a tendency to behave, contribute and interact with other people in a certain way"

These team roles are formed over the course of the team's existence and represent different patterns of behavior. There is no good or bad team role. Each of them is useful for the team's activities. Rarely do members possess the characteristics of only one role. Also, a person may have one role profile in one team and a different one in another. This depends not only on himself, but also on the other members of the team, the socio-psychological climate, the set goals and tasks, etc.

There are many studies and qualifications of the various team profiles. Meredin Belvin's model distinguishes nine different team roles – discoverer, specialist, coordinator, observer-evaluator, doer, finisher, resource explorer, shaper and masseur. These nine roles fall into three groups: action-oriented roles; roles, people-oriented and intellectually oriented roles. The first group includes the roles of shaper, executor and finisher. The second group includes the roles of coordinator, mass worker and resource researcher. In the third group are the roles of discoverer, observer, evaluator and specialist. The characteristics of each of the team roles following the model of Meredin Belvin are summarized in Table 1.

Table 1. Types of team roles according to the model of Meredin Belvin

Groups of team roles	Team roles	Positive qualities	Negative traits	Corrective measures
Action oriented roles	Shaper	Emotional, open, ambitious, irreconcilable to violations and irregularities. Action-oriented, stimulates team efforts	He tends to ignore the human factor. Often impatient, irritable and aggressive, strives and requires rapid achievement of the set goals / quick decisions and, fulfillment of the tasks set	To master his desire for quick success and progress, which creates unnecessary tension and exacerbates the microclimate in the team
	Performer	He has strong character, leadership qualities, competence. Able to turn ideas and concepts into real-life tasks and work procedures He is fully dedicated to the common work.	Unstable under dynamic conditions Is reluctant to accept/get involved in the realization of new and untested ideas. It lacks flexibility. Tend to show unconstructive and negative criticism	To encourage flexible decision-making skills under unstable and rapidly changing conditions
	Finisher	Strict, precise, observes even the smallest details and details	Does not support other people's initiative often bogs down in detail and loses the overview of common	To develop skills for a multilateral/more holistic view and understanding of

			goals, tends to constantly doubt and worry	the objectives and objectives set
Roles, orientation to people	Coordinator	-natural leader and authority, -dominates without applying command style -Able to motivate -positive and with a true judgment for each of the team members -coordinates the joint efforts and communicates well, -tolerant, but strong enough not to accept inappropriate advice and opinions	With a manager with another profile, intolerance and conflicts are possible	To be given a leadership position in the team
	Masseur	It contributes significantly to the cooperation and the good atmosphere in the team. - Well-meaning and sociable, - detects the moods in the team. Understand the needs and concerns of individual members. He has diplomacy and insight. He hates tension and conflict and tries to resolve them.	He rarely has his own ideas and suggestions.	Assign him personal tasks to perform.
	Resource Researcher	seeks out new developments, brings in contacts, ideas and information, encourages new initiatives. Is able to successfully apply the knowledge of others. Positive, responds with enthusiasm, sociable and inquisitive. Keeps the team from stagnating	Tend to lose interest quickly.	To encourage perseverance and greater thoroughness
Intellectually Oriented Roles	Discovered	-has a very high intellect and potential, - naturally creative, a source of creative and unusual ideas and solutions	- often underestimates the practical details and accompanying procedures -prone to disregard for other people's opinions and confrontation Direct in your judgments and criticisms	It is necessary that his natural creativity be guided in the desired direction, so as not to lead to deviation from the common goals and interests
	Observer-evaluator	Thoroughly consider and analyze problems objectively evaluate the proposed ideas and solutions can find the optimal	He tends to downplay the contribution of others. shows inappropriate criticism and	He is not given a leadership position. No manifestations of

		solution in the presence of a large number / numerous proposals	tactlessness, He rarely has ideas of his own, lacks original thinking.	/Deliberate tactless attitude is parried
	Specialist	Has in-depth knowledge in a specific area contributes to finding expert solutions	His interests are related only to his field and he is not interested in things outside it	to integrate into tasks that require the expansion of his field of knowledge /application of knowledge from other fields

The discoverer is the person from the team with the greatest potential and intelligence, the source of the original and non-standard ideas and thoughts. He sees the big picture and is not interested in the details, which is why he often underestimates the practical details, the inevitable procedures and rules. He is direct in his judgments and criticisms, prone to confrontation and disrespecting other people's opinions. It is necessary that his natural creativity be guided in the right direction so as not to allow deviation from common goals and interests.

A specialist has in-depth knowledge of a particular field and is usually not interested in things outside of it. He devotes himself entirely to activities and problems related to his specialization, follows his own goal and acts on his own initiative.

The coordinator is best suited as a team leader. He has a natural authority, dominating without commanding. Thinks positively, keeps cool and self-discipline when disagreements arise. He knows how to distinguish the strengths and weaknesses of each of the members and motivate them. He has a balancing position, coordinates joint efforts, communicates well, is tolerant, but also strong enough to ignore inappropriate opinions and advice.

The observer - evaluator is the person in the team who thoroughly considers and analyzes the problems, evaluates the proposals and opinions, discovers imperfections in the ideas and arguments. He rarely has his own ideas, lacks creativity, is usually serious and distant, prone to tactlessness, inappropriate criticism and belittling the contributions of others. Therefore, teams led by such personalities are not particularly productive. The contribution of the observer-evaluator is essential in the presence of numerous ideas, requiring complex and complex decision-making.

The executor is the one who turns strategies, concepts, plans and decisions into practical work procedures and executable tasks. He is distinguished by a strong character, practicality, high organization, but is unstable in dynamic and unstable conditions. His leadership style is extremely effective, although he tends to show unconstructive and negative criticism towards others. He devotes himself entirely to the common work. He knows how to work precisely, systematically and efficiently, but he lacks flexibility. He is reluctant to respond to new and untested ideas.

The finisher is the person who strictly follows the order and the work program. Checks for the observance of even the smallest details and details, tends to worry and doubt incessantly. He has a strong character, often loses sight of general goals and gets bogged down in details. If he is the leader of the team, these qualities hinder the initiative of the others. Nevertheless, with his strictness, he does not allow important details to be missed and contributes to the team's success.

The resource researcher looks for news, brings contacts, ideas and information to the group, promotes new initiatives. Can successfully use the knowledge and skills of others. He is sociable, inquisitive, reacts with enthusiasm, but tends to lose interest quickly. His contribution to the team is that it prevents it from stagnation and maintains contacts with the outside world.

The shaper stimulates the action and efforts of the team, unites its goals, ideas and opinions in a working project. Possesses openness, ambition and emotionality. It tends to ignore the human factor. He is often impatient, irritable and aggressive, which unnecessarily aggravates the atmosphere in the team. Nevertheless, with his intransigence to violations and irregularities, as well as the desire for quick solutions and implementation, he is extremely useful to the team and moves it forward.

The masseur is the most sensitive member of the team. He is very sociable and well-intentioned. Shows a strong interest in people, understands their needs and concerns, perceives the mood in the team. Possesses diplomacy and insight. He hates tension and conflicts and tries to resolve them. He rarely presents his own ideas himself, but rather builds on the ideas of his colleagues. His contribution is that he contributes significantly to the good atmosphere, cooperation and harmony in the team.

5- Formation of student teams when working on projects.

In order for all students to actively participate in project work, regardless of their level of knowledge, and to contribute to the achievement of overall success, it is extremely important how the teams will be formed. In an express diagnosis of the characterological features of the personality is presented, which includes the Eysenck Questionnaire, an adapted version for adolescents, a legend for calculating the results of the Eysenck Questionnaire, a classification of the types of behavior depending on the ratio of the results on the scale of neuroticism and the scale of introversion, description of the characterological features and manifestations of each type, directions of interaction and ways of correcting the behavior of adolescents according to the respective type. The close types according to Eysenck from the point of view of psychological-pedagogical features of the students can be united in the following five main groups, conditionally designated as group A, group B, group C, group D and group F. Characteristic features and guidelines for impacting the negative aspects of each of the groups, as well as the Eysenck types that each of them unites, are summarized in Table 1. For the effective work of any student team, it is necessary that it includes a competent student who has in-depth knowledge and can find the necessary information, a creative student who has out-of-the-box thinking and generates original ideas, and an executive student who, although not a source of ideas and not having in-depth knowledge, contributes to the team's success by diligently and responsibly performing specific tasks. Of course, this division is very general and is in the context of the achievement of educational goals. But it can serve as a starting point when creating student teams.

Table 2. Characteristic groups and types according to Eysenck

Characteristic groups	Types according to Eysenck	Characteristic features
Group A	3,11,12,2123 ,29,30	+ : sociable, energetic, purposeful, active, fighting, persistent, leaders - : ambitious
Group B	2,8,9,10, 17,24,25	+ : sociable, cheerful, emotional, confident, executive, balanced, calm, - : non-initiative, non-targeted, do not aspire to leadership Recommendations: Do not give them leadership positions; to join groups with a strong leader
Group C	1,7,18,19, 27,28,31	+ : active, executive, empathetic, calm, modest, independent, benevolent, independent, diligent - vulnerable, shy, insecure, silent
Group D	13, 14, 15, 20, 22, 26, 32	+ : confident, energetic, persistent, purposeful - : conflicted, vindictive, lack of empathy and sympathy, ambitious, haughty, emotionally limited
Group F	4, 5, 6, 16	+ : executive - : insecure, non-initiative, inactive, vulnerable, shy, with distorted evaluations and self-evaluations, indecisive

Empirical Research Of Students' Communication Skills Formed Through Teamwork On Projects

1. Organization of the study

The research was conducted with 60 high school students over a period of two academic years. In the training of technical subjects, the students developed learning projects, and in parallel with the achievement of educational goals, they also developed skills for effective communication and dialogue. The formation of the student teams was done by testing the students with the Eysenck Questionnaire, an adapted version for adolescents. Based on the results obtained, 6 teams of four students each were created, so that in each team there were types from different characterological groups, according to table 1, and which, from the point of view of educational level, included both "competent" students and "executive" students. Original and non-standard thinking is usually manifested in the very process of project work through purposefully formulated tasks to be performed by the teacher, and that is where the "creative" students can be found. This can also be achieved through preliminary research of students /pedagogical observation, testing, surveying, etc./ to establish this competence for creative thinking. In the process of developing the learning projects, the teacher's role is to promote the lively exchange of information and knowledge between team members. It should motivate all members to be sympathetic to the achievement of common goals and to act jointly to achieve them, working together or independently, but in a constant relationship with each other, as well as the problems accompanying the work to be discussed openly and resolved in a timely manner.

2. Methodology of the study of students' communicative and dialogic skills

The study of students' communicative and dialogic skills was carried out by means of survey and testing methods. It was held twice - at the beginning and at the end of the research period, covering two groups of students - experimental and control. The students from the experimental group were trained in teams by developing projects. In the control group, the training kept the classic class-lesson format. The questionnaire developed for the study of communication skills includes seven statements with five possible answers - never, rarely, sometimes, often, always. Respondents need to choose only one of these answers.

Survey

- I know how to listen to others and communicate with them.
- When I'm talking to someone, I can easily lose my train of thought.
- I express my opinion freely.
- It is not easy to say openly what I really think.
- It happens that I want to say something, but I don't know how to express myself.
- When I speak, others listen attentively
- If someone needs advice, I patiently try to help them.

Testing was performed with the Eysenck questionnaire, adapted version for adolescents.

According to the level of manifestation of communication skills, the Eysenck types were grouped into the following three categories:

- first category - types with a high level of manifestation
- second category - types with a medium level of manifestation
- third category - types with a low level of manifestation

The types belonging to each of these categories are shown in Table 2.

Table 3: Levels of manifestation of communication skills

	Levels of communication skills	Eysenck Types, Adapted Version for Adolescents
First category	High level of manifestation	2,9,10,11,12,13,21,23,26
Second category	Medium level of manifestation	3,8,17,24,27,29,30,31
Third category	Low level of manifestation	1,4,5,6,7,14,15,16,18,19,20, 22,25,28,32

3. Analysis of results

The results of the testing with the Eysenck questionnaire of the students of the experimental group are summarized in table 3 and presented graphically in figure 1.

Table 4.Levels of communication skills – testing

Levels of communication skills - testing	high level	medium level	low level
Initial testing	20%	37%	43%
Final testing	37%	53%	10%

From the results obtained by testing with the Eysenck questionnaire, it is established that at the beginning of the study, 43% of the students have unsatisfactory communication skills, 37% are at an average level and only 20% show skills for effective communication and dialogue. At the end of the study, after project training, the percentage of students with a high level of manifestation increased by 17%, and those with a low level decreased by 20%.

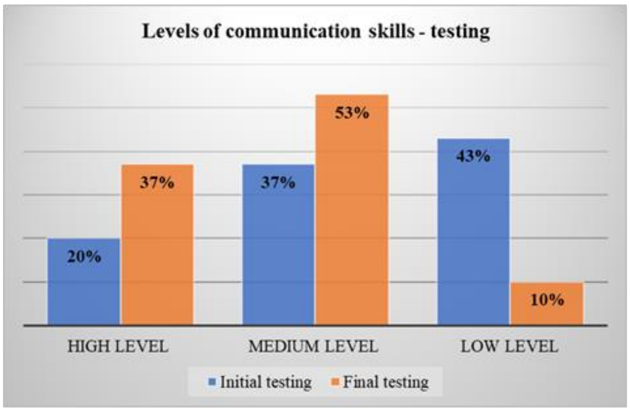

Figure 1. Levels of communication skills – testing

Table 4 and Figure 2 summarize the results of the expert group survey.

Table 4. Levels of communication skills – polling

Levels of communication skills - polling	high level	medium level	low level
Initial testing	20%	33%	47%
Final testing	44%	50%	6%

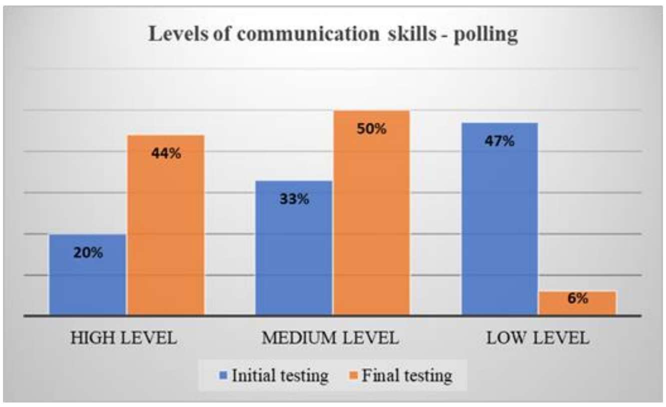

Fig. 2 Levels of communication skills – polling

The data obtained with the survey method are close to those established with the testing method. The initial survey shows that 47% of respondents have a low level of manifestation of communication skills, 33% have an average level and 20% have a high degree of manifestation. At the end of the training with the experimental group, the percentage of students with low levels was reduced to 6%, and the percentages of students with medium and high levels of manifestation increased by 17% and 24%, respectively.

The results of the parallel surveys and tests of the control group at the beginning of the research period are close to those of the experimental group, but at the end of the study, the positive changes in the direction of improving the communicative and dialogical skills of the control group are insignificant.

Conclusion

Project-based learning, which is related to team organization of work, free communication, expressing a personal position, listening to someone else's point of view, arguing and defending one's opinion, contributes to increasing students' communication skills and dialogic behavior, as the strongest influence is established in the direction of overcoming the low levels of manifestation of these skills.

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A Methodological Critique of Focus on the "Average Student" in Psychological and Educational Research

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Abstract: Research in psychology and education tend to use large-N group designs that necessitate reporting of mean measures analyzed mostly with null hypothesis statistical testing (NHST), but sometimes with Bayesian, or the estimation approaches in inferential statistics. These approaches all render the average person or student as the the putative "subject" of interest in psychology and education, in addition to the myriad of serious problems, such as widespread replication failures, they have manifested. In reality, however, more often than not, it is the individual person or student who learns, not some nonexistent average person or student.A case is made that a largely ignored alternative to group designs is the Small-N or single-case designs that have a long and productive history in psychology, education, and medicine. They involve studying in-depth only a few subjects at a time under different conditions explored in some detail while observing systematic changes in behavior as those conditions change. In so doing, these designs not only focus on the individual, they reveal functional relationships between his or her behavior and the prevailing environmental conditions. In education, such environments range from the school, the classroom, or teacher (variables) to teaching methods, materials, and/or technology. Undoubtedly, adopting such designs more broadly in psychological and educational research would require a significant shift in how we approach asking questions, collecting data, analyzing and interpreting data, and making research and practice decisions. Not doing so, however, is like repeating the same mistake over and over and expecting a different result.

Keywords: Average measures, Average students, Methodology, Large-N group designs, Small-N single-subject designs

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Introduction

How often do we hear the phrase “average student” to categorize learners? Dutch students have a variety of answers for what the “average” means, some readily translatable in statistical terms, and others questionable (Bakker, 2003). Lay conceptions of what is average, therefore, may or may not be consistent with the technical usage that we are all familiar with. When lay people use or hear the phrase "average student," it usually conjures up some comparative assessment (see Anuupadhyay, 2023), usually of academics. It often refers to learners as mediocre. If some are mediocre, of course, others are exceptional in whatever manner of intellectual attribute. Despite widespread use in daily life, the idea of an "average student" in psychology and education is largely based on statistical considerations rather than experimental or experiential necessity. So, such consolatory statements as "[a]verage people or students are also great. It's just that they may not get noticed and recognized as publicly" (Anuupadhyay, 2023) is sometimes warranted. We have to ask ourselves why there is so much focus on the "average person or student" in psychology and education if both disciplines presumably are essentially studies of the individual. The answer is rooted in the historical marriage of measurement and inferential statistics broadly speaking and particularly between that of measurement error and statistical control (i.e., as opposed to experimental control; see Cowles, 2001; Perone, 1991, 1999; Sidman, 1960).

History of Statistics in Psychology and Education

Academic achievement and performance are preeminently tied to measurement in both disciplines. The history of measuring human attributes in particular and nature more generally was characterized by challenges in discerning true measures and measurement errors due to the limitations imposed by our attempts to quantify and attach numbers to many attributes (Cowles, 2001; Stigler, 1992). According to Stigler, in regard to the entry of statistics into education, it was Francis Edgeworth's 1888 work that used the "normal distribution… as a scaling device" for exams (1992, p. 68). It is no wonder today that student performance is categorized based on the normal curve, readily having a place for the "average student" (see Anuupadhyay, 2023).

In an 1885 work on observations, Edgeworth was quoted as having stated: "Observations and statistics agree in being quantities grouped about a Mean; they differ, in that the Mean of observation is real, of statistics is fictitious" (Stigler, 1992, p. 67). At about the same time of Edgeworth's writings, Fechner and Charles Peirce were developing experimental attempts to quantify weight sensations in psychophysics. In replicating the earlier work of Fechner, Pierce had devised "a blind randomized experiment" with himself as subject and, in doing so, adopted "randomization to create an artificial baseline," which set the stage for "statistical investigation" in psychology ever since (Stigler, 1992, p. 65).

A most unfortunate aspect of the history of the linkage between statistical inference and experimental design is that most contemporary researchers believe they are operating a "unified theory of statistical inference" (Hubbard, 2004) in their use of null hypothesis statistical testing (NHST), when in fact it is a jumbled mishmash of technically incompatible statistical positions held by R. A. Fisher and Neyman-Pearson respectively (Schneider, 2015; see Imam, 2021, 2022). Imam (2022) described how psychology enjoys perhaps a unique status of having two research traditions, one using the ubiquitous snapshot group-designs approach to experimental investigations and the other relying on in-depth analyses of small numbers of subjects exposed to multiple conditions of experimental manipulation. The latter has been the saving grace for behavioral psychology by escaping the embrace of inferential statistics' historical trap experienced by the former creating a deluge of averages in the literature (Imam, 2021).

As far back as the later decades of the 19th century, the average had been scrutinized. Writing contemporaneously with Edgeworth, Fechner, and Pierce mentioned earlier, the esteemed physiologist Claude Bernard (1927/1957) discussed the mistakes that can stem from physical, chemical, and biological averages. He argued that averages inevitably produce errors and therefore should be eschewed to avoid the muddling and misrepresentation they wield while "aiming to unify… and…to simply" (Bernard, 1927/157, p. 135).

Although the experimental psychologist may appear to need "statistical, as opposed to experimental control" (Cowles, 2001, p.20) due to perceived inability to achieve the latter on par with the physical sciences, "[a] major criticism of the effect of the use of statistical approach in psychological research is the failure to differentiate adequately between general propositions that apply to most, if not all, members of a particular group and statistical propositions that apply to some aggregated measure of the members of the group" (p. 19). Indeed, the apparent need for inferential statistics resulted from the emergence of "controlled experimentation in psychology" (Cowles, 2001, p. 172) in the 1920s and 1930s following R. A. Fisher's works on statistics and experimental design (see pp. 176-181).

Subject Matter and Subjects in Psychology and Education

Considering the definitions of psychology and education is a good place to begin a methodological critique of the phenomenon of the "average person or student" in psychology and education. The declared subject matters and the putative subjects in both disciplines are intricately linked. It is now standard to define psychology as the scientific study of behavior and mental processes, presumably, of the individual subject, human or animal (e.g., Bernstein et al., 2007). The focus on the individual is what differentiates psychology from sociology or anthropology. The definition of education is less precise and more varied (see Arslan , 2018), but a common theme is often that of learning and acquisition of knowledge (see Dragoescu, 2018). Again, by the individual subject, in this case though, only the human subject.

Despite the central interest in the individual person or student as the putative subject in psychology and education, the predominant experimental methodology in both disciplines is focused on averages. That is largely because of the heavy reliance on large-N group designs that are strictly tied to inferential statistics, which mostly take the form of null hypothesis statistical testing or NHST in both disciplines (e.g., Bohannon, 2014; Fidler et al., 2004; Gliner et al., 2002). The other two additional inferential approaches that are considerably less common in use are the estimation (e.g., Cumming & Calvin-Jageman, 2017) and the Bayesian (e.g., König & Schoot, 2018) approaches. At any rate, one thing the three approaches have in common is their reliance on the computation of the mean in order to make sense of data.

Statistics and Research Designs in Psychology and Education

The arithmetic mean (2008) is the most commonly used of the measures of central tendency, for good reason. When Babylonian astronomers of the third century BC first exploited it for planetary location, they could not have anticipated the impact or ubiquity of the arithmetic mean (2008) in the yet undefined social and psychological sciences of these days. And since then, in all the centuries before the entry of inferential statistics into modern research, the mean served prominently in the evaluation of data (see Smith et al., 2000;) and had not been smeared. Today, it is required for inference. The t-test and the F-test in the frequentist tradition, for example, are two common inferential statistics used in psychology and education to test hypotheses (see, e.g., Nestor & Schutt, 2015; Cohen et al., 2011). They estimate population parameters from sample statistics, usually the mean (e.g., Corty, 2016; Jackson, 2016; Runyon et al., 1996). For example, t = the difference in group means / total sample variance (or effect variance and error variance, respectively). As noted in the previous section, the use of inferential statistics is intricately linked to contemporary experimental design (see Jackson, 2016; Imam, 2021).

To illuminate on the pervasiveness of group designs and the attendant reliance on inferential statistics, let us consider the topical coverage of designs and statistics in research methods textbooks. A cursory survey of some such textbooks in psychology and education (see Table 1) reveals that, in both disciplines, research methods textbooks devoted: 1) substantially more space to group designs than to single-subject designs on the experimental design end, and 2) substantially more space to NHST than to Estimation and none at all to Bayesian approaches to inferential statistics on the quantitative methods end. A comparative assessment of the coverage in each discipline shows that qualitative methods in education received the most coverage of all followed by group designs in psychology, being the highest coverage in the discipline. Of the quantitative methods, there was negligible coverage of the estimation approach, but better than the zero coverage for the Bayesian approach in both disciplines. The table also shows that whereas there was more coverage of group designs and small-N designs in psychology compared to education, there was more coverage of qualitative methods, case studies , and NHST in education than in psychology in the textbooks.

Although NHST received the most coverage of the quantitative methods, all the three inferential statistical approaches require the mean for their respective roles in interpreting experimental data in psychology and education. Surprisingly, “only 17% (2 out of 12) of the texts” examined by Gliner et al. covered the doggedly widespread NHST controversies (2002, p. 89). This kind of findings probably account for why most researchers are oblivious to the ravages of the impact of NHST in psychological and educational research. Among other things, Sharpe posited “lack of awareness” as one factor responsible for researchers ignoring criticisms of NHST and other innovations recommended in their place (2013, pp. 573-574; see also Fidler et al., 2004). Not grasping the criticisms of NHST (see Lynch & Martin, 2017), researchers may be ignorant of the importance of the alternatives or assume they are all “equivalent” (Fidler et al., 2004, p. 120). The choice of textbooks may greatly inform what is taught or learned. Leaving out the controversies in textbooks, leaves readers ignorant and uninformed about the costs and benefits of using the tools taught. In blissful ignorance, how do researchers conduct their work?

It is useful to consider the process of experimental research in psychology and education to better appreciate the need to be wary of the implications and side effects of the ubiquity of the mean measure in both disciplines. Typically, research begins with a formulation of a hypothesis (hopefully informed by theoretical considerations; see Szucs & Ioannidis, 2017; for contrary evidence), for which we select an appropriate experimental design (using experimental and control groups; Jackson, 2016), after which we recruit subjects (usually college students; Jaffe, 2005). Sometimes, a pilot study is conducted (ill-advisedly as a prelude to the real thing, see Sidman, 1960, pp. 217-233) at times badly (Francis, 2012), data collection then begins, and data analyzed (using NHST almost exclusively; see, e.g., Nickerson, 2000). The findings are then disseminated via conference presentation and/or publication. Finally, we hope, such findings contribute to theory building and more hypotheses (see, e.g., Oberauer & Lewadowsky, 2019).

It is equally important, however, to consider what is missing from how that process should work, in terms of basic methodological requirements. There is a problem of not satisfying the requirements of some fundamental statistical assumptions from the outset or of basic best practices. For example, specifying alpha and/or p value a priori as required from the outset (usually rarely done; see, e.g., Finch et al., 2001), specifying the relevant population of interest (required for the purpose of estimating parameters of the population; see Runyon et al.

Table 1. Number of pages (% of total/book and of psychology and education respectively) devoted to design and statistics topics in psychology and education research methods textbooks.

	Quantitative						
Book (edition)	NHST	Estimation	Bayesian	Qualitative	Group Designs	Case Study	Single-Subject
				Psychology			
Christensen et al., 2011 (11e)	35 (66%)	3 (6%)	0	15 (28%)	40 (63%)	3 (5%)	21 (33%)
Cozby & Bates, 2012 (12e)	23 (77%)	1 (3%)	0	6 (20%)	59 (89%)	2 (3%)	5 (8%)
Nestor & Schutt, 2015 (2e)	12 (29%)	1 (2%)	0	28 (68%)	64 (71%)	0	26 (29%)
Rosnow & Rosenthal, 2008 (6e)	83 (86%)	2 (2%)	0	11 (12%)	33 (89%)	0	4 (11%)
Total	153 32%	7 1%	0	60 13%	196 41%	5 1%	56 12%

				Education			
Ary et al., 2010 (8e)	64 (40%)	4 (3%)	0	91 (57%)	59 (53%)	46 (41%)	7 (6%)
Cohen et al., 2011 (7e)	56 (43%)	3 (2%)	0	70 (54%)	25 (60%)	14 (33%)	3 (7%)
Fraenkel & Wallen, 2009 (7e)	54 (28%)	7 (4%)	0	132 (68%)	33 (53%)	2 (3%)	27 (44%)
Lodico et al., 2010 (2e)	16 (6%)	0	0	80 (83%)	27 (73%)	0	10 (27%)
Total	190 23%	14 2%	0	373 45%	144 17%	62 7%	47 6%

1996), or ensuring that population or data meet the normality requirement (rarely checked /usually unknown); see Bakker, 2014). Power analysis is often ignored (see, e.g., Finch et al., 2001) or inadequate (Button et al., 2013; Lodge et al., 2021; Stanczak et al., 2022; Weare, 2019). Random sampling is hardly ever done (relying instead on convenient samples of college students; see Jaffe, 2005; Grohol, 2010; Henrich et al., 2010).

Random assignment is sometimes flimsy (see Brown et al., 2023; Sella et al., 2021). So, just to reiterate, because of the pervasive use of group designs that require mean measures for experimental work in both disciplines, all the inferential statistical approaches treat the "average person or student" as the putative "subject" of interest (see Imam, 2022) in psychology and education. In reality though, more often than not, it is the individual person or student who learns, not some nonexistent "average person or student."

The use of the three statistical approaches, particularly NHST, has resulted in serious adverse consequences for psychology (see DeCoster et al ., 2015) and education. Such outcomes include rampant p-hacking (see Imam, 2018; Lindsay, 2015), replication failures (see Cesario, 2014; Makel & Plucker, 2014), lack of representativeness and generalizability (see Imam 2021; Jaffe, 2005), lack of a cumulative science (see Branch, 2014), a literature awash with massive psychological and educational averages (see Imam, 2022), to name a few. In the face of these dire consequences of the overwhelming reliance on large-N group designs, what else is left to do? The answer is in a largely ignored alternative to group designs that has a long and productive history in psychology, education, and medicine (see Bernard, 1927/1957; Moran & Malott, 2004; Sidman, 1960; Tankersley et al., 2008), namely, small-N single subject designs.

Basic Features of Small-N Designs in Psychology and Education

Small-N single-subject designs have served as the default method of investigating basic (Perone, 1991; Sidman, 1960) and applied (McLaughlin, 1983) processes in behavioral psychology since its inception in the early decades of the last century (Iversen, 2013). Over the course of its development, behavioral psychology has become differentiated in its approach to the study of behavior, with the experimental analysis of behavior (EAB) focused on basic investigations of behavior and applied behavior analysis (ABA) focusing eminently on socially important behaviors. Both have thrived in their development as substantive areas in psychology to establish an independent research tradition that has avoided the trappings of inferential statistics experienced by the rest of psychology (Imam, 2021). To be clear, in the phrase small-N single subject design, if "the term 'single' describes the unit of analysis -the behavior of the individual- not the size of the sample," (Perone, 1991, p. 138), the small-N alludes to the sample size in contradistinction to the large-N requirement of group designs.

ABA has been the nexus for the introduction of small-N designs into the educational setting as a socially important setting (see McLaughlin, 1983; Sulzer-Azaroff & Mayer, 1994abc). Small-N single-subject designs focus solely on the individual, situation, or setting; mostly the individual, studying only a few of them at a time, each extensively exposed to various conditions of the relevant variables, each exposure lasting until measurement stability (see Perone, 1991). The interweaving of experimental and control conditions for each subject ensures that the individual experiences both, serving as his or her own control (McLaughlin, 1983). The real treat is that they reveal functional relationships between behavior and environmental conditions (McLaughlin, 1983; Perone, 1991; Sidman, 1960). In education, such environments can range from the school, the classroom, or teacher (variables) to teaching methods, materials, and/or technology (see Sulzer-Azaroff & Mayer, 1994abc). The following section provides three examples in the use of small-N single-subject designs in education to illustrate how small-N research works to preserve the ontological status of the individual in the research environment.

Illustrative Examples of Small-N Research in Education

The following examples show that small-N methodology is not all that foreign to educational research, as further attested to by the fact that some amount of space was devoted to their coverage in research methods textbooks in education (see Table 1). They represent only a sample of work that have been reported on educational topics in ABA.

In the first example, Witt and Elliott (1982) implemented a response cost lottery to manage student behavior in the classroom with minimal teacher resources. Three students previously exhibiting problem behaviors participated in an ABAB design. The results showed that for each child, appropriate on-task behaviors increased during each intervention (68% and 73%) relative to the respective baselines (of 10% and 43%).

Notably, the second baseline (showed more appropriate behavior (43%) than the first baseline (10%). The authors reported concomitant % changes in completed assignments: 27% for Baseline 1, 87% for Intervention 1, 38% for Baseline 2, and 90% for Intervention 2, supporting the effectiveness of the intervention in extending to other academically important behaviors.

In the second example, Munro and Stephenson (2009) reported on the use of active responding in a vocabulary classroom with 10-11 year olds of different nationalities. They compared hand raising (HR) to the use of response cards (RC) in different conditions in an ABAB (A = HR, B = RC) design. Across the conditions, they also recorded the teacher's questioning and feedback to students. The results showed that, on the part of the teacher, questioning was consistently at about the same rate throughout (about 1 response per minute or resp./min., under the first three conditions and 1.5 in the last) on the one hand, but feedback, on the other hand, increased when students used the response cards (to about 1.22 and 1.55 resp./min. under RC1 and RC2 respectively) relative to hand-raising (from .92 and .82 resp./min. under HR1 and HR2 respectively) baselines.

The students' results showed that active responding increased for each child when they used response cards (to about 85-100% and 90-100% under RC1 and RC2 respectively) compared to using hand raising (from about 10-30% and 12-28% respectively). Notably, the increase for Alice was not as high (to about 40-50% under both RC1 and RC2) as for the other students (perhaps because she was always at 0% during both of her baselines). If these kids had formed a response card experimental group in a group design, the group mean would have been reported, missing out on reporting the peculiarities of Alice's data in an average snapshot. Active responding has a positive effect on their test performances across the board, except for Alice (Nicky was absent for the final test), again demonstrating extensions to other relevant academic behaviors. Their tests scores thus improved in the two corresponding HR-RC comparisons except for Alice's and Nicky's second comparisons; i.e., not counting Nicky's absence, indicating 88% improvement cases.

Finally, in the third example, Bohan and Smyth (2022) studied academically engaging and disruptive behaviors of two targeted students and the whole class of 9-10 year olds in an all-boys school in Ireland, using the Caught Being Good Game (CBGG) intervention. The design was an ABAB reversal design. For the whole class: 1) percentage of intervals with Academically Engaging Behavior (AEB) increased with CBGG relative to the baselines, and 2) Disruptive Behavior (DB) decreased with CBGG relative to the baselines. Notably. Only one data point overlapped during the first CBGG condition (with the initial baseline). The whole class as a unit of analysis thus exhibited orderly and consistent patterns of change as a function of the CBGG intervention.

At the individual level, for Adam, one of the two targeted students, 1) there was more variability in both baseline and under CBGG for both AEB and DB, compared to whole class behaviors, but 2) nevertheless, the results generally were consistent with the general functional effects of the contingencies, with generally higher percentage of AEB and lower DB under CBGG. For Ben, the second targeted student, 1) there was less variability in both baseline and under CBGG for both AEB and DB, and more consistent with the whole class, compared to Adam, and 2) DB was substantially higher compared to the whole class in baselines. The results of Bohan and Smyth demonstrate the value of individualizing data collection and analysis even when there is interest in the group as a whole.

Contrarian Approaches

To revisit the adverse outcomes emanating from the over reliance on group designs mentioned earlier, a comparison of each of the aforementioned outcomes under small-N design regimes shows that they are nonexistent in the small-N designs. Indeed, they represent contrarian approaches for psychological and educational research.

Table 2 provides the contrasting features of the two approaches in terms of their respective adverse impacts on the state of psychological and educational research practice. Whereas p-hacking is afforded by focus on statistical control in large-N designs, it is irrelevant and nonexistent in small-N designs that are focused on experimental control. The rampant failures of replication that has characterized NHST-based large-N designs are foreign to small-N designs because replications are built in by default both within and across conditions, as well as across subjects, settings, or situations. Because of the almost exclusive use of convenient samples, large N designs have been rendered lacking in representativeness and generalizability unlike in small-N designs in which the variety of replications ensure generality of reported effects. The problem of an evasive cumulative science under the large-N group design regimes becomes mute when small-N designs are implemented correctly. Finally, with a literature awash with averages as byproducts of the intersection of inferential statistics and experimentation in large-N group designs, which then implicates the putative subject of interest in psychology and education as the "average person or student," with small-N designs, the use of averages does not define the individual person or student.

Table 2. Contrarian approaches to experimental research in psychology and education Large-*N* Group

Designs	Small-*N* Single Subject Designs
p-Hacking (from focus on statistical control)	Utterly irrelevant (experimental control)
(rampant) Failures to replicate across conditions	Replications are built-in by default within and
• Lack of representativeness and generalizability functional (due to almost exclusive use of convenient samples)	Replication ensures generality (focus on relationships, not sampling
• Lack of a cumulative science	Mute issue
Literature awash with averages per person or student	Use of averages does not define the individual

As McLaughlin pointed out, small-N designs "avoid some of the obvious problems encountered in classroom action research such as control groups, randomization procedures, complex statistical analyses which are difficult for the classroom teacher to employ and carry out" (1983, p. 41). There then may be some incentives for education researchers and practitioners to embrace small-N methodology more intentionally and reap the attendant benefits.

Implications of of Small-N Designs Acceptance

What are the implications of a wide acceptance of small-N single subject designs? First, it would focus attention on mastery in education, instead of perpetuating mediocrity by implication on account of the "average student." The ready acceptability of the notion of average student rooted in the ubiquity of the arithmetic mean in reporting research data is in part due to the extant nature of education, which educational systems tend to deliver in the classroom setting. That mode of delivery has meant that individual learners tend not to have one-on-one attention to their particular learning processes governed by their particular learning environment.
Assessment of learning, therefore, have tended to be collective and comparative, and thus conveniently conducive to evaluation via the bell curve. Hence, the "average student."

Mastery is the hallmark of personalized systems of instruction (PSI), also known as "the Keller Plan" (Buterbaugh & Fuller, 1975; Fox, 2004). There is a long history in education with PSI, most commonly in hard sciences (e.g., Fuller, 1975), but now even more with instructional design advances afforded with computers (Fox, 20004) and artificial intelligence (AI). The typical PSI requires a proctoring tutor in addition to lectures designed to motivate the learner, among other things (Buterbaugh & Fuller, 1975; Fox, 2004). With AI, as Khan describes it, tutoring is not just for the student as it is in standard PSI, but help is provided for the teacher as well (2023, 0:49-0:58), bringing "the two sigma problem" to bear on raising the bar beyond "mastery" achieved with 1:30 ratio mastery learning to two standard deviations better performance with 1:1 ratio personal tutoring, transforming "average students into exceptional students and below average into average students" (see graphic, etc., Khan, 2023, 1:07-1:52) by using the Khan AI, Khanmigo. A whole different approach to education than the conventional one we are all familiar with, with a superior outcome, all centered on the individual learner.

Second, widespread adoption of small-N designs would require a significant shift in how we approach research in psychology and education. To begin with, asking questions would no longer require attending to pre-experimental statistical considerations such as a priori alpha and power (Finch et al., 2001) and parametric concerns about normality and homogeneity of variance (Bakker, 2014). The nature of data collection would change, from the snapshot approach aimed at computing group averages for comparison, to collecting data extensively on individual behavior for in-depth comparisons across conditions of manipulated variables (Perone, 1991). Analyzing and interpreting data would no longer be the exclusive purview of inferential statistics, which would retire to the remote circumstances where true group designs are warranted by the research questions, moving us closer to the behavioral reality of the individual instead. Finally, making research and practice decisions would be based on revealed functional relations, rather than statistical imperatives.

Conclusion

In conclusion, there is nothing that is inherently wrong with the average measure per see. Indeed, it has a long history that predates the invention of inferential statistics, some of which have come to symbolize its diminution as a quantitative tool. The real culprit is how we have been using it to make sense of data that we have encountered in our attempts to quantify nature and humanity. In good stead, we are not condemned to live with the "average student" side effect of our heavy reliance on large-N group designs, whose usually inadequate implementation has been responsible for the myriad of methodological problems including replication failures. There are demonstrably effective, viable alternatives in small-N single-subject designs that remove the cloak of mediocrity that inadvertently adorns many putative subjects in psychology and education. These designs ought to be more widely adopted for the myriad of methodological advantages they bring to the table. Not doing so is like repeating the same mistake over and over and expecting a different result.

Recommendations

- As researchers and educators, we should be wary of labeling learners as "average students."
- To do this most effectively, we need to be cognizant of the roots of its usage and how it is tied to statistics.

In deed, the idea is not based on experimental or experiential necessity.

- There are alternatives to NHST and large-N group designs for scientific research; consider small-N single subject designs for their myriad of methodological advantages for research and practice. The time and effort is well worth it.

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Bibliometric and Visualization Analysis of Research Articles on Traditional Chinese Medicine

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Abstract: This study conducted a comprehensive review based on 1185 studies from 2020-2023 retrieved from the Web of Science database with the aim to explore the main contributors, research status, hot topics and research frontiers concerning traditional Chinese medicine related to COVID-19 through a metrical and visualization analysis of the literature. CiteSpace 6.1. R6 software was applied to visualize the publication countries, authors, institutes, keywords and references of the literature and to draw a visual knowledge graph. The study shows that 81% of articles were published from China, followed by 8.2% from the USA and 5.3% from India, with China Aca Chinese Med Sci contributing the most publications. Moreover, research hotspots of coronavirus included molecular docking, sar, systematic review and herbal medicine. The study also revealed several problems. The translation strategy of traditional Chinese medicine should combine domestication and foreignization to maintain the originality of TCM's nature. Instead of blindly merging into the Western medicine system, the spread of traditional Chinese medicine ought to broaden its span and convey the theoretical framework, philosophical thoughts and traditional culture as a whole. In addition, cooperation between research institutes can be further strengthened to deliver an integrated and united research pattern.

Keywords: traditional Chinese medicine; COVID-19; CiteSpace; visualization analysis

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Introduction

Since being defined as a "Public Health Emergency of International Concern" by the WHO, the COVID-19 pandemic has caused hundreds of thousands of cases globally. There was no doubt that COVID-19 was the largest global health crisis since the 21st century, which caused enormous trauma in the economy, tourism, transportation and all other fields worldwide. However, since the World Health Organization recommended the development of potential vaccines and antiviral medicines at the second meeting of the Emergency Committee on January 30, 2020, there has been no confirmed effective antiviral therapy for COVID-19(Zhuang et al., 2021). Because of the advantages of traditional Chinese medicine in the treatment of complicated diseases, Chinese medical institutes spare no effort in conducting many studies to determine the most effective prescription. General Secretary Xi and Premier Li Keqiang attached great importance to the industrialization and modernization of traditional Chinese medicine, which carries profound universal value and unique curative effects and should be well protected, developed and inherited("Xi Gave Important Instructions to the Work of Traditional Chinese Medicine," 2019). It is essential to give full play to the unique advantages of traditional Chinese medicine in disease prevention, treatment and rehabilitation, especially in this global health crisis. Traditional Chinese medicine is not only a scientific accomplishment but also a cultural heritage for millennia. The Chinese government has upgraded the promotion and innovation of TCM since the 18th National Congress of the Communist Party of People’s Republic of China, along with nearly 30 policies and measures.

The outbreak of the COVID-19 pandemic was a huge challenge to the medical system in all countries globally. The treatment of coronavirus has become a major global public health concern. At the same time, it was also an opportunity to further demonstrate the advantages of traditional Chinese medicine. TCM holds an irreplaceable status in medical treatment, while its global acknowledgment still far from where it deserves to be. The awarding of the Nobel Prize in 2015 of Tu Youyou substantially boosted the popularity of TCM worldwide. However, the efficacy of TCM has been questioned. Zhang GongYao from Central South University called traditional Chinese medicine pseudoscience because of its lack of randomized, controlled trials in terms of drug safety and efficacy(Qiu, 2007). The dissemination of TCM faces obstacles, including the stereotype of “unscientific” and “empiricist”(Chen, Tong, Ren, Yu, & Cui, 2019). Thus, a systematic investigation of the active countries, authors, institutions, high-frequency references and keywords involved in coronavirus research is critical to the future promotion of traditional Chinese medicine. It helps to improve international communication in the medical field and to turn traditional Chinese medicine into soft power in the postpandemic era.

Literature Review

Traditional Chinese medicine has developed for thousands of years, since the era of ancient China. It has contributed greatly to the treatment and prevention of COVID-19. During the pandemic, the Chinese government successively released ten editions of *Guidance for Coronavirus Disease: Prevention, Control, Diagnosis and Management*, recommending the characteristic treatment of traditional Chinese medicine, among which "three drugs and three prescriptions" were proven to be effective through clinical screening. "Three drugs" refers to Jinhua Qinggan Granules and Lotus Qingwen Gum capsule/granule and Xuebijing injection. The National Drug Administration has approved the inclusion of the indication of COVID-19 treatment in the "three drugs". "Three prescriptions" refer to Qingfei Detox Decoction, Huashi Baidu Fang and Xuanfei Baidu Fang. Qingfei Detox decoction was derived from five classic prescriptions from the *Treatise on Febrile and Miscellaneous Diseases.* Xuebijing injection was first developed and marketed during SARS in 2023. Combined

use with Western medicine can improve the rate of cure and discharge("The "Three Drugs and Three Prescriptions" of Traditional Chinese Medicine during the Pandemic,"). The World Health Organization (WHO) released the report of the “WHO Expert Evaluation Meeting on Traditional Chinese Medicine in the Fight against COVID-19”, which affirms the contribution of traditional Chinese medicine in the fight against COVID-19, encouraging member states to consider the integrated Chinese and Western medicine model (integrated medicine model) developed and applied in China.(Gaoli, Yingjian, & Fuchun, 2023) A total of 113 member countries of the World Health Organization recognized acupuncture and other traditional Chinese medicine diagnosis and treatment methods, and TCM has already spread to over 196 countries and regions(Gaoli et al., 2023). At the beginning of 2020, traditional Chinese medicine was involved in 92.41% of the treatment of COVID-19, and the effective rate reached 97.78%(Lu, 2021). Despite the vital role traditional Chinese medicine plays in the treatment and rehabilitation of patients, it still lacks recognition and application on a global scale.
Scholars such as Chen Yao and Zeng Yueyang conducted thorough research using information visualization analysis to illustrate the knowledge map of network meta-analysis (NMA) in traditional Chinese medicine(C. Yao, Xueyang, Fengwen, & Feng, 2020). Chen Yibing and other scholars worked together to construct a bibliometric review of current research trends in traditional Chinese medicine from 2000 to 2016. They found that despite the growth, the publications were published rarely in top academic journals, and most-quality papers preferred medical analysis rather than pharmacology(Chen et al., 2019). Wang Wanying introduced a detailed evolutionary course of TCM, focusing on the related policies and measures. The number of students in TCM universities, the number of TCM agencies and fiscal appropriation to TCM agencies all improved from 2012 to 2017. Under the prosperous surface are all kinds of difficulties. Lack of international communication and recognition is one of them. Dong Jian and Wang Tianfang et al. also used CiteSpace to analyze Chinese research articles on Chinese medicine terminology translation. With bibliometric approaches, they provided a full and systematic view of the articles published from 1991 to 2015(Jian, Tianfang, Lilan, & Qing, 2017). In terms of specific types of TCM, there have also been studies to prove their efficacy. Jie Qinzhuang and Xingzhen Bai et al. conducted clinical application of Lianhua Qingwen in the treatment of COVID-19, indicating its effectiveness in improving clinical symptoms and reducing the rate of clinical change to severe or critical conditions(Zhuang et al., 2021).

However, there is a lack of research concerning the performance and international recognition of TCM during the pandemic. The statistical analysis of TCM-related articles published in international journals can help researchers grasp the focus and promote the dissemination of TCM on the global stage. Currently, there has not been a scientometric study using mathematical and statistical methods to analyze the intellectual landscape, basic characteristics, current status and emerging trends regarding TCM research as a treatment for the COVID-19 pandemic. Thus, this study addresses this gap and provides a full picture of the research on traditional Chinese medicine specifically as a treatment for COVID-19. CiteSpace 6.1. R6 was adopted to form a visualization analysis of the research countries, authors, institutes, references and keywords in the publication of TCM related to COVID-19.

Data Collection

The literature related to traditional Chinese medicine for COVID-19. In this study, the data were retrieved on February 20, 2023, from the WoS (with Web of Science Core Collection only) database created by Clarivate Analytics (United States) in 1997. Web of Science Core Collection is the world's leading citation database, containing a curated collection of over 21,000 peer-reviewed, high-quality scholarly journals published worldwide("Web of Science Core Collection: Introduction,"). It is also the largest comprehensive information resource and most trusted publisher-independent global citation database(Chen et al., 2019). The topic of studies ("TS", which comprises Title, Abstract, Keywords and Keywords Plus) is chosen as "TS=("traditional Chinese medicine" and "COVID-19")) and their Boolean combination. The period from January 2020 to February 20, 2023 was selected. A total of 1185 records were retrieved. There are 663 articles, 403 reviews, 40 letters, and 54 editorial materials in total. The document types are shown in Table 1. All identified records were downloaded from the WoS database on February 20, 2023, and imported into CiteSpace for further studies.

document types	count
Article	663
Article; Data Paper	1
Article; Early Access	10
Correction	4
Editorial Material	54
Letter	40
Meeting Abstract	2
News Item	3
Proceedings Paper	3
Review	403
Review; Early Access	2

Table 1. The document types of selected articles

Data Analysis

The analysis was carried out using CiteSpace 6.1. R6 software

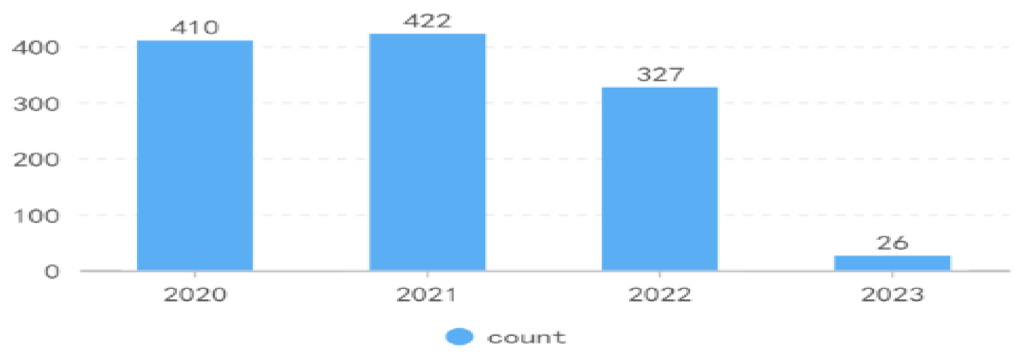

Figure 1. Time distribution diagram of the related papers on traditional Chinese medicinetreatment of COVID-19

The number of medical publications concerning the treatment of coronavirus has been generally steady. The data collection ended by February 20th, 2023. 2021 was a small peak in the past three years. The number of average publications on traditional Chinese medicine as a treatment for COVID-19.

Analysis of countries

Count	Centrality	Year	Countries
960	0.61	2020	PEOPLES R CHINA
98	0.12	2020	USA
63	0.06	2020	INDIA
32	0.09	2020	ENGLAND
26	0.05	2020	AUSTRALIA
25	0.14	2020	SAUDI ARABIA
21	0.11	2020	GERMANY
20	0.12	2020	IRAN
18	0.15	2020	PAKISTAN
17	0.03	2020	SOUTH KOREA
16	0.02	2020	CANADA
15	0.08	2020	MALAYSIA
13	0.02	2020	BRAZIL
11	0.10	2020	FRANCE
11	0.08	2020	ITALY
10	0.11	2020	TURKEY
10	0.00	2020	JAPAN
10	0.12	2021	BANGLADESH

Table 2. Countries that contributed the most to TCM as a treatment for COVID-19

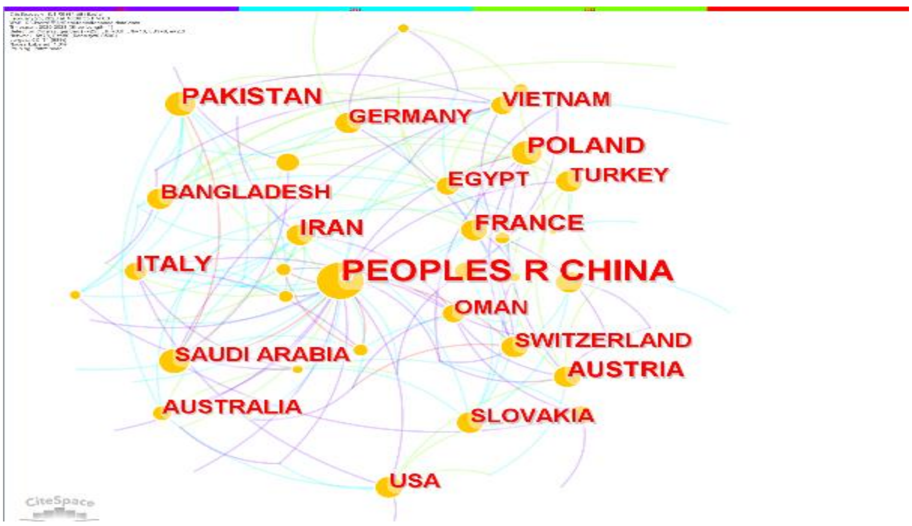

Figure 2. Country co-occurrence analysis of traditional Chinese medicine as a treatment for COVID-19

According to Table 2, 960 articles were published from China, followed by 98 publications from the USA, 98 publications from India, 32 publications from Australia and 25 publications from Saudi Arabia. The central nodes with centrality≥0.1 were China, USA, Saudi Arabia, Germany, Iran, Pkistan, France, Turkey, Switzerland and Bangladesh. Although India, England, and Australia published a larger number of articles in international journals, their research was conducted comparatively independently, with less cooperation with other countries.

81% of articles were published from China, followed by 8.2% from the USA and 5.3% from India. The publications from three countries in total covered more than 90% of the articles, which means that to date, the study of traditional Chinese medicine has been highly centralized domestically, lacking global recognition and involvement. The generated country analysis graph has 78 nodes and 150 lines. The country with the highest frequency and centrality was "Peoples R China", with a centrality of 0.61. High centrality indicates the importance of the node in the text. The greater the centrality of the node is, the closer the relationship between the node and the surrounding nodes(Hu & Zhang, 2021).

Analysis of authors

Count	Centrality	Year	Authors
17	0.13	2020	Zhang, Junhua
15	0.21	2020	Zhang, Ying
13	0.04	2020	Tong, Xiaolin
12	0.06	2020	Zhang, Wei
9	0.02	2021	Wang, Yu
8	0.06	2020	Liu, Bin
8	0.12	2020	Lian, Fengmei
8	0.07	2021	Fang, Bangjiang
8	0.14	2020	Luo, Hui
7	0.06	2021	Li, Jing
7	0.03	2021	Huang, Luqi
7	0.03	2020	Chen, Yaolong
7	0.00	2020	Li, Li
6	0.04	2021	Zhou, Wei
6	0.09	2020	Zhang, Lei
6	0.02	2020	Luo, Hua
6	0.12	2020	Wang, Yanping
6	0.13	2021	Liu, Qingquan
6	0.01	2020	Chen, Ying
6	0.10	2021	Wang, Jian
5	0.00	2022	Su, Yi-Chang
5	0.00	2022	Wang, Yan
5	0.00	2020	Li, Xiuyang
5	0.00	2021	Liu, Wei
5	0.01	2021	Wang, Fei
5	0.01	2021	An, Xuedong
5	0.02	2022	Zhang, Han
4	0.00	2020	Wu, Hezhen
4	0.00	2021	Liu, Yang
4	0.00	2021	Zhang, Wen
4	0.01	2020	Gao, Ya
4	0.00	2020	Chen, Yu
4	0.00	2022	Tseng, Yu-Hwei
4	0.00	2020	Ang, Lin
4	0.01	2020	Zheng, Yujiao
4	0.00	2020	Chen, Yong
4	0.02	2020	Tian, Jinhui
4	0.02	2020	Zhang, Qing
4	0.01	2022	Wang, Hui
4	0.00	2021	Chen, Jun
4	0.00	2020	Wang, Jin
4	0.00	2020	Lee, Myeong Soo
4	0.01	2020	Che, Jinhua
4	0.00	2021	Liu, Jian-Ping
4	0.03	2021	Li, Bin
4	0.01	2022	Zhao, Ting
4	0.01	2021	Yang, Zifeng
4	0.05	2021	Zhong, Nanshan
4	0.00	2020	Shi, Yu
4	0.00	2021	Li, Jun
4	0.03	2020	Zhou, Hua
4	0.02	2021	Zhao, Chongbo
4	0.08	2021	Li, Fang
4	0.00	2021	Wang, Dong
4	0.02	2021	Ni, Xiaojia

Table 3: Authors with the most publications on traditional Chinese medicine related to COVID-19

Keyword map related to the authors of the articles. A total of 225 nodes and 276 connection lines were obtained. 225 nodes refer to 225 authors. 276 Connection lines indicate the collaboration network. The authors visualized in Figure 3 were those who published more than five articles. Different colors represent different years. Purple represents 2020, blue represents 2021, green represents 2022 and red represents 2023. In the map, it is obvious that Zhang Junhua published the most articles and Zhang Ying has the highest betweenness centrality (0.21).

Nodes with centrality≥0.1 are called central nodes. The central nodes shown in Table include Zhang Ying (0.21), Luohui (0.14), Liu Qingquan (0.13), Zhang Junhua (0.13), Lian Fengmei (0.12), Wang Yanping (0.12), and Wang Jian (0.1). Betweenness centrality was based on structural hole theory, which was originally developed for social networks. High betweenness centrality indicates a larger value in the network.

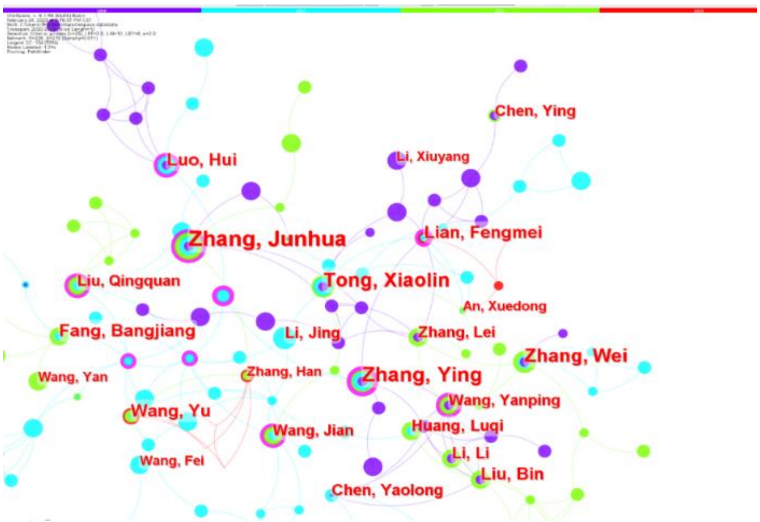

Figure 3: Author cooccurrence analysis of traditional Chinese medicine related to COVID-19

Analysis of institutes

Count	Centrality	Year	Institutions
77	0.13	2020	China Acad Chinese Med Sci
77	0.17	2020	Beijing Univ Chinese Med
61	0.05	2020	Shanghai Univ Tradit Chine...
49	0.07	2020	Tianjin Univ Tradit Chinese ...
48	0.03	2020	Chengdu Univ Tradit Chine...
41	0.05	2020	Chinese Acad Sci
35	0.03	2020	Fudan Univ
35	0.15	2020	Guangzhou Univ Chinese M...
35	0.12	2020	Capital Med Univ
33	0.03	2020	Huazhong Univ Sci & Technol
31	0.18	2020	Sichuan Univ
31	0.10	2020	Hubei Univ Chinese Med
29	0.03	2020	Shandong Univ Tradit Chine...
28	0.03	2020	Zhejiang Chinese Med Univ
27	0.04	2020	Lanzhou Univ
25	0.03	2020	Zhejiang Univ
24	0.05	2020	Guangzhou Med Univ
22	0.09	2020	Shanghai Jiao Tong Univ
22	0.02	2020	Hosp Chengdu Univ Tradit ...
18	0.00	2020	Macau Univ Sci & Technol
18	0.02	2020	Univ Macau
18	0.01	2020	Wuhan Univ
17	0.09	2020	Nanjing Univ Chinese Med
17	0.23	2020	China Med Univ
17	0.04	2020	Southern Med Univ
17	0.01	2020	Jinan Univ
16	0.04	2020	Peking Univ
15	0.14	2020	Nanjing Med Univ
15	0.06	2020	Shandong Univ
15	0.02	2020	Chinese Univ Hong Kong
14	0.04	2020	Chinese Acad Med Sci
14	0.06	2020	Hubei Prov Hosp Tradit Chi...
14	0.01	2020	Univ Chinese Acad Sci
13	0.08	2020	Cent South Univ
13	0.05	2020	Sun Yat Sen Univ
13	0.12	2020	Chinese Acad Med Sci & Pe...
12	0.08	2020	King Saud Univ
12	0.03	2020	Xiamen Univ
11	0.00	2020	China Pharmaceut Univ
11	0.02	2020	Shaanxi Univ Chinese Med
11	0.02	2020	Zhengzhou Univ
11	0.05	2020	Hong Kong Baptist Univ
10	0.07	2020	Naval Med Univ
10	0.03	2020	Soochow Univ

Table 4: institutes with most contributions of traditional Chinese medicine related to COVID-19

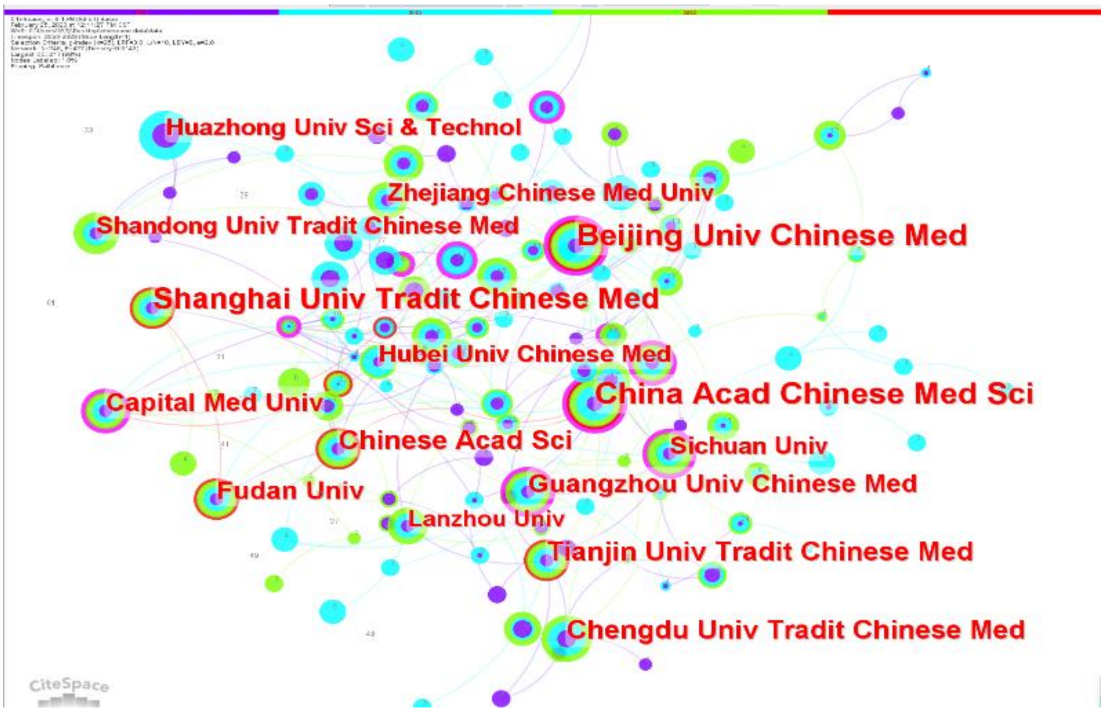

Figure 4: Visualized map of the leading institutes contributing to traditional Chinese medicine related to COVID-19

CiteSpace 6.1. R6 software was used to draw the cooccurrence map of the published institutions of the relevant literature on the treatment of COVID-19 with traditional Chinese medicine. Figure 4 related to the institutes of the articles. A total of 245 nodes and 427 connection lines were obtained. 245 nodes refer to 245 institutes. 427 Connection lines indicate the collaboration network between different institutes. The thickness of the ring depicts the value of the betweenness centrality. According to the figure, China Acad Chinese Med Sci and Beijing Univ Chinese Med are the institutions that published the most articles. Both of them published 77 articles in the past 3 years, with Beijing Univ Chinese Med's betweenness centrality (0.17) slightly higher than China Acad Chinese Med Sci (0.13). Shanghai University Tradit Chinese Med has 61 publications, Tianjing University Tradit Chinese Med has 49 publications, Chengdu University Tradit Chinese Med has 48 publications and Chinese Aca Sci has 41 publications. China Med Univ (0.23) published 17 articles and had the highest betweenness centrality, which was used to detect boundary-spanning potentials and novel brokerage connections in scholarly publications("the overview of betweeness centrality," 2023). Moreover, Beijing Univ Chinese Med, Guangzhou Univ Chinese Med, Capital Med Univ, Sichuan Univ, hubei Univ Chinese Med, Chinese Acad Med Sci & Peking Union Med, Nanjing Med Univ showed a relatively higher centrality compared with their number of publications, which indicates their higher level of connection and collaboration with other institutes during the research. In contrast, Shanghai University Tradit Chinese, Chengdu University Traidic Chinese, Fudan University, and Huazhong University Sci & Technology were more prone to develop traditional Chinese medicine related to COVID-19 on their own. To form an intensive and uniform research system for traditional Chinese medicine, domestic institutes should develop an integrated model with shared information and scientific research achievements.

Analysis of key words

Keywords related to both TCM and COVID-19 research. A total of 320 nodes and 742 connection lines were obtained, as shown in Table 5.

Count	Centrality	Year	Keywords
383	0.03	2020	traditional chinese medicine
133	0.05	2020	network pharmacology
125	0.08	2020	coronavirus
92	0.02	2020	molecular docking
87	0.01	2020	coronavirus disease 2019
81	0.04	2020	covid 19
78	0.00	2020	sar
77	0.08	2020	pneumonia
75	0.01	2020	systematic review
67	0.04	2020	herbal medicine
57	0.01	2020	chinese medicine
56	0.03	2020	antiviral activity
56	0.03	2020	sars cov 2
52	0.04	2020	in vitro
48	0.03	2020	acute respiratory syndrome
46	0.04	2020	acute lung injury
46	0.01	2020	medicine
45	0.01	2020	infection
42	0.00	2020	virus
42	0.08	2020	replication
42	0.07	2020	inflammation
42	0.02	2020	sars coronavirus
42	0.03	2020	protein
41	0.11	2020	cytokine storm
40	0.02	2020	nf kappa b
39	0.02	2020	mechanism
39	0.00	2020	inhibition
36	0.02	2020	chinese herbal medicine
36	0.01	2020	natural product
33	0.02	2020	wuhan
32	0.01	2020	spike protein
31	0.02	2020	respiratory syndrome corona...
30	0.04	2020	identification
30	0.01	2020	expression
29	0.04	2020	cell
29	0.03	2020	outbreak
27	0.01	2020	receptor
27	0.01	2020	extract
25	0.01	2020	traditional chinese medicine ...
25	0.05	2020	xuebijing injection
25	0.02	2020	ace2
24	0.06	2020	inhibitor
23	0.01	2020	randomized controlled trial
23	0.05	2020	efficacy
21	0.02	2020	decoction
21	0.01	2020	coronavirus disease 2019 (c...
21	0.00	2020	novel coronavirus pneumonia
20	0.03	2020	corona virus disease 2019
20	0.04	2020	drug
20	0.05	2020	oxidative stress

Table 5: High-frequency keywords and centrality of traditional Chinese medicine related to COVID-19

The figure represents the topics that were most studied in the field of TCM related to COVID-19. The top 5 frequently occurring keywords in the literature are traditional Chinese medicine, network pharmacology, coronavirus, molecular docking and coronavirus disease 2019, suggesting that these may be hot spots that are extensively studied in the field. It is worth noting that “cytokine storm (o.11)” is the only keyword whose betweenness centrality is over 0.1, which means that it plays a vital role in linking other keywords and became a hot spot.

The keywords beside traditional Chinese medicine and COVID-19 can be summarized into three types: traditional Chinese medicine (herbal medicine, Chinese herbal medicine, decoction, xuebijing injection, etc.), medical terminology (network pharmacology, in vitro, acute respiratory syndrome, acute lung injury, cytokine storm, inflammation, NF-kappa B, ACE2, etc.), the outcome of treatments (efficacy, randomized controlled trial, systematic review, etc.) There are two characteristics in the figure that are worth noting. One is that there are seldom any TCM terminologies except for Xuebijing injection.

Chinese herbal formulas for the treatment of SARS-CoV infection include Ma Xing Shi Gan decoction, Da Yuan Yin decoction, Qing Fei Pai Du decoction, Sang Ju Yin and Yu Ping Feng San(Mirzaie, Halaji, Dehkordi, Ranjbar, & Noorbazargan, 2020). Jinghua Qinggan granules, Lianhua Qingwen granules and capsules, and Xuebijing injection are the three traditional Chinese medicine products that have been approved to treat patients with COVID-19 by the National Medical Products Administration of China(Xiong et al., 2021). Xuebijing injection is one of the treatments among the "three drugs and three prescriptions" recommended by the National Administration of Traditional Chinese Medicine.

Top 10 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2020 - 2023
acute respiratory syndrome	2020	4.6	**2020**	2020	
wuhan	2020	4.11	**2020**	2020	
infection	2020	3.51	**2020**	2020	
mers cov	2020	2.49	**2020**	2020	
identification	2020	3.75	**2022**	2023	
lianhua qingwen	2022	3.14	**2022**	2023	
mechanism	2020	2.92	**2022**	2023	
decoction	2020	2.48	**2022**	2023	
rat plasma	2022	2.24	**2022**	2023	
mortality	2022	2.24	**2022**	2023	

Table 6. Top 10 Keywords with Strongest Citation Burst

The top frequency keywords with the strongest citation bursts in 2020 were acute respiratory syndrome, wuhan, infection, and mers cov, and the top keywords from 2022 to 2023 were identification, lianhua qingwen, mechanism decoction, rat plasma and mortality. In 2020, the research topic mainly focused on the disease itself, which slightly turned to the solution, treatment, methods and results in 2022.

In Figure 5, it can be observed that keywords were clustered into ten groups by the CiteSpace clustering method: drug-metabolizing enzyme, cardiovascular system, human coronaviruses, testing treatment, core outcome, systematic analyses, systematic review, traditional usage, ongoing COVID-19 pandemic and apparent discordance.

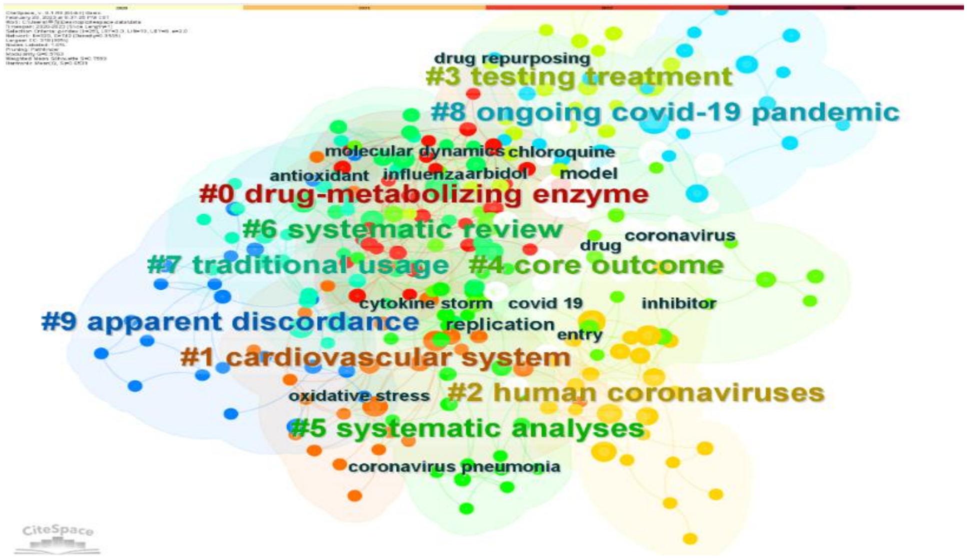

Figure 5: Visualized map of the high-frequency key words of traditional Chinese medicine related to COVID-19

Analysis of references

Count	Centrality	Year	Cited References
197	0.02	2020	Huang CL, 2020, LANCET, ...
173	0.05	2020	Yang Y, 2020, INT J BIOL S...
173	0.01	2020	Zhu N, 2020, NEW ENGL J ...
166	0.05	2020	Ren JL, 2020, PHARMACOL...
157	0.06	2020	Li RF, 2020, PHARMACOL ...
141	0.02	2020	Guan W, 2020, NEW ENGL ...
132	0.07	2021	Hu K, 2021, PHYTOMEDICI...
120	0.02	2020	Luo H, 2020, CHIN J INTEG...
113	0.03	2020	Chen NS, 2020, LANCET, V...
86	0.02	2020	Lu RJ, 2020, LANCET, V395...
85	0.01	2020	Hoffmann M, 2020, CELL, V...
84	0.06	2014	Ru JL, 2014, J CHEMINFOR...
82	0.02	2020	Cao B, 2020, NEW ENGL J ...
73	0.01	2020	Zhang DH, 2020, J INTEGR ...
70	0.04	2020	Holshue ML, 2020, NEW EN...
69	0.01	2020	Zhou F, 2020, LANCET, V39...
69	0.01	2020	Wang ML, 2020, CELL RES,...
67	0.03	2020	Liu M, 2020, PHARMACOL ...
67	0.03	2020	Wrapp D, 2020, SCIENCE, ...
66	0.01	2020	Yang RC, 2020, PHARMAC...
66	0.01	2020	Zhou P, 2020, NATURE, V5...
63	0.03	2017	Ding YW, 2017, BMC COMP...
62	0.00	2020	Lu HZ, 2020, BIOSCI TREN...
59	0.04	2020	Xiao MZ, 2020, PHARMACO...
59	0.01	2020	Chan JFW, 2020, LANCET, ...
59	0.00	2020	Huang YF, 2020, PHARMAC...
57	0.00	2020	Jin YH, 2020, MILITARY ME...
57	0.00	2020	Wang ZW, 2020, BIOSCI TR...
52	0.02	2020	[姚开涛 Yao Kaitao], 2020, ...
52	0.00	2020	Wang C, 2020, LANCET, V3...
51	0.00	2020	Wu ZY, 2020, JAMA-J AM ME...
51	0.05	2020	Mehta P, 2020, LANCET, V3...
50	0.01	2020	Wang DW, 2020, J COASTA...
50	0.03	2020	Xu Z, 2020, LANCET RESP ...
50	0.00	2020	Chan KW, 2020, AM J CHIN...
49	0.03	2020	Wang YM, 2020, LANCET, V...
49	0.01	2020	Bai Y, 2020, JAMA-J AM ME...
49	0.04	2020	Zhou P, 2020, NATURE, V5...

Table 7: High-frequency cited references of traditional Chinese medicine related to COVID-19

In Table 7, we can see that Huang CL had the highest cited reference, which was cited 197 times in the past 3 years, followed by Yang Y and Zhu N, whose articles were cited 173 times, Ren JL 166 times, Li RF 157 times, Guan W 141 times and Hu K 132 times. The references cited in articles were rather scattered, among which the article published by Hu K (0.07) had the highest centrality. Most top-frequency cited articles were published in 2020, while the article published by Ru RJ was published in 2014.

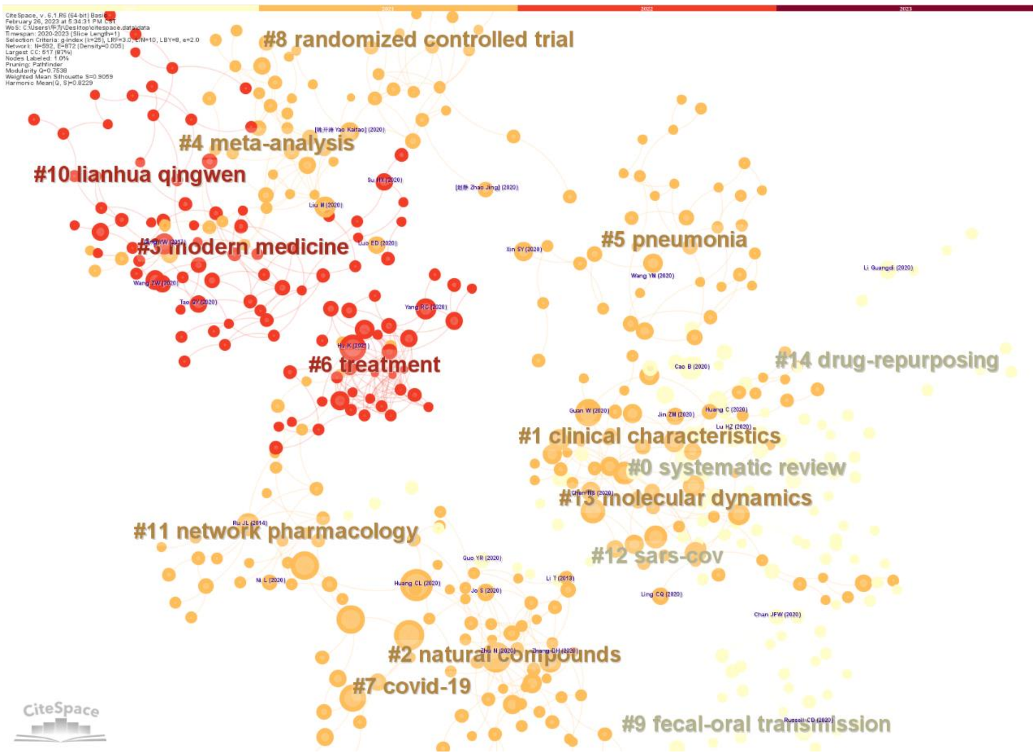

Figure 6: Visualized map of the leading cited references to traditional Chinese medicine related to COVID-19

There were a total of 592 nodes and 872 links within the visualized map 5, indicating a rather high rate of overlapping references in the selected 1185 articles. After optimizing the layout and style of the clustering based on keywords and label clusters with indexing terms, statistics showed that there were 15 clusters of references: systematic review, clinical characteristics, natural compounds, modern medicine, meta-analysis, pneumonia, treatment, COVID-19, randomized controlled trial, fecal-oral transmission, lianhua qingwen, network pharmacology, SARS-CoV, molecular dynamics, drug, repurposing, complementary and alternative medicine. The cited articles within the cluster were closely related to each other. In 2022, treatment, modern medicine and Lianhua Qingwen became hot spots in the field.

Table 8 illustrates the 5 top references with the strongest citation bursts together with their strength and duration. Bursts mean a frequency surge of a particular type of event. Citations by Xiong XJ, Su HX, Ni LQ, Wiersinga WJ and Zhao J experienced a sharp increase from 2021 to 2023, which demonstrates that their research results were the frontier results during this period.

Top 5 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2020 - 2023
Xiong XJ, 2020, PHARMACOL RES, V160, P0, DOI 10.1016/j.phrs.2020.105056, DOI	2020	2.64	**2021**	2023	
Su HX, 2020, ACTA PHARMACOL SIN, V41, P1167, DOI 10.1038/s41401-020-0483-6, DOI	2020	2.37	**2021**	2023	
Ni LQ, 2020, ACTA PHARM SIN B, V10, P1149, DOI 10.1016/j.apsb.2020.06.009, DOI	2020	2.09	**2021**	2023	
Wiersinga WJ, 2020, JAMA-J AM MED ASSOC, V324, P782, DOI 10.1001/jama.2020.12839, DOI	2020	1.96	**2021**	2023	
Zhao J, 2021, PHYTOMEDICINE, V85, P0, DOI 10.1016/j.phymed.2020.153315, DOI	2021	1.71	**2021**	2023	

Table 8: Top 5 references with the strongest citation bursts

Discussion

The translation of traditional Chinese medicine

In 1995, Lawrence Venuti proposed the concepts of two translation strategies, domestication and foreignization, regarding the degree to which translators make a text conform to the target culture. Foreignization in the translation of traditional Chinese medicine, two strategies should be used together. However, even though the articles are retrieved with the topic of “traditional Chinese medicine”, in the list of high-frequency keywords, we can hardly see any transliteration or specific terminology used only in TCM. According to the research, from 1989 to 2018, compared with foreignization, domestication was the dominant translation strategy of Chinese medicine ingredients, whose ratio increased from 78% to 96% over the years. For example, Wutou alkali was translated to aconitine, and Danggui acid was turned into angelic acid. Foreignization benefits interdisciplinary research with compound analysis while losing national characteristics within TCM.(Wang & Tingyu, 2019) Overly catering to the needs of the Western medicine system would diminish the nature of TCM, which in essence holds a different theoretic system from Western medicine. TCM focuses on the harmony of the human body as a whole. There is no equivalent terminology in Western medicine. Thus, transliteration is necessary in some cases to preserve the original meaning of TCM and stay loyal to the source culture. Current translation can adopt dual translation as a transition, which can preserve the culture while helping target language readers understand the content, such as translating “风火眼” to “wind-fire eye (acute conjunctives)” and "釜底抽薪” to “raking the firewood from beneath the cauldron (drastic purgative treating method)”(En & Sulin, 2022). The classic literature of traditional Chinese medicine contains a complete theoretical system that can only be fully conveyed by its own metaphors. Traditional Chinese doctors focus on the human body from a holistic view. Instead of treating the disease, some traditional Chinese doctors choose to heal the body and improve the overall state. There was a huge gap between the need in the TCM translation market and the talents nurtured by traditional teaching methods. Thus, translators with rich TCM knowledge were an indispensable part of the international communication of TCM.

Moreover, the translation of traditional Chinese medicine lacks systematic research. Different research groups should enhance cooperation, reduce duplicate research and establish standardized translation networks. There are more than 1000 pharmacopoeia books about traditional Chinese medicine, of which only approximately 20 books were translated(Lu, 2021). Western At present, there are only three TCM translation corpora built in China: the English-Chinese parallel corpus of traditional Chinese medicine established by Heilongjiang University of Traditional Chinese Medicine, the Chinese-English bilingual corpus platform of traditional Chinese medicine established by Jiangxi Normal University and the parallel corpus of classical Chinese medicine literature created by Shanghai University of Traditional Chinese Medicine(Wang & Tingyu, 2019). The World Health Organization, World Federation of Chinese Medicine Societies and International Organization for Standardization/Technical Committee are the international standards for the translation of traditional Chinese medicine(En & Sulin, 2022). However, the existing standard focused mainly on qualitative research, which lacked empirical research in general. Moreover, some medicines had different translations based on different standards, undermining the spread of certain prescriptions. There is an urgent need to build a comprehensive corpus for international communication, along with a standardized discourse system and terminology criteria. The standard of translation should take international communication and cultural differences into consideration.

Research orientation

On the one hand, the development and modernization of the traditional Chinese medicine industry has benefited greatly from the Western medicine system. Computer-aided, structure-based drug discovery helped to narrow down a large amount of natural compounds of traditional Chinese medicine into a relatively short time with limited resources(Ling, 2020). On the other hand, the publication of traditional Chinese medicine in international journals tends to sacrifice its own nature in exchange for Western recognition. Traditional Chinese medicine experiences a process of modernization and westernization, while merging into the western system often means the loss of the original theoretical framework and spirit. Due to discrepancies in culture, history and philosophical views of health care and medication, American and European governments chose to warn of the possible harm of traditional or herbal medicine rather than utilize traditional knowledge and sources such as China or other countries with traditional medication history and theory. Thus, facing the inconsistent or even polarized international pattern, it is necessary to spread the culture and philosophical system along with the medical cure. Yin Xiong and Min Gao et al. performed research on traditional medicine or herbal medicine related to COVID-19 using the Web of Science Core Collection, MEDICINE, Current Contents Connect, and SCIELO Citation Index databases and found that among 634 records of TM/HMs, 48.9% of the data were contributed by institutes in China, compared with only 13.56% of the USA(Xiong et al., 2021). TCM prescriptions and therapies were included and recommended in the guidelines released by the State Administration for Market Regulation and adopted in all stages of prevention, treatment and rehabilitation of COVID-19. Chinese people are accustomed to adopting “integrative” treatment by receiving TCM and biomedicine at the same time to promote each other. Herbals are one of the most commonly used interventions in TCM, while most herbal medicines sold in the US are marketed as food or dietary supplements rather than for medical uses. In general, Western countries lack traditional use and well-designed clinical trials(Xiong et al., 2021). Although TCM has suggested great clinical experiences and effective and applicable herbal formulas for the inhabitation and treatment of respiratory diseases, the unfavorable environment for traditional medicine in western counties cannot be changed overnight. Thus, for better acceptance of traditional Chinese medicine, the spread of TCM culture, philosophy and theory should spread along with the pharmacy to build a friendly foundation among the Western public.

Incompatible media image

Although traditional Chinese medicine has gradually gained scientific acknowledgment worldwide and shown a rather steady publication trend in international journals, the public opinion toward traditional Chinese medicine distorted by mass media has been unfavorable in Western countries. For example, Lianhua qingwen was developed by Shijiazhuang Yiling Pharmaceutical and contains Forsythia suspensa and Lonicera japonica. It was used to treat influenza and contributed first in 2003 in the fight against severe acute respiratory syndrome (SARS). Developed from two prescriptions, Maxing-Shigan-Tang and Yinqiao-San, it contains 11 herbal components and has been authorized by the National Medical Products Administration (NMPA) to treat SARS, tape An influenza virus, H1N1 pandemic in 2009, H7N7, H3N2 and coronavirus disease-19 caused by severe acute respiratory syndrome coronavirus 2 (SARS-COV-2) in 2020, which has also been widely used as a treatment for common cold with wind-heat syndrome, chronic rhinosinusitis (CRS), amygdalities and chronic obstructive pulmonary disease(Shen & Yin, 2021). Other clinical applications have also demonstrated the effectiveness of Lianhua qingwen and other officially recommended medicines. Kai-tao Yao and Ming-yu Liu et al analyzed the clinical effect of Lianhua Qingwen in the treatment of COVID-19 and demonstrated that Lianhua Qingwen can significantly relieve cardinal symptoms in COVID-19. In a retrospective study, Lianhua Qingwen reduced fever duration and improved patients' symptoms(K.-t. YAO, LIU, LI, HUANG, & CAI, 2020).

However, despite satisfactory clinical effects, the acceptance of traditional herbal products among the American public is still low. Some media deliberately discredited traditional Chinese medicine and made up all kinds of conspiracy theories to safeguard the interests of large pharmaceutical companies in the United States. The accusation was pointed out at Zhong Nanshan, the most celebrated commercial health professionals who, as an epidemiologist, was appointed to head an expert group at the National Health Commission due to his contributions after managing SARS in 2003. Western media claimed that Zhong recommended Lianhua qingwen because of his commercial ties with pharmaceutical factories(Primross Riordan, 2022). The spread of these kinds of rumors not only undermined the image of Chinese epidemiologists and reduced government credibility but also damaged the reputation of traditional Chinese medicine as a whole. To date, there has been no confirmed effective antiviral therapy for COVID-19, and the main approaches are only symptomatic and supportive treatment. Thus, Western media took advantage of the occasion and denied the efficacy of traditional Chinese medicine.

Conclusion and Future Research

In conclusion, the research and development of traditional Chinese medicine worldwide is still mainly centralized in domestic institutes. Research institutes should increase collaboration and scientific connections to form an intensive research network. Contrary to the steady improvement in the research field of traditional Chinese medicine, the acceptance of herbal products in the Western world remains rather unsatisfactory in general. The publications in international journals showed a strong urge to be acknowledged by the Western medicine system and in turn lost their originality and nature to some extent. At the same time, Western media maliciously doubted the reason why the Chinese government recommended traditional Chinese medicine as a treatment for COVID-19, creating obstacles for TCM to be trusted by the public. In the future, the combination of domestication and foreignization of the translation of traditional Chinese medicine should become a major trend. More interdisciplinary talent should be nurtured to meet the huge demand in the TCM translation market. In addition, cooperation between research institutions and researchers should be further strengthened, forming a unified standard for better communication. The research should be oriented toward the combination of modern technology and traditional Chinese philosophy. The spread of culture and TCM books ought to be improved to a compatible status with scientific development.

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The System of Distance Learning in the Scientific and Engineering Staff Training

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Abstract: The proposed computer system implements a scheme of joint - classroom and distance learning, scientific and exploratory research in order to motivate and stimulate students' independent work in acquiring professional competencies. The developed system reflects both the traditional structure of education in universities using groups of students, specialties and curricula, as well as modern trends in the transition to distance learning, i.e. the opportunity to study at any time and in any place, according to individual plans and schedules. The presented development can be used by students to acquire and develop competencies in the field of improving and managing technological processes for the production of metal products, including the design of machines and metal structures for additive technologies. This is ensured both by the created (and permanently updated) database of mechanical and technological characteristics of steels and alloys used in the production of materials for special purposes, including for the nuclear power industry and the chemical industry, product quality and environmental safety, and by programs developed on based on author's methods and implemented in the system of distance education, in particular, for calculating the modes of shaping and energy-power parameters in the formation of metal products.

Keywords: Distance learning, Engineering training

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Introduction

The educational sphere differs from all others in that it is always relevant to improve the technology of curriculum management. Therefore, innovative work in this type of activity never stops, and at present, with the development of computer technology, it has also intensified. In addition, the amount of knowledge that a student needs to acquire in order to meet professional competencies is also increasing. Therefore, scientific and technological research is carried out in the education system in the methodology of mastering knowledge and evaluating its effectiveness.

The problem of distance learning using the Internet (E-learning) has recently received much attention in the world (Sadoy & Mashkova, 2022; Osadchy, et al., 2019). This is due to the advantages that open up when using this form of training, first of all, there is no need to move students for a long time to the location of the university. This makes it possible to obtain the necessary knowledge for those who, for example, cannot leave work or leave for some other reason. In addition, teachers from leading universities can teach students around the world, which has been actively practiced in recent years by leading universities and educational centers.

The SCORM distance interactive learning standard developed and currently in force defines the general requirements for software (Vorontsov, 2023). This direction is recognized as progressive among educational projects (Semenova, 2013; Novikov, 2019). It must be developed so that residents of small towns and rural areas, as well as in large cities where the required specialty is not available at the local university, can receive vocational training that meets educational standards.

Currently available systems of distance learning are in fact limited to either only the provision of educational materials, or, in extreme cases, provide the opportunity for testing. At the same time, "intelligent" learning systems have not yet been sufficiently developed. Such systems should provide automatic management of the learning process, starting with planning in time, tracking and eliminating gaps in knowledge, and then changing the learning trajectory depending on the individual training and abilities of each student.

Independent work of students in the study of any disciplines, including fundamental and technical, as well as research work, is a very important component of the educational process, since it affects the level of knowledge and skills acquired by students. The development of computers and the Internet can be of great help in developing the competencies of future engineering graduates and beyond. Today, students spend a lot of personal time online, and this should be used for educational purposes. Therefore, improving the organization of this area of the educational process is the goal of this work.

In the process of acquiring the competencies of engineering specialties, for example, a metallurgical profile, a student is faced with a wide variety of steels and alloys, their heat treatment modes, service characteristics, as well as methods of obtaining and testing. In the process of carrying out his research work, it becomes relevant for him to have a database of such materials. For this purpose, the program of the database of mechanical and technological characteristics of steels and alloys was adapted into the developed software package.

Thanks to the development of network information technologies, a program is built into the proposed computer system, which, in research work, including student work, along with the use of structured data, makes it possible to implement mathematical models of phenomena and technological processes. In this direction, the developed program, in particular, carries out computer design of technological equipment in the manufacture of roll-formed profiles, the production of which has recently been growing significantly.

Method

A computer system (software package) has been created, which is an educational and scientific platform that implements a scheme of mixed (classroom and distance) learning, scientific and exploratory research in order to motivate and stimulate students' independent work in acquiring professional competencies. The main purpose of the system: providing educational materials; automatic generation and issuance of tasks; organization and control of independent work of students; knowledge control; determining the rating of students; obtaining operational information about the state of the educational process, its analysis and improvement; use of active teaching methods; introduction of various forms of communication into the educational process; transparency of teachers' work; issuance of documentation and reports; performing calculations and scientific research.

Distance learning process

The paper proposes and puts into practice an approach, the purpose of which is to ensure the systematic work of students - this is a “rigid” scheme that regulates the conditions for studying each discipline, learning along the so-called “individual trajectory”. The essence of this method lies in the fact that the student consistently receives portions of educational material and tests to test the assimilation of knowledge. In case of unsatisfactory passing of the test, the system returns it to the re-study of the relevant sections of the course (discipline). At the same time, the deadlines and the actual time spent are automatically controlled. As a result, information is accumulated on the degree of assimilation of the material (grades and points). Penalty points for late completion of work and the use of additional attempts stimulate the regularity of work and careful study of the material. The teacher at any time can see the progress of each student along his trajectory and receive information about the assimilation of the material on each topic, which makes it possible to eliminate gaps in knowledge.

Independent research work

Database of mechanical and technological characteristics. To store information about the chemical composition of metallic materials, their properties and other characteristics, a database of the Microsoft SQL-server type was created in the Microsoft Visual Studio environment to work under the Microsoft Windows operating system and the Microsoft SQL Server DBMS. In addition to characteristic data, each database table contains information for organizing links between tables, as well as about the creation of a record and the changes made (author and date) in order to increase its reliability.

The program allows you to enter new information, edit existing information and make queries to find the right data. Search results are displayed on the screen and in a file in the form of text, tables and graphs.

Calculation of the stress-strain state. To calculate the shaping mode, energy-power parameters during the formation of a pipe billet in accordance with the developed methods, a computer program was created in the Visual Studio environment in the C# language. The program is a Web-application for the Internet with a modern interface, embedded in a distance learning system. The program algorithm is an implementation of a mathematical model of the process of profiling a strip with horizontal and vertical rolls, which makes it possible to calculate the geometric and energy-power parameters of the process (Osadchiy et al., 2007; Osadchy et al., 2018; Osadchy, Savina, & Savin, 2018). The computer program “Gnut” was used as a basis for calculating roll gauges in the production of bent symmetrical and asymmetrical profiles of almost any real configuration with the issuance of a complete set of drawings. The program has no analogues so far.

Results

The results of using the software product in the educational process

The presented data concern mainly only students of one institute. although these approaches are also applicable when reading fundamental and technical disciplines for students of other institutes/universities.

After authorization on the site (figure 1), the student chooses the academic discipline of the current semester and receives a complete set of educational and methodological materials, as well as additional materials - scanned sources, which eliminates the need to waste time searching for the literature agreed with the teacher. In addition, the system has a library of scanned textbooks and manuals (over 5,000 titles) available for reading to students and teachers, as well as a catalog of books and magazines in the reading rooms.

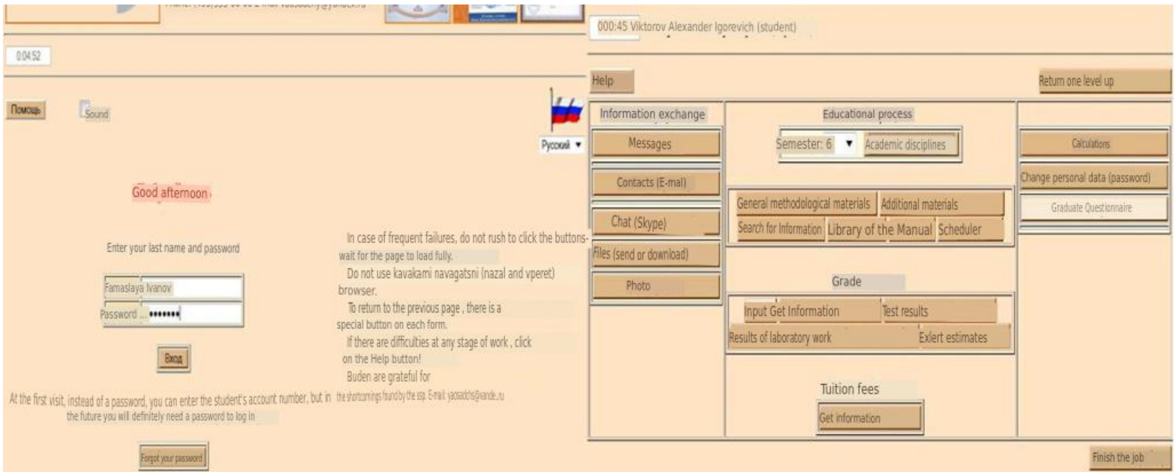


Figure 1. Authorization pages (login) and the main form of student work

A “rigid” scheme has been developed and implemented that regulates the conditions for studying each discipline - this is training along the so-called “trajectory” (figure 2). The student consistently receives portions of educational material and tests to test the assimilation of knowledge. In case of unsatisfactory passing of the test, the system returns it to the re-study of the relevant sections of the course. In order to exclude formal turning, the minimum time for studying a fragment (page) is set.

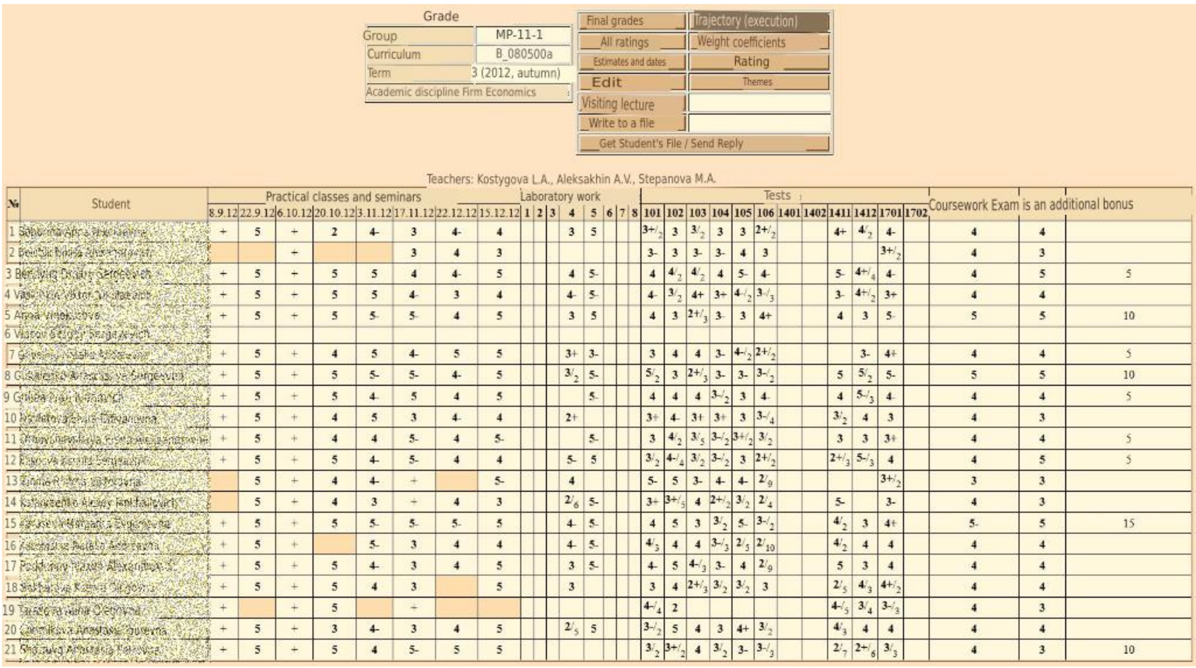
Semester 2. Microeconomics

No.	Designation	Level training	Type of activity	File name or Recommendation number	Topic number (didactic units)	Coefficient difficulties	Term	Term final	Minimum time, min	Maximum time, min	permitted number attempts	Conditions	return			
1	1-1	average	allowance (literature)	Introduction. market, his structure	1	1	16.02.2013 (10)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
2	1-2	average	allowance (literature)	Influence of factors on demand	1	1	22.02.2013 (16)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
3	1-3	average	test	101	1	1	22.02.2013 (16)	26.06.2013 (140)		5	3		1-1	Delete	Insert	Edit
4	2-1	average	simulation (literature)	Analysis and allowance behavior consumers on the	2	1	01.03.2013 (23)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
5	2-2	average	allowance (literature)	Consumer chooses basket like this so that	2	1	07.03.2013 (29)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
6	2-3	average	test	102	2	1	07.03.2013 (29)	26.06.2013 (140)		5	3		2-1	Delete	Insert	Edit
7	3-1	average	allowance (literature)	Analysis and modeling behavior enterprises at	3	1	14.03.2013 (36)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
8	3-2	average	allowance (literature) in	Company chooses a basket such a way that the	3	1	20.03.2013 (42)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
9	3-3	average	test	103	3	1	20.03.2013 (42)	26.06.2013 (140)		5	3		3-1	Delete	Insert	Edit
10	4-1	average	allowance (literature)	Economic expenses. Analysis and modeling suggestions	4	1	27.03.2013 (49)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
11	4-2	average	allowance (literature)	Let's pretend that one type available products, about	4	1	02.04.2013 (55)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit
12	4-3	average	test	104	4	1	02.04.2013 (55)	26.06.2013 (140)		5	3		4-1	Delete	Insert	Edit
13	5-1	average	allowance (literature)	Analysis and modeling economic behavior pr	5	1	09.04.2013 (62)	26.06.2013 (140)	3	30	5			Delete	Insert	Edit

Figure 2. The trajectory of the study of the academic discipline

The teacher has the ability to adjust the trajectory (for example, the dates of work). Students have access to individual steps of the trajectory about a week before the deadline. The deadlines and time spent has been controlled. As a result, information is accumulated on the degree of assimilation of the material (grades and points). Penalty points for late completion of work and the use of additional attempts stimulate the regularity of work and careful study of the material.

The teacher in a visual form in a graphical form at any time can see the progress of each student of the group along the trajectory. The teacher also can get information about the assimilation of the material on each topic, as well as questions that the student could not give the correct answer for the interview, which actually allows you to eliminate gaps in knowledge. The teacher enters into the system: class attendance and grades given in practical and seminar classes, for tests, homework, essays, term papers, grades in tests and exams (figure 3).



№ Student	Practical classes and seminars								Laboratory work								Tests												Coursework	Exam	is an additional bonus
	8.9.12	22.9.12	6.10.12	20.10.12	3.11.12	17.11.12	22.12.12	15.12.12	1	2	3	4	5	6	7	8	101	102	103	104	105	106	1401	1402	1411	1412	1701	1702			
1 [illegible]	+	5	+	2	4-	3	4-	4				3	5				3+/$_2$	3	3/$_2$	3	3	2+/$_2$			4+	4/$_2$	4-		4	4	
2 [illegible]			+			3	4	3									3-	3	3-	3-	4	3					3+/$_2$		4	3	
3 [illegible]	+	5	+	5	5	4	4-	5				4	5-				4	4/$_2$	4/$_2$	4	5-	4-			5-	4+/$_4$	4-		4	5	5
4 [illegible]	+	5	+	5	5	4-	3	4				4-	5-				4-	3/$_2$	4+	3+	4-/$_2$	3-/$_3$			3-	4+/$_2$	3+		4	4	
5 [illegible]	+	5	+	5	5-	5-	4	5				3	5				4	3	2+/$_3$	3-	3	4+			4	3	5-		5	5	10
6 [illegible]																															
7 [illegible]	+	5	+	4	5	4-	5	5				3+	3-				3	4	4	3-	4-/$_2$	2+/$_2$				3-	4+		4	4	5
8 [illegible]	+	5	+	5	5-	5-	4-	5				3/$_2$	5-				5/$_2$	3	2+/$_3$	3-	3-	3-/$_2$			5	5/$_2$	5-		5	5	10
9 [illegible]	+	5	+	5	4-	5	4	5					5-				4	4	4	3-/$_2$	3	4-			4	5-/$_3$	4-		4	4	5
10 [illegible]	+	5	+	4	5	3	4-	4				2+					3+	4-	3+	3+	3	3-/$_4$			3/$_2$	4	3		4	3	
11 [illegible]	+	5	+	4	4	5-	4	5-					5-				3	4/$_2$	3/$_5$	3-/$_2$	3+/$_2$	3/$_2$			3	3	3+		4	4	5
12 [illegible]	+	5	+	5	4-	5-	4	4				5-	5				3/$_2$	4-/$_4$	3/$_2$	3-/$_2$	3	2+/$_2$			2+/$_3$	5-/$_3$	4		4	5	5
13 [illegible]		5	+	4	4-	+		5-				4					5-	5	3-	4-	4-	2/$_9$					3+/$_2$		3	3	
14 [illegible]		5	+	4	3	+	4	3				2/$_6$	5-				3+	3+/$_5$	4	2+/$_2$	3/$_2$	2/$_4$			5-		3-		4	3	
15 [illegible]	+	5	+	5	5-	5-	5-	5				4-	5-				4	5	3	3/$_2$	5-	3-/$_2$			4/$_2$	3	4+		5-	5	15
16 [illegible]	+	5	+		5-	3	4	4				4-	5-				4/$_3$	4	4	3-/$_3$	2/$_5$	2/$_{10}$			4/$_2$	4	4		4	4	
17 [illegible]	+	5	+	5	4-	3	4	5				3	5-				4-	5	4-/$_3$	3-	4	2/$_9$			5	3	4		4	4	
18 [illegible]	+	5	+	5	4	3		5				3					3	4	2+/$_3$	3/$_2$	3/$_2$	3			2/$_5$	4/$_3$	4+/$_2$		4	4	
19 [illegible]	+		+	5		+											4-/$_4$	2							4-/$_5$	3/$_4$	3-/$_3$		4	3	
20 [illegible]	+	5	+	3	4-	3	4	5				2/$_5$	5				3-/$_2$	5	4	3	4+	3/$_2$			4/$_3$	4	4		4	4	
21 [illegible]	+	5	+	5	4	5-	5	5									3/$_2$	3+/$_2$	4	3/$_2$	3-	3-/$_3$			2/$_7$	2+/$_6$	3/$_3$		4	3	10

Figure 3. Teacher's Journal

Testing is provided to ensure the objectivity of the results. Along with the usual types of test questions, complex tasks with an arbitrary number of numeric and text parameters to be checked, with a given algorithm, are widely used. The program determines the difficulty of the question, highlights questionable and too easy questions. In addition, it also provides for confirmatory (in the classroom, with a teacher) testing and independent monthly mandatory testing on issues based on existing educational standards. The dynamics of testing is shown in Figure 4. Note that the peak of testing can be shifted in time depending on the total academic load (load) of the student in the current semester.

Given that people remember quite a bit of what they see, more of what they see and hear, a lot of what they see, hear and do, much attention is paid to the creation of a laboratory workshop. Students can perform laboratory work both in the computer classes of the educational institution and from home computers. At the same time, in all laboratory work, a tolerance in the form of a test is provided. The description of the laboratory work, as well as other educational materials, may contain video fragments. In the educational process in fundamental and technical disciplines, films are used that are sometimes shown in the classroom, but more often students are given the task to watch them at home in the system for subsequent discussion in class.

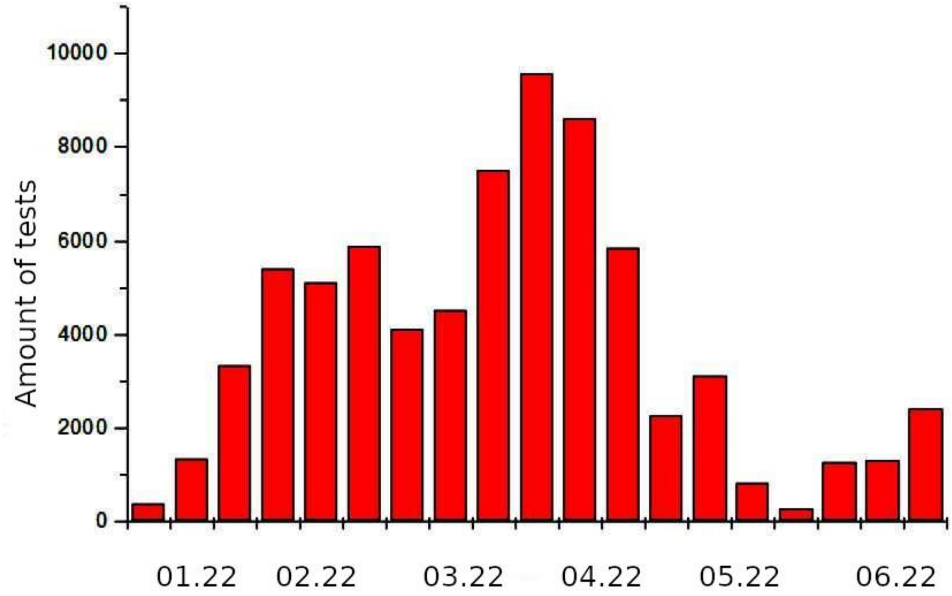


Figure 4. Test dynamics

The student sends completed tasks to the teacher from the page of the academic discipline, and the teacher sees them and receives them on the page of the journal. Teachers have the ability to control the dynamics of each student's work. The system implements automatic registration of attendance at lectures in classrooms where computers are installed.

The results of using the software package in research work

The figure 5 shows the page for selecting a subroutine to perform certain calculations.

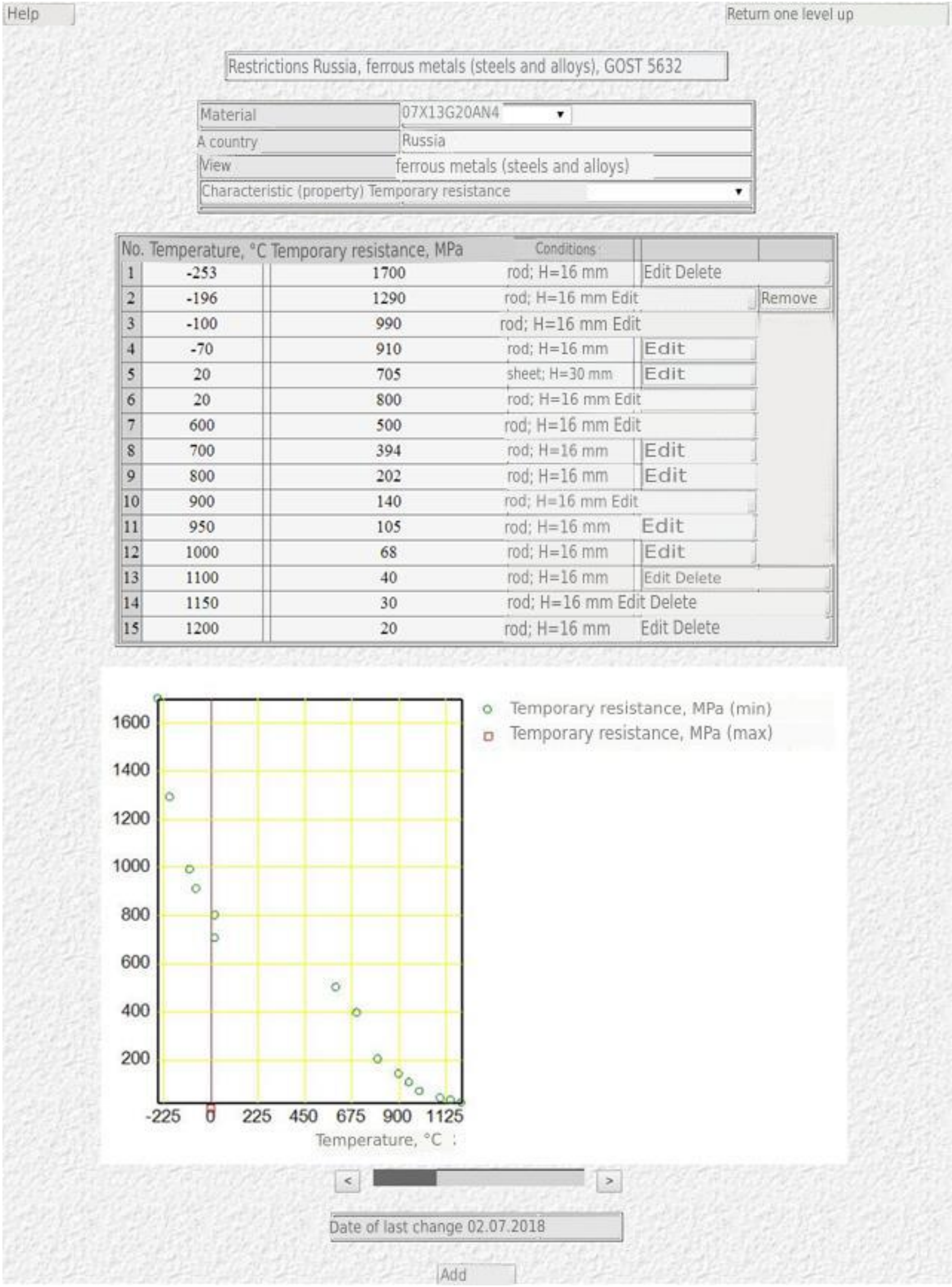
Figure 5. Scientific research and calculations

The results of working with the database. Given the needs of production, the database includes, in fact, all types of metallic materials. All branded variety of materials is subdivided according to a number of classification features - type (black and non-ferrous), alloying degree, purpose. The chemical composition of the material indicates the content of 66 elements - in fact, all the elements used in pure form, in the form of alloys or as alloying additives. As characteristic features of each group of materials, the limiting content of elements in them is given. Tables have also been created to store information about the technological characteristics, physical and mechanical properties of materials, including taking into account the features of their production and heat treatment modes. Taking into account the classification of metallic materials, they are divided into a number of groups, information about which is stored in the MateGr table. The chemical compositions of various grades of metal materials in Russia and other countries, some of their characteristics are stored in the Maters database.

The main form of the program is presented in the form of a menu - buttons for switching to one of the main functions (Figure 6). In addition, the program contains a section that allows you to quickly perform various conversions of mass, length, time, pressure, density, speed, temperature and many other units of measurement used in engineering calculations. The converter provides the ability to convert complex values of units of measurement from one system of units to another. For this option to work, a special database table has also been created and filled.

When analyzing the brand composition, you can set various conditions for selecting materials: by country, by type, by standard, by group (from one to another), by product and purpose (a word or a combination of words in the description of which these words occur). The program allows you to proceed to the program search for analogues of this material among domestic and foreign materials. You can also search for information on the properties of materials, including technological ones. The program provides screen forms with information on the physical and mechanical properties of materials (as shown in Figure 7), resistance to deformation during metal forming, as well as for selecting a physical or mechanical characteristic and for determining the estimated approximate value of this characteristic based on a given chemical composition material.

Figure 6. Main form of the program



No.	Temperature, °C	Temporary resistance, MPa	Conditions		
1	-253	1700	rod; H=16 mm	Edit Delete	
2	-196	1290	rod; H=16 mm Edit		Remove
3	-100	990	rod; H=16 mm Edit		
4	-70	910	rod; H=16 mm	Edit	
5	20	705	sheet; H=30 mm	Edit	
6	20	800	rod; H=16 mm Edit		
7	600	500	rod; H=16 mm Edit		
8	700	394	rod; H=16 mm	Edit	
9	800	202	rod; H=16 mm	Edit	
10	900	140	rod; H=16 mm Edit		
11	950	105	rod; H=16 mm	Edit	
12	1000	68	rod; H=16 mm	Edit	
13	1100	40	rod; H=16 mm	Edit Delete	
14	1150	30	rod; H=16 mm Edit Delete		
15	1200	20	rod; H=16 mm	Edit Delete	

Figure 7.Mechanical properties of the materials

Analysis of the technological properties of the material offers the following information (Figure 8):

- critical temperatures: melting point; liquidus temperature; temperature A_{c1}; temperature A_{r1}; temperature A_{c3}; temperature A_{r3}; temperature A_{cm}; temperature M_n;
- technological properties: weldability; workability; tendency to temper brittleness; flocenosensitivity;
- temperature range of hot deformation: upper limit; lower limit;
- the temperature of the beginning of intensive scale formation;
- cooling conditions after hot deformation;
- operating temperatures: lower limit; very long; for a long time; limited; briefly;
- additional characteristics and features.

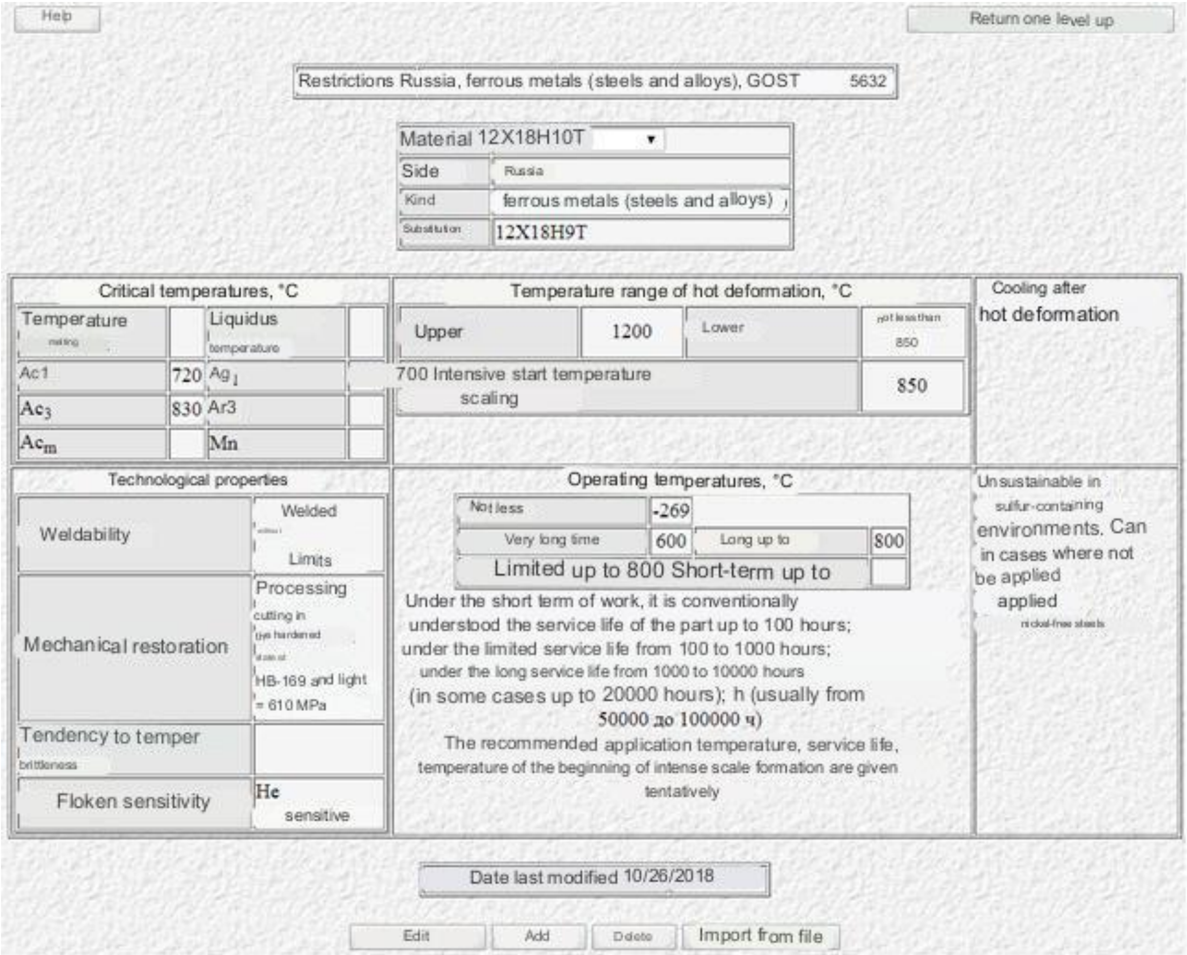


Figure 8. Technological properties of the material

The program selects the materials closest in chemical composition for which the values of this mechanical characteristic are available, builds a regression equation of its dependence on the chemical composition and calculates the approximate expected value: after selecting the material grade and characteristic, the required information is presented in the form of a table and a graphical dependence of it on the test temperature . For the main alloying elements, you can get the nature of their influence on the properties of steels and alloys (Figure 9).

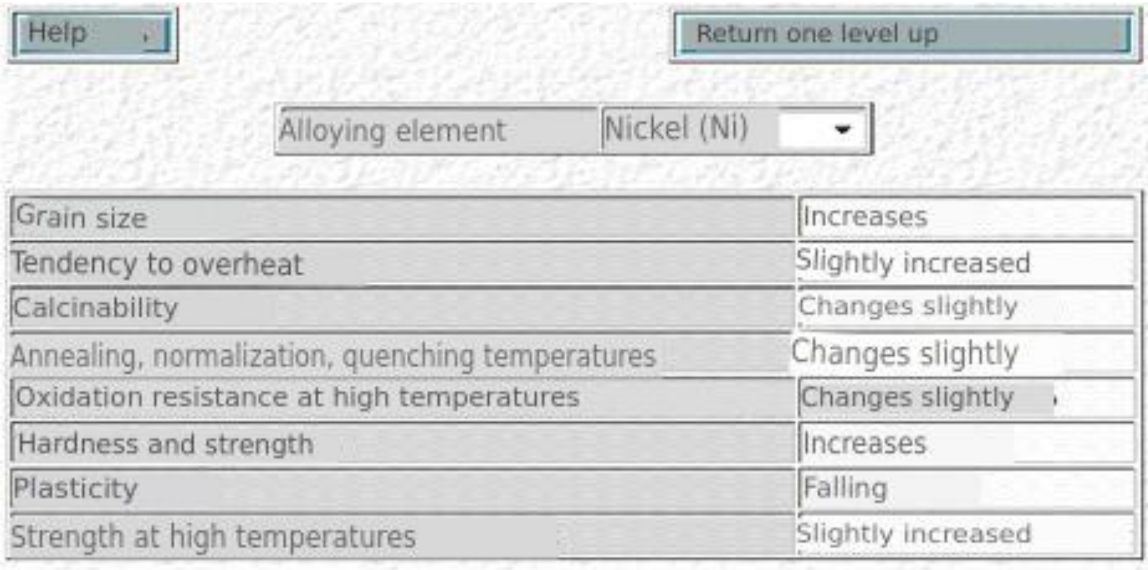


Figure 9. Influence of alloying elements and impurities on steel properties

Results of using routines for calculations. Login to the system to perform calculations is shown in Figure 10.

Figure 10. Page of programs for calculations

In this work, we used a system that includes the following main components: calculation of the deformation mode (calibration) of forming a pipe billet according to one-radius and two-radius schemes; evaluation of energy-power parameters of the process. The screen form for entering initial data has the following form (Figures 11 and 12).

The results are given in the form of two tables with deformation parameters in the molding and sizing stands. An example of a screen form for single-radius calibration is shown in Figure 13, and an example of calculating the energy-power parameters of forming a pipe billet is shown in Figure 14.

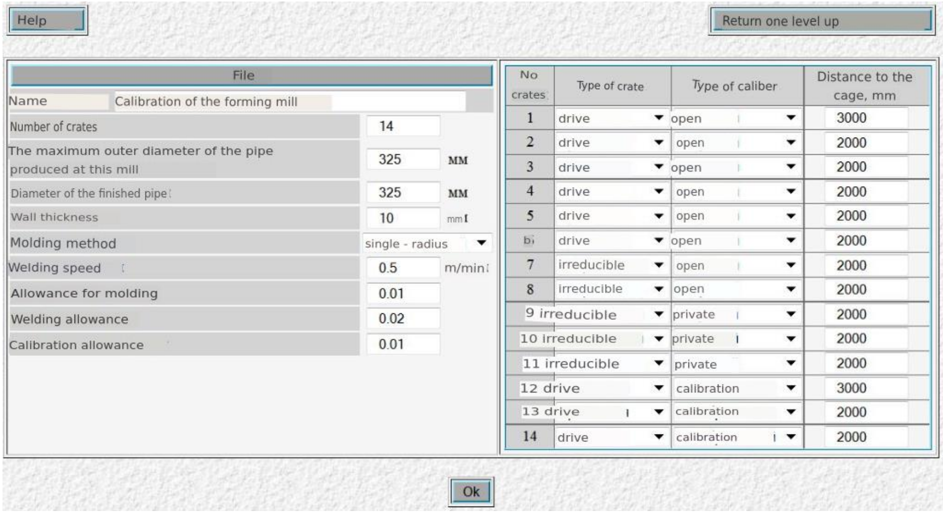


Figure 11. Screen form for entering initial data for calculating the mode of forming a tubular billet

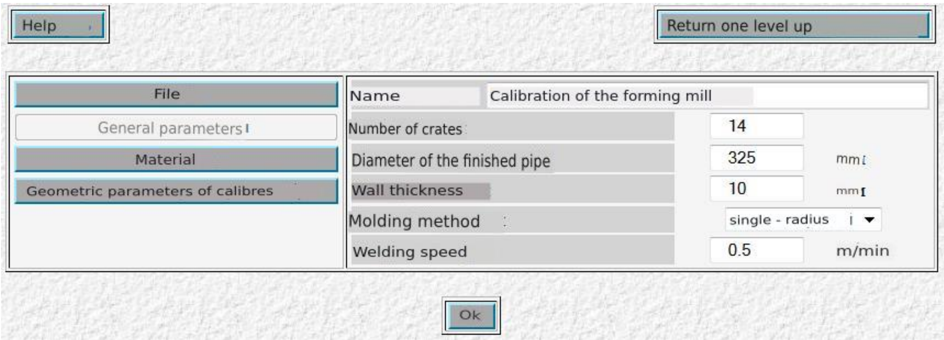
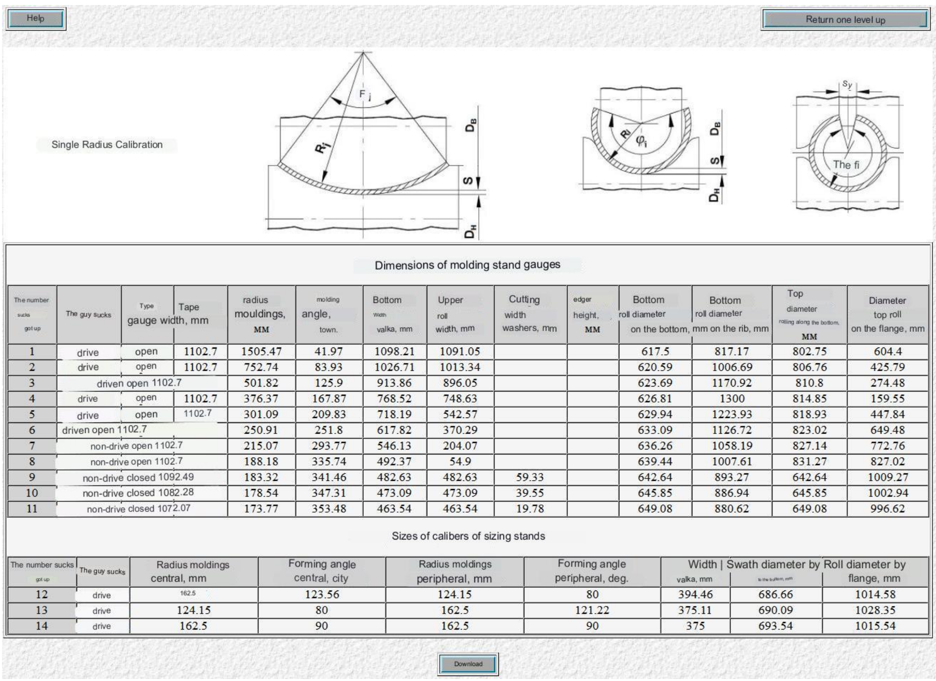


Figure 12. Screen form for entering initial data for calculating power parameters



Dimensions of molding stand gauges

The number sucks got up	The guy sucks	Type	Tape gauge width, mm	radius mouldings, MM	molding angle, town.	Bottom Width valka, mm	Upper roll width, mm	Cutting width washers, mm	edger height, MM	Bottom roll diameter on the bottom, mm	Bottom roll diameter on the rib, mm	Top diameter rolling along the bottom, MM	Diameter top roll on the flange, mm
1	drive	open	1102.7	1505.47	41.97	1098.21	1091.05			617.5	817.17	802.75	604.4
2	drive	open	1102.7	752.74	83.93	1026.71	1013.34			620.59	1006.69	806.76	425.79
3	driven open 1102.7			501.82	125.9	913.86	896.05			623.69	1170.92	810.8	274.48
4	drive	open	1102.7	376.37	167.87	768.52	748.63			626.81	1300	814.85	159.55
5	drive	open	1102.7	301.09	209.83	718.19	542.57			629.94	1223.93	818.93	447.84
6	driven open 1102.7			250.91	251.8	617.82	370.29			633.09	1126.72	823.02	649.48
7	non-drive open 1102.7			215.07	293.77	546.13	204.07			636.26	1058.19	827.14	772.76
8	non-drive open 1102.7			188.18	335.74	492.37	54.9			639.44	1007.61	831.27	827.02
9	non-drive closed 1092.49			183.32	341.46	482.63	482.63	59.33		642.64	893.27	642.64	1009.27
10	non-drive closed 1082.28			178.54	347.31	473.09	473.09	39.55		645.85	886.94	645.85	1002.94
11	non-drive closed 1072.07			173.77	353.48	463.54	463.54	19.78		649.08	880.62	649.08	996.62

Sizes of calibers of sizing stands

The number sucks got up	The guy sucks	Radius moldings central, mm	Forming angle central, city	Radius moldings peripheral, mm	Forming angle peripheral, deg.	Width valka, mm	Swath diameter by to the bottom, mm	Roll diameter by flange, mm
12	drive	162.5	123.56	124.15	80	394.46	686.66	1014.58
13	drive	124.15	80	162.5	121.22	375.11	690.09	1028.35
14	drive	162.5	90	162.5	90	375	693.54	1015.54

Figure 13. Tables with the results of calculating the mode of forming a tubular billet

Help Return one level up

Number of the mill crate	Vertical force, kN	Resistance force in caliber, kN	Pulling force, kN	The frequency of rotation of the rolls, rpm.	Torque on the shaft, kN·m	The moshness per crate, kW
1	196.95	21.433	3.1413	0.1948	63.99	1.3051
2	205.08	21.428	3.7919	0.1581	75.172	1.2445
3	215.14	21.433	4.5963	0.1359	85.214	1.2129
4	229.51	21.433	5.7463	0.1224	95.737	1.2274
5	232.7	21.428	6.0011	0.13	94.623	1.2885
6	241.81	21.433	6.7296	0.1413	94.736	1.4013
7	250.21	21.433	7.4015	0.1504	95.24	1.5
8	258.01	21.433	8.0257	0.158	95.976	1.5875
9	415.71	30.233	33.257	0.1782	22.113	0.4126
10	413.11	30.044	33.049	0.1794	21.979	0.413
11	411.85	29.953	32.948	0.1807	21.915	0.4148
12	737.05	53.604	58.964	0.1569	48.06	0.7895
13	737.05	53.604	58.964	0.1548	51.892	0.841
14	737.05	53.604	58.964	0.1567	48.127	0.7898

Download.

Figure 14. The results of the calculation of the energy-power parameters of forming a tubular billet

The developed methodology and programs of the proposed computer system were used to calculate the roll gauges and the stress-strain state of the metal, and were tested when calculating the production process of longitudinally welded pipes on the Olimpia 80 production line (Techno trade LLC, Ozerki, Kaliningrad region, Russia).

Discussion

Distance learning system. It provides a number of additional features, in particular, it is possible to estimate the time spent by students on the study of individual academic disciplines, to evaluate the assimilation of individual topics based on test results, as well as the load by semesters. Independent testing allows you to evaluate the compliance of the programs used with the requirements of the standards

Practice has shown that a liberal scheme for the presentation of educational materials, when a student is given full access to educational materials, and he himself determines the sequence and timing of the implementation of activities, weakly stimulates systematic work. Pathway learning provides stimulation for students to work during the semester, and timely apply administrative measures to manage the learning process. The presence of test protocols with student data and correct answers reduces the risk of conflict situations.

Systematic sequential testing ensures the availability of a sufficient number of grades and points for each discipline per student, allows you to increase the reliability of knowledge assessment and implement the rating calculation. The rating calculation takes into account all types of control activities (practical and seminar classes, tests, homework, essays, laboratory work, self-testing, classroom testing, attendance, rhythm) with weighting coefficients. At the same time, the number of attempts is limited, and for each subsequent attempt, the score is reduced by 5%. This encourages the student to study the material before testing, rather than trying to achieve a result through additional attempts. The current rating can be calculated at any time, which allows you to identify lagging students at the beginning of the semester. A sufficiently large number of assessments, a shift in emphasis to intra-semester work increases the objectivity of knowledge assessment.

Along with improving the organization of the educational process, the use of a computer system clearly shows the work of teachers - the availability of educational materials, tests, the presence of grades, exactingness, activity in the system, both the teachers themselves and students in a particular academic discipline. The rather successful use of computer control of independent work of students has largely become possible due to the fact that it practically does not increase the workload of teachers, except for their direct responsibility - to prepare teaching materials and control tools, as well as to monitor the work of students. Administrative control is an important factor. The administration has up-to-date information about the availability of educational materials in the system and can check and control it, as well as the duration of students' work in each academic discipline, can easily check the compliance of educational material with tests and the course program.

Research using the database program. The use of the database program and its supporting application showed that it is a description of the data bank of ferrous and non-ferrous metals and alloys in Russia and a number of foreign countries, their technological properties, heat treatment modes, physical and mechanical characteristics at various temperatures and in real time using A flexible query system allows you to obtain the necessary information in order to make optimal decisions in the process of planning both an experiment and a real production process.

Research and analysis of the process of production of tubular blanks of a characteristic assortment (as part of student research work or graduation qualification work). The results of the calculation of the stress-strain state showed that the maximum level of longitudinal tensile strains and stresses lies in the region of the elastic state, which indicates that there is no danger of corrugation at the edges of the strip. Predicting the magnitude of residual stresses also showed that they are at a fairly low level.

Conclusion

The system allows to implement a model of blended learning (full-time and part-time), as well as individual learning along trajectories that increases motivation and stimulates independent work of students. The system has an intuitive and user-friendly interface and does not require any special knowledge from users when working with it. Due to the introduction of a point-rating system, the quality of education increases (a more serious attitude of students to study and an improvement in the level of knowledge). It is possible to receive operational integrated information about the progress of individual students, groups of students, etc., and also allows parents to control their children.

The developed database with its structure and application, as well as the data entered into it on the chemical composition of steels and alloys, heat treatment modes, physical, mechanical and technological properties, as well as subroutines for calculating technological problems, are a significant part of the independent work of students in the process of acquiring professional engineering competencies.

Recommendations

The software package (system) of distance education created and proposed in this work can be recommended for use both for educational purposes and in scientific research in the development, improvement, management of technological processes for the production of metal products, design of machines and metal structures.

Notes

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Correlation Analysis of Visual İmaginary EEG Signals İn Different Frequency Bands

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Abstract: Brain-computer interface-based EEG devices, is a field that supports and assists challenged individuals to perform daily functions without any motor action, such BCI devices communicate directly to user intention, by decoding EEG signals. There are two types of BCI systems motor imagery and visual imagery, in this article, we will focus on the second one. The EEG signals, in our case, were recorded from 22 subjects, while performing an imaginary selection from an interface with two options (Turn on / Turn off the light). We aimed through this article at finding the best features to extract from EEG signals. The EEG dataset was measured by Pearson's correlation coefficient to find the linear association between feature pairs, in different EEG frequency subbands. NeuroSky headset was used to collect data, the data is displayed in eight frequency bands (delta, theta, alpha (1- 2), beta (1- 2), gamma (1-2)). The results show that the beta bands have the highest correlation index than in gamma, theta, and delta bands. The best two features were the mean and standard deviation pair. The mean and standard deviation features pair has the highest linear relationship, the standard deviation and variance pair was relatively high in the beta 2 bands, and the mean and variance features pair correlation was not very significant.

Keywords: Brain-computer interface, EEG Signals, Visual Imaginary, Correlation.

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Introduction

Brain-computer interfaces (Millán et al., 2010) are nowadays, an alternative human-machine interface for the control of assistive devices (Nijboer, 2015)(Roy & Bhaumik, 2022)(Rușanu, 2022), and help users with neuromuscular impairment(Pinheiro et al., 2018)(Lazarou et al., 2018) by using the usual mean of communication (Wolpaw et al., 2002). Such devices detect EEG signals (Su et al., 2023) which are in reality neuron activity resulting in brain signals. BCI systems rely on brain signals that are recorded non-invasively. A

BCI system consists of four sequential components: signal acquisition, feature extraction, and classification output, which interfaces to assistive devices.

Before recording EEG signals, the user must perform cognitive tasks to control a BCI. There are two types, motor imagery MI (Catrambone et al., 2018)(Mwata-Velu et al., 2021) and visual imagery VI (Fu et al., 2022). Motor imagery is an application, which requires subjects to imagine certain parts of their body moving. The motor imagery is recognized especially in the mu and beta frequency band (Plucińska et al., 2022) over the sensorimotor cortex, via some characteristics (Leeuwis et al., 2021). However, imagination is so difficult for the subjects and needs extensive training, for that reason this type is unreliable. Visual imagery supposes to be the best alternative to motor imagery BCIs (Kilmarx et al., 2022). Visual mental imagery is the action to visualize mentally a thinking, or an action, involving specific neural mechanisms (Kwon et al., 2021). The visual imagery BCI is promoting field of research(Lee et al., 2020)(Kosmyna et al., 2018), due to their intuitive method based on just visualization, the study and the analysis of EEG signals during imagination are important, to identify which frequency band there is a change. The EEG is described generally in terms of its frequency (Nacy et al., 2016), the main bands are :

Table 1. EEG frequency bands and related Brain states

Frequency band	Frequency HZ	Brain states
Gamma	35	Concentration
High beta	[21,30]	Alertness
Midrange beta	[16,20]	Thinking, aware
LowBeta	[12,15]	awake, focused attention
Alpha	[8–12]	Awake, non-focused
Theta	[4–8]	Visual imagery
Delta	[0.5–4]	Dream states

A variety of devices has been used to record brain signals, in this study we used NeuroSky MindWave headset (*NEUROSKY MINDWAVE MOBILE USER MANUAL Pdf Download | ManualsLib*, n.d.) which can detect raw brain signals, to measure the power spectrum density of 7 frequency bands, delta, theta, low beta, midrange beta, high beta, and gamma, and has lower noise detection.

Materials and methods

Data acquisition

Data were collected from 22 subjects in good health (male, female). The age of all subjects fell into the age group of 19 to 22 years. The EEG signals were recorded through a NeuroSky MindWave (*EEG - ECG - Biosensors*, n.d.) Headset with a 512 HZ sampling rate. The selection of this device was due to its low price, and ease of use. Users were asked to visualize the action of lighting on the room for about 60 seconds, and lighting off the room also for about 60 seconds. Figure 1 shows the data recorded for one subject, visualizing the two-state of lighting the room. During the recording of signals, subjects were said to sit on the chair very comfortably and concentrate at the task of visualization.

The NeuroSky Mindwave's data is received every second, and the raw EEG data is given as 8 different signals which are low gamma, high gamma, high alpha, high beta, low beta, delta, and theta. The application Brainflex was used as an interface to collect EEG from the NeuroSky headset. The connection between the application and the headset is paired through Bluetooth.

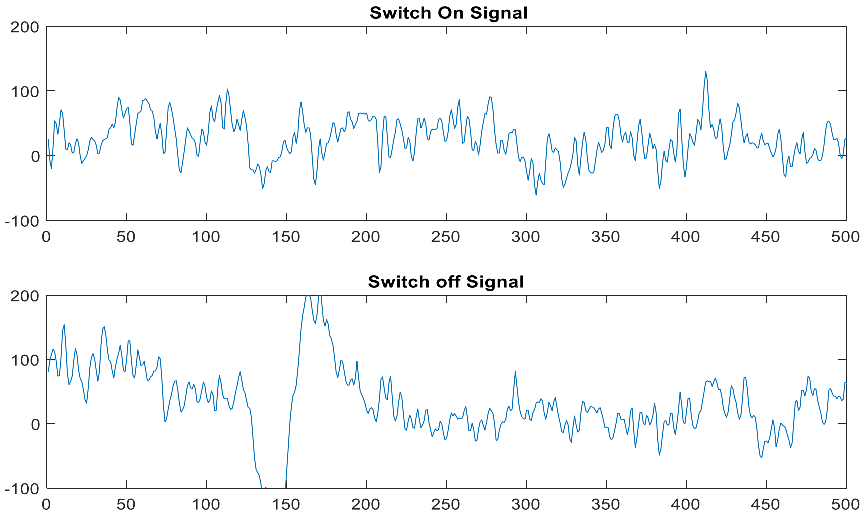

Figure 1 Recording signals from one subject while visualizing the two tasks

Features extraction

We have calculated Mean, Standard Deviation, and Variance while imagination of task 1 and imagination of task 2, for 22 subjects.

Mean

The arithmetic mean or arithmetic average, is the ratio of all values of dataset to the size of the dataset. If the dataset is consisting of the values $x_1, x_2, \dots, x_n$, the arithmetic mean M is defined as :

$$M=\frac{\sum_{i=1}^{n} x_i}{n}$$

Where: n : total number of values

x_i : values of the dataset

Variance

The variance shows the degree of distribution in the dataset from its mean value. The variance is equal to the mean of the squared differences from the average, its formula is:

$$\mathrm{Var}(x) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})}{n}$$

Where : $\bar{x}$: the mean value of the dataset

Standard deviation

The standard deviation shows how are the values spread out, commonly in statistical analysis is abbreviated as SD or sigma ‘σ’. The SD formula is the square root of the variance:

$$\mathrm{SD} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})}{n}}$$

Correlation Coefficients

The correlation coefficient (Choong et al., 2021)(Park & Chung, 2020) is the most widely used index to measure the degree of the linear relation between two or more sets of variables. Generally, it varies from -1 through 1, the positive value indicates the perfect positive linear relationship between variables, otherwise, and the negative value indicates the perfect negative relation.

The correlation coefficient is equal to the covariance between two variables (X and Y) divided by the product of their standard:

$$r(X,Y) = \frac{cov(X,Y)}{s_x s_y} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X}) \sum_{i=1}^{n}(Y_i - \bar{Y})}}$$

where X, Y: the series of samples

cov(x,y): is the covariance of X and Y

s_x : is the standard deviation of X s_y : is the standard deviation of Y

$\bar{X}$: the arithmetic mean of X $\bar{Y}$: the arithmetic mean of Y

r(X, Y): correlation value varies from -1 to +1.

Results and discussion

First, we computed the correlation coefficient between different sub-bands, unfortunately, the correlation was not significant the results are shown in Table 1. The most significant relationship was 0.85, between low beta and high beta bands.

Table 2. The correlation coefficients between all frequency sub-bands

	Theta	Low alpha	high alpha	Low beta	High beta	Low gamma	Mid gamma
Alpha	**0,57**	**0,29**	**0,21**	**0,26**	**0,28**	**0,28**	**0,14**
Theta		**0,48**	**0,43**	**0,47**	**0,53**	**0,58**	**0,33**
Low alpha			**0,59**	**0,74**	**0,67**	**0,67**	**0,4**
high alpha				**0,73**	**0,74**	**0,81**	**0,53**
Low beta					**0,85**	**0,76**	**0,49**
High beta						**0,8**	**0,64**
Low gamma							**0,71**

So, we have computed the values of mean, standard deviation, and variance features, for each subband and searching the relationship between these features. The values of correlation coefficients between features using Pearson measure for each frequency were plotted in Figure 2 for the eight sub-bands, which are (alpha, theta, low alpha, high alpha, low beta, high beta, low gamma, and mid gamma). Table 1 shows the value of correlation for each band, with the correlation of each two features.

Table 3. The correlation coefficients between every two features for each sub-band

Correlation between	**Alpha**	**Theta**	**Low alpha**	**High alpha**	**Low beta**	**High beta**	**Low gamma**	**Mid gamma**
				Imaginary task 1				
Mean And Standard Deviation	0,79	0,89	0,94	0,96	0,97	0,95	0,93	0,95
Mean And Variance	0,69	0,70	0,80	0,91	0,91	0,92	0,85	0,86
Standard Deviation And Variance	0,94	0,87	0,92	0,92	0,94	0,96	0,94	0,94
				Imaginary task 2				
Mean and standard deviation	0,78	0,92	0,91	0,87	0,97	0,92	0,94	0,83
mean and variance	0,68	0,89	0,82	0,83	0,92	0,93	0,79	0,64
standard deviation and variance	0,92	0,92	0,95	0,95	0,95	0,97	0,92	0,93

The computed coefficient of mean with standard deviation and standard deviation with variance features, shows the most significant correlation values, especially in high beta frequency, for the first imaginary task, and in low beta frequency, for the second imaginary task. The correlation value between the mean and standard deviation was 0.97 in the low beta subband, which was the best correlation value.

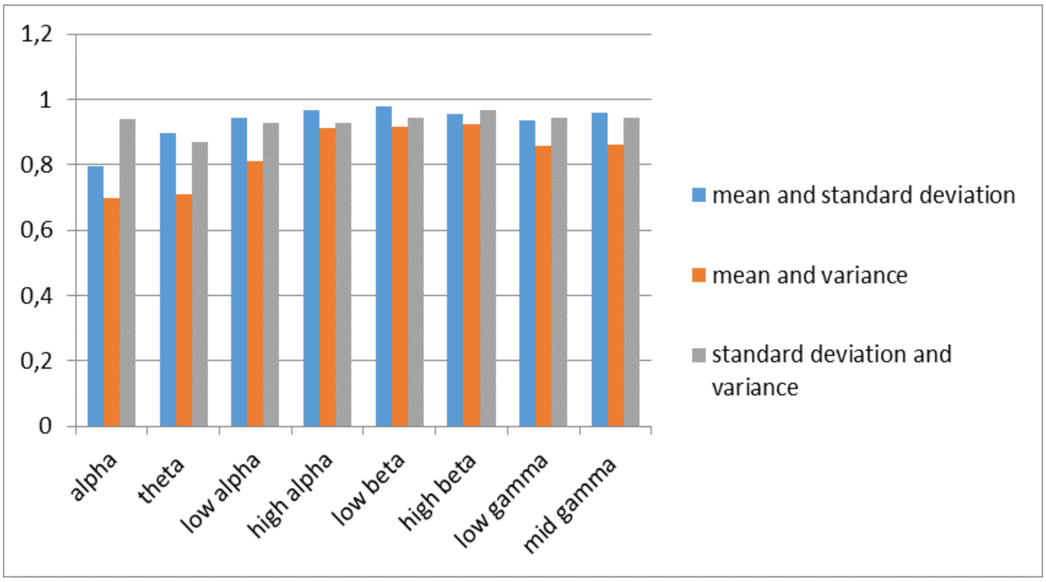

Figure 2: Correlation coefficients in different sub bands for imagination task 1

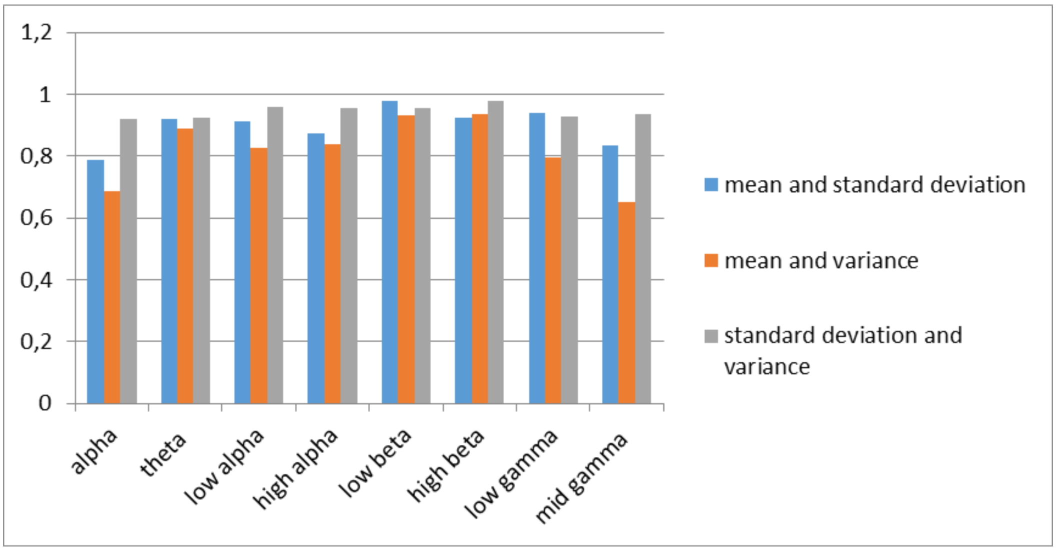

Figure 3: Correlation coefficients in different sub-bands for imagination task 2

Conclusion

This paper discussed the Pearson correlation coefficient in analyzing EEG data for imaginary tasks. The dataset was recorded by NeuroSky MindWave EEG headset from 22 subjects. The highest correlation was between standard deviation and variance features, in the low beta and high beta frequencies. The less significant correlation was between mean and variance features, and the low significant frequencies were in the alpha and mid-gamma subband. The study shows that the most significant frequency band, for our imaginary task was beta frequency, represented with mean and standard deviation features, which will help to filter and classify the dataset.

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Eliminate Image Noisy Pixel Values: Remove Undesired Noisy Pixels in Image with the Parameter of Pixel Width (Remove Pixels as Width - RPW)

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Abstract: Image Denoising, Deblurring, and Enhancement techniques are most commonly used on the images to reduce or completely remove the noise. The noisy images are not capable of perfectly using the solution of the desired problems such as object edge detection, object segmentation, and object classification. Because the edges of these objects have much bluer or more noise pixels for clearly stable detection. The main motivation of this study is to solve the problem of detection and elimination of the undesired noisy pixels on the encountered images. These noisy pixels are needed to be removed from the obtained images which are the results of throughout determined image processing steps. The main reason for this study motivation come out that to find the actual inscription fault has some noisy (undesired) pixels when extracting the true difference between the two images has been subtracted from each other. The subtracted image results are used in the inscription inspection process that controls the accuracy of the inscription quality. In the inscription inspection process, subtracted image results are used to determine the accuracy of the inscription quality. These subtracted images are formed by subtraction from each other of reference images and sample images. In these subtracted images if truly exist inscriptions faults or sometimes that could be occurred undesired noisy pixels at the same time in the subtraction process. This study focused on detecting and eliminating the undesired noisy pixels in order to reach actual inscription faults in the images. Thus, the remove pixels as width algorithm (RPW) has been developed and applied to these specified images.

Keywords: Image Denoising, Image Enhancement, Remove Image Noise, Eliminate Pixels, Detection Line Pixels

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Introduction

The inspection process used for printing helps control some plastic parts' inscriptions that contain printed objects such as text, characters, and symbols. These printed objects are in a variety of types and different fonts. Also, printed objects are not only belong onto plastic parts. There are many area that have the inscriptions, text, characters or symbols which are used for identify and classification of the products. Thus, nearly any industrial products have many printing characters that processed with engraving, embossed, debossed or printing techniques.

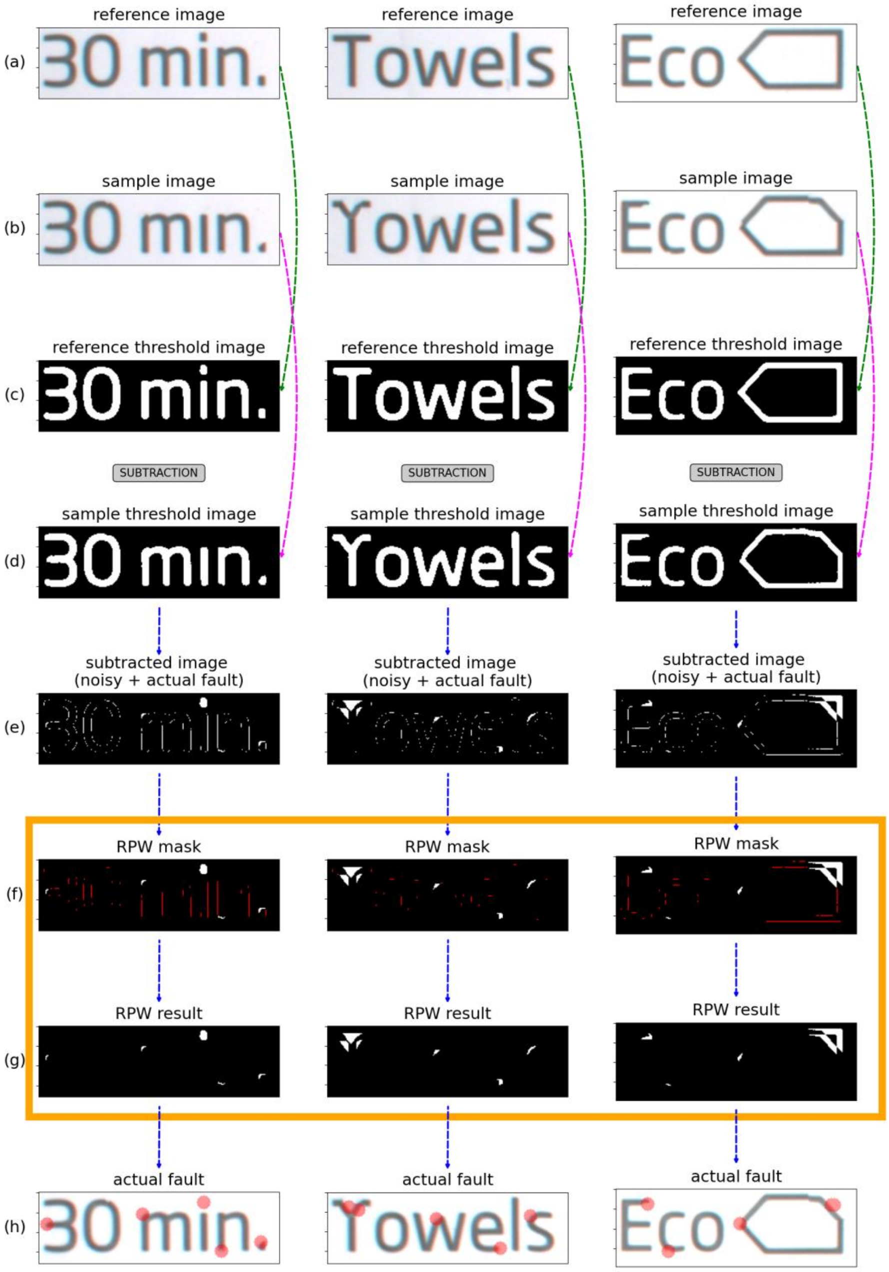

Figure 1. RPW algorithm's flow diagram is shown as initially a) reference images and b) sample images in order to compare with its related images. c) Reference and d) sample threshold images are extracted after applying many image pre-processing techniques. e) Subtracted images these are the results of subtraction process of the reference and the sample images. f) Applied RPW-mask that means detection noisy (undesired) pixels and detected pixels are pointed in red color. g) The result images of the RPW algorithms that applied on subtracted images, and also, the RPW algorithm has exposed only actual printing fault while perfectly eliminating the undesired noisy pixels. h) Exactly actual printing faults are pointed through onto sample image with small red circle

In this study, printing objects onto the plastic parts have been used as sampling to apply of RPW (Remove Pixels as Width) algorithm. These printed objects also consist of various types like text, characters, and symbols. As shown in (see Figure 1 (a) and (b)), these objects have symbols, characters, and numbers. Also, (see Figure 1 (a) and (b)) to show which images were used to develop the RPW algorithm, and clearly can be seen these plastic parts contain printed objects. Occasionally, undesirable inscription errors occur during the print processing steps, as shown in (see Figure 1 (b)) (Looking carefully, the difference between with (see Figure 1 (a)) can be seen. Some characters are not sleekly printed or looks like they had deformed/decomposed).

In this study, the focus is on detecting and eliminating undesired noisy pixels in images obtained through various image processing steps. These noisy pixels often occur as a result of the subtracting process (see Figure 1 (a)) of the sample images (see Figure 1 (b)) from the reference images (see Figure 1 (a)) in the inscription inspection process, which is used to determine the accuracy of inscription quality. These subtracted images (see Figure 1 (e)) occasionally contain actual faulty pixels while also having noisy pixels as shown in (see Figure 1 (e)). Removing these noisy pixels is necessary to accurately detect any inscription faults in the images. To address this problem, the 'Remove Pixel as Width' (RPW) algorithm has been developed and applied to the specified images.

Literature Review

There are multiple techniques (Motwani, Gadiya & Motwani, 2004), (Kumar & Gupta, 2017) (Singh, Yadav & Kumar 2018) available for reducing noise in images.

Linear filters are a class of image processing techniques that use simple mathematical operations to reduce the amount of noise in an image. They are called "linear" because they preserve the linear relationships between the pixels in an image. Two commonly used linear filters are the Mean Filter (Pratt, 1978), (Gonzalez & Woods, 2018) and the Gaussian Filter (Geman & Geman, 1963), (Gonzalez & Woods, 2018). The Mean Filter, also known as the Blurring Filter, calculates the mean of the pixel values in an image and uses this value to replace the value of each pixel. This process effectively smooths out the image, reducing the amount of noise present. However, it also has the effect of blurring the edges and details of the image, so it is not suitable for all situations. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (b)). The Gaussian Filter is similar to the Mean Filter, but it uses a convolution smoothing filter with kernel weights drawn from a Gaussian distribution. This filter is more effective at preserving edges and details while still reducing noise, making it a popular choice for many image processing applications. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (c)).

Non-linear filters are another class of image processing techniques that do not preserve the linear relationships between the pixels in an image. They are more effective at preserving edges and details, but may not be as effective at reducing noise. One commonly used non-linear filter is the Median Filter, which replaces the value of each pixel with the median value of the surrounding pixels (Lee, 1977). This filter is effective at removing salt and pepper noise (Erkan et. al., 2020), but may not be as effective at removing other types of noise. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (j)).

Other non-linear filters include the Kuwahara Filter (Kuwahara et. al. 1976), which uses a window of pixels to calculate the mean and variance of the image and then uses this information to smooth out the image. According to the (Kyprianidis, Kang, & Döllner, 2009) two different approach using Kuwahara Filter. One approach is The Gaussian Kuwahara filter can be considered as an extension of the classical Kuwahara filter. The Kuwahara filter divides an image into different regions according to their variances and computes the optimal statistical calculations for each region. The Gaussian Kuwahara filter adopts the same idea, but smoothed the boundaries between the regions with a Gaussian function, resulting in a smoother and more homogeneous filtering outcome. The Gaussian Kuwahara filter is particularly effective on images with severe noise and is often used in combination with other filters.

In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (g)). This filter operates slower compared to the classical Kuwahara filter, but produces higher quality results. The other approach is Mean Kuwahara filter (Guo et. al., 2018) which is a variant of the Kuwahara filter that uses the mean instead of the median to estimate the local statistics of an image. Unlike the classical Kuwahara filter, which can produce sharp discontinuities between different regions, the Mean Kuwahara filter produces smoother transitions due to the use of mean values. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (f)). The Mean Kuwahara filter is particularly effective for images with large regions of uniform texture and is often used in combination with other filters. However, it may not perform well on images with sharp edges or small details.

Non-Local Means (NLM) Image Denoising algorithm (Buades, Coll & Morel, 2005) is a widely used image denoising algorithm that operates on the principle of finding similar patches in the image and averaging their values to obtain a denoised version of the image. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (h)). The key idea of NLM is to exploit the self-similarity property of natural images, which means that similar image patches occur frequently in different regions of the image. The algorithm works by estimating the similarity between two patches using the Euclidean distance between their pixel values and a predefined window size. The patches with high similarity are then used to calculate the weighted average of the pixel values in the central patch. The weighting coefficients are calculated based on the similarity between the patches. This process is repeated for each pixel in the image, resulting in a denoised version of the original image.

Hough Lines algorithm, which uses the Hough Transform (Hough, 1962) to detect and remove the lines in an image. The paper presented a novel approach to detect complex shapes in images, such as lines, circles, and ellipses. The algorithm is based on the idea of representing the shapes in a parametric form and transforming the image space into a parameter space, where each shape can be represented as a point (Duda & Hart, 1972). By doing so, the problem of detecting shapes in the image is transformed into a problem of finding patterns in the parameter space. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (k)).

Other popular non-linear filters include the Bilateral Filter (Tomasi & Manduchi, 1998) is a filtering technique used in image processing that filters the image taking into account not only the pixel intensities but also the differences in pixel positions. As a result, it is an effective method for many applications such as noise reduction and sharpening. Compared to many other filtering methods, the bilateral filter creates less blurring and helps to preserve edges in images. The filtering process can be controlled by parameters such as kernel size, density variance, and spatial variance. Due to these features, bilateral filter is a widely used technique in image processing applications. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (d)).

The Box Filter (Pires, Singh & Moura, 2011) (Gonzalez & Woods, 2018), which uses a simple averaging technique to smooth out the image (see Figure 2 (e)).

The Minimum Filter (Verbeek, Vrooman & Vliet, 1988), which replaces the value of each pixel with the minimum value of the surrounding pixels. This filter performs filtering by using the smallest value of pixel intensity instead of calculating the mean or median of pixel intensities. Therefore, the minimum filter is effective in applications such as noise reduction and edge detection. It is particularly suitable for shape-based image processing methods such as morphological operations. The minimum filter, along with the maximum filter, is a basic component of max-min filters. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (i)).

Overall, there are a variety of techniques available for reducing noise in images, each with their own strengths and limitations. The appropriate technique will depend on the specific requirements of the application and the type of noise present in the image. The remove pixel as width (RPW) algorithm developed in this study provides a solution for detecting and eliminating undesired noisy pixels in images. If we look at the (see Figure 2) in which the results of the algorithm in this study are compared with the results of the similar methods mentioned above, the others methods can not capable to remove or eliminate all noisy (undesired) pixels except the Minimum filter and the Median filter. It is possible to reduce noisy pixels by using the Minimum filter (see Figure 2 (i)) and the Median filter (see Figure 2 (j)). In spite of this, those two filters were unable to keep the actual faults while eliminating noisy pixels and removed them (see Figure 2 (i) and (j)). This situation is not acceptable because of applied procedure of the inscription inspection process.

Figure 2. a) Sample images which are using as a test images to developing RPW algorithm. Comparing with some methods results can be capable are reducing noise such as; b) Mean Filter, c) Gaussian Filter, d) Bilateral Filter, e) Box Filter, f) Mean-Kuwahara Filter, g) Gaussian-Kuwahara Filter, h) Non-Local Means Denoising Filter, i) Minimum Filter, j) Median Filter, k) Hough Transform and l) the result of the RPW algorithm

Method

The Remove Pixel as Width algorithm is specially focused the mainly actual fault in the subtracted images which have noisy pixels and actual faults (see Figure 3 (a)). The RPW algorithm have two different approaches in order to make decision which one is the actual fault and which one is the noisy pixels. First approaching is using a coefficient that is positive integer number. This number determines the width of noisy pixels to be eliminated from the images.

Moreover, this coefficient is defined as k in the (see Equation 5). This coefficient is determined by the user, who can decide how wide the noisy pixels should be. Thus, the RPW algorithm is eliminate the noisy pixels less than and equal to the coefficient value. Concurrently, it detects the actual fault according to greater than the specified coefficient value (see Equation 5).

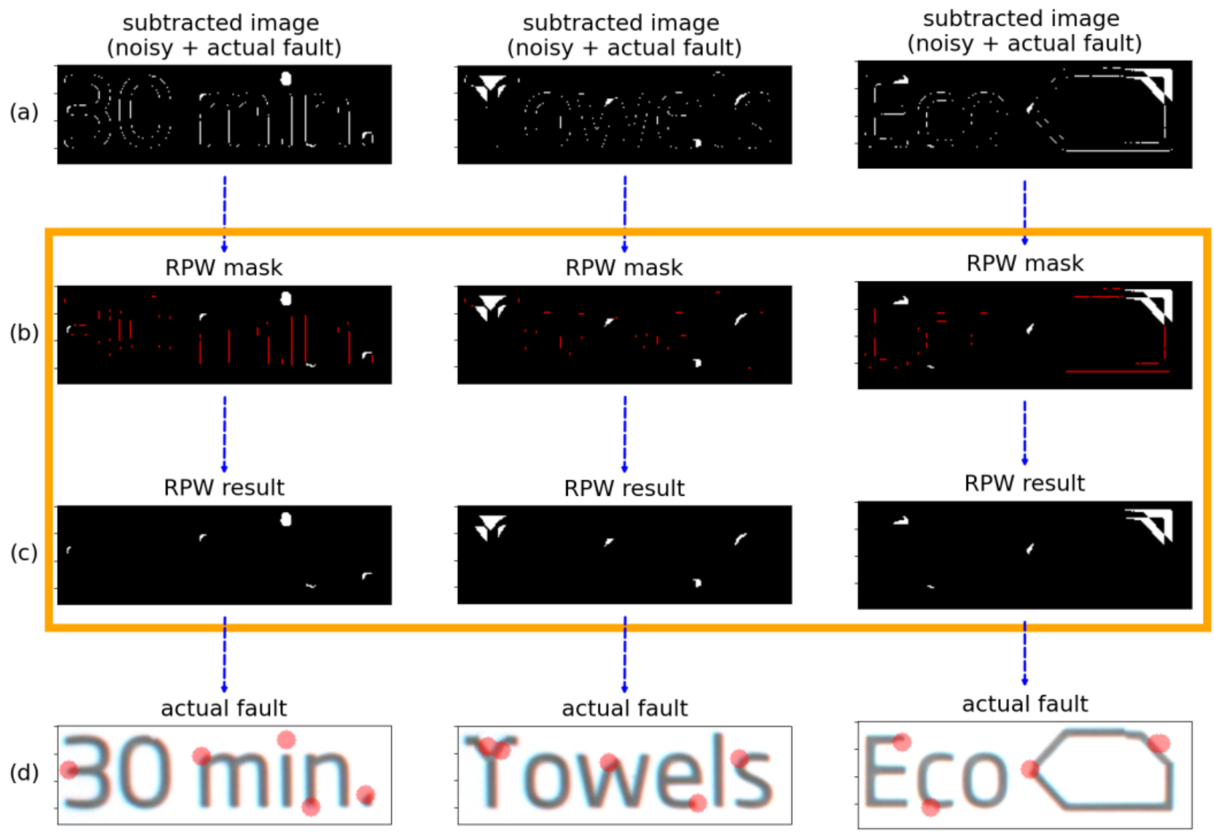

Figure 3. The RPW algorithm is applied through on the (a) subtracted images, (b) RPW mask image is detection the whole undesired noisy pixels as marked with red color and detection actual faults, (c) eliminate the detected noisy pixels and conserve the actual faults, (d) show detect the actual faults and marking them as red circles onto the sample images

The subtraction images are produced by the pre-image processing techniques shown in (see Figure 1 (c) and (d)). These techniques consist of several steps of main convectional image processing that include grayscale transform, sharpen filter, sobel edge detector and the thresholding process within settled parameters.

$$I(x) = [\, x_1 ,\ x_2 ,\ x_3 ,\ \dots,\ \ x_n \,] \tag{1}$$

$$I(y) = [\, y_1 ,\ y_2 ,\ y_3 ,\ \dots,\ \ y_n \,] \tag{2}$$

$$\Delta^x = |\ x_i \ - x_{i+1}\ | \tag{3}$$

$$\Delta^y = |\ y_i \ - y_{i+1}\ | \tag{4}$$

In equation 1, where x is an array of coordinate value on the x-axis of the subtracted image. In equation 2, where y is an array of coordinate values on the y-axis of the subtracted image. In equation 3, where Δ^x is an array containing the absolute values of the coordinate differences between all x values. In equation 4, where Δ^y is an array containing the absolute values of the coordinate differences between all y values.

$$RPWmask(x, y) = \begin{cases} I(x) = 255,\ I(y) = 255\,,\ if\ \ \Delta^x\ \cup\ \Delta^y \le k \\ \quad I(x) = 0,\ \ I(y) = 0,\ \ otherwise \end{cases} \tag{5}$$

In equation 5, where $RPWmask(x, y)$ is the result image that can able to detect noisy pixels (see Figure 3 (b)) and actual faults (see Figure 3 (b)), therefore eliminate only noisy pixels (see Figure 3 (c)). And, k is the coefficient value that provides the wide of the noisy pixels.

Results

These printing objects onto the plastic parts have been used as sampling to apply of RPW algorithm. These printed objects also consist of various types like text, characters, and symbols. The other hand, these are much more useful to candidate and clearly eliminate the undesired noisy pixels. Thus, more sample image used to apply of RPW algorithm and results of the RPW algorithm are showing in (see Figure 4 (g)).

Conclusion

The subtracted images (see Figure 4 (e)), these are have both noisy pixels and actual faults. The sample images (see Figure 4 (b)) could be used for RPW algorithm and the other compared methods. Therefore, a performance metric can be read onto the (see Table 1). In Table 1, first sample image (see Figure 1 (a)) is used to compare to the other methods as Input Image.

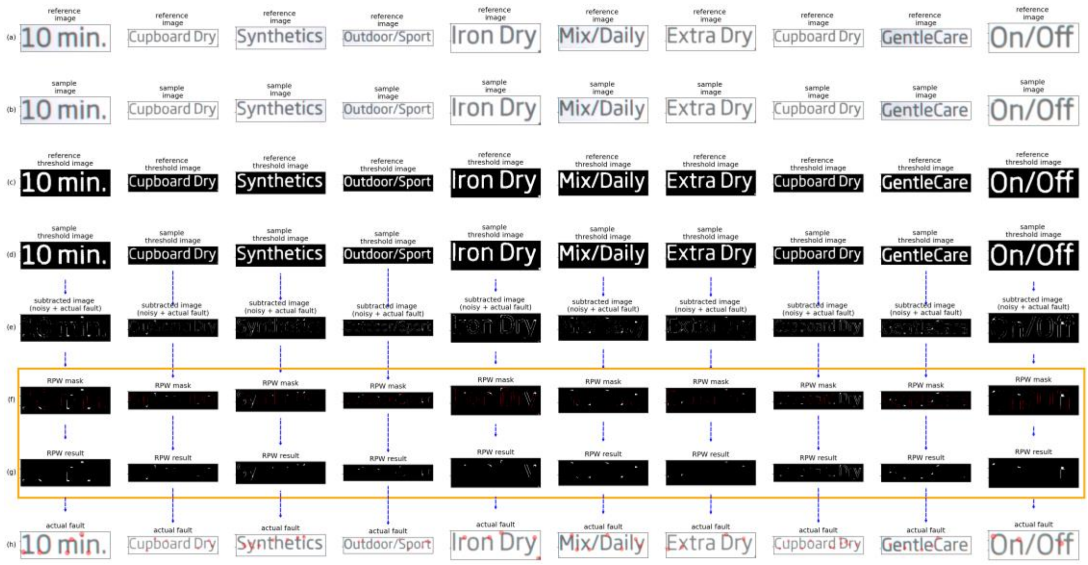

Figure 4. RPW algorithm's flow diagram is shown as initially a) reference images and b) sample images in order to compare with its related images. c) Reference and d) sample threshold images are extracted after applying many image pre-processing techniques. e) Subtracted images these are the results of subtraction process of the reference and the sample images. f) Applied RPW-mask that means detection noisy (undesired) pixels and detected pixels are pointed in red color. g) The result images of the RPW algorithms that applied on subtracted images, and also, the RPW algorithm has exposed only actual printing fault while perfectly eliminating the undesired noisy pixels. h) Exactly actual printing faults are pointed through onto sample image with small red circle

In Table 1, where "Total Contours" express the amount of the total pixel of the input image. "Eliminated Noisy Pixels" is the number of the eliminated contours pixels. "Detected Actual Faults" is the number of the detected actual faults. And, "Preserve Actual Faults" is the number of the detected contours and carried the actual faults to the method's results. Also, "*" expression is the real numbers of the input image.

Table 1. Performance contours of total pixels in a sample image

Methods	Total Contours	Eliminated Noisy Pixels	Detected Actual Faults	Preserve Actual Faults
Input Image	114	*109	*5	N/A
Mean Filter	37	77	37	37
Gaussian Filter	37	77	37	37
Bilateral Filter	114	0	114	114
Box Filter	37	77	37	37
Mean-Kuwahara Filter	110	4	110	110
Gaussian-Kuwahara Filter	108	6	108	108
Non-Local Means Denoising	73	41	73	73
Minimum Filter	1	113	1	1
Median Filter	1	113	1	1
Hough Transform	34	80	34	34
RPW	**5**	**109**	**5**	**5**

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Students' Learning Obstacles in Solving Early Algebra Problems: A Focus on Functional Thinking

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Abstract: This study describes students' learning obstacles in solving early algebra problems requiring functional thinking ability. To reach this aim, qualitative research was conducted in this study. Participants of this study were 39 ninth graders and a mathematics teacher at one of the lower secondary schools in Bandung, Indonesia. The data were collected through the written test about early algebra problems, interviews, and document study. The findings revealed that fewer students achieve the correspondence level in their functional thinking ability. Many of them are on covariation or recursive patterns level. The variety of students' functional thinking levels in solving the problem is influenced by their previous learning experiences with early algebra, mainly functions. By exploring students' learning experiences, this study shows that students have some learning obstacles, including ontogenic obstacles due to students' lack of prerequisite knowledge about the concept of variables, didactical obstacles due to the teacher's teaching implementation focusing solely on the operational rather than the structural conception of functions, and epistemological obstacles due to students' limited knowledge in the concept of variables and functions. Therefore, the identified learning obstacles can be one of the references when developing a lesson design about functions for enhancing students' functional thinking ability.

Keywords: Functional Thinking, Early Algebra, Functions, Learning Obstacle

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Introduction

Learning obstacle is a condition that makes the students' new knowledge acquisition during the learning process run slowly or restricted, allowing students to experience problems in learning. These problems can be seen in errors made by the students (Brousseau, 2006). Moreover, the notion of *learning obstacle* itself initiated by Bachelard & Piaget's discursion (in Brousseau, 2006) that mistakes conducted by students during learning are not solely sourced from themselves. However, mistakes can result from their prior knowledge, which seems right and proper to solve specific problems, but that knowledge becomes useless for solving another problem with the same characteristic. One example is Adu-Gyamfi et al.'s (2015) study, which reported that most students wrote $6s=p$ instead of $6p=s$ in the question "*the students' population is six times the professors*" because they thought variables as representing an object or abbreviation rather than quantities that vary. This kind of learning obstacle does not happen without *causal factors*, which Kansanen and Meri (1999) proposed can be observed based on the teacher-student-topic relationship.

According to its source, learning obstacles can be categorized into three types: ontogenic obstacle, didactical obstacle, and epistemological obstacle (Brousseau, 2006). The ontogenic obstacle occurs due to learning activity or the tasks given are incompatible with students' cognitive development. The task can be too difficult for the student to solve, or else it can be too easy to solve, causing them to lose the sense of being challenged. The didactical obstacle occurs due to the teacher's teaching sequences. Teachers might focus on the *know-how* aspect, such as ensuring that students can memorize formulas and problem-solving procedures, and pay less attention to the *know-why* aspect, which fosters students' reasoning. The epistemological obstacle can be identified when students' knowledge is limited to a particular context. All these obstacles can happen during the student's learning process, especially when they learn about algebra. This study focuses on early algebra since it is considered a well-known topic that causes many student problems (Kieran et al., 2016).

The Background of Study

Learning arithmetic and algebra separately can cause students to experience difficulties in developing their cognitive process from concrete to abstract (Carraher & Schliemann, 2007; Kieran et al., 2016). This issue makes the notion of early algebra learning within school mathematics noteworthy among researchers. Early algebra is not *the formal algebra* but more like a bridging topic for students, mostly in elementary school, to prepare them to learn the formal one. According to Kaput (2008), the main aspect of early algebra is generalization and symbolization. From Kaput's idea, Blanton et al. (2018) proposed the math content area for early algebra: generalized arithmetic; equivalences, expressions, equations, and inequalities; and functional thinking. This study will focus on functional thinking as it is the bridge for students to learn and understand functions.

Functional thinking (FT) is an individual cognitive process to generalize functional relations between varying quantities (variables) in mathematics (Lichti & Roth, 2018). Students' FT can be examined based on how they identify a relation between quantities, which is categorized into three levels (Confrey & Smith, 1994; Doorman et al., 2012; Smith, 2008). The lowest level is *recursive patterns*; students see the quantities' relation as the input-output process. Following this process, the students may identify that the value change in a variable influences the value change of the other variable. This level of thinking is included in *covariation*. At the end of the students' generalization process, they can determine the relationship between variables in general (applies to any value of the existing variables). This process involves the highest level of thinking, namely *correspondence*.

In mathematics learning, FT is essential as one of the core abilities students require to master. Since elementary school, FT has been involved in learning object configurations and number patterns (Kaput & Blanton, 2005; National Council of Teachers of Mathematics [NCTM], 2000). The learning continues to high school about linear and non-linear functions and calculus for higher education (NCTM, 2000).

Although the importance of FT is often discussed in the literature, many studies revealed students' challenges in solving problems requiring FT (Pinto & Cañadas, 2021; Ramírez et al., 2022). The frequent issue in studies is students' inability to recognize a pattern, whether in a sequence of numbers or object configurations (El Mouhayar, 2018; Wilkie & Clarke, 2016). Students who have better FT ability often use natural language to express the functional relation between variables due to a lack of understanding of the variable's notation (Ayala-Altamirano & Molina, 2020; Lucariello et al., 2014; Wilkie, 2016a). In FT, and therefore in functions, students ought to understand that a variable represents a *varying quantity* (Doorman et al., 2012; Kleiner, 1989). However, the students' restricted image of a variable is commonly influenced by their prior learning experiences, for instance, in linear equations, which hold an understanding that a variable is *the unknown* (representing a single quantity).

Following these issues, some authors try to analyze further how students work on problems that require FT, particularly through the early algebra lesson. Many of them emphasize their study on the exploration of students' FT in generalizing geometrical shapes and object configurations (Pinto & Cañadas, 2021; Ramírez et al., 2022; Wilkie, 2016a) and word problems (Ayala-Altamirano & Molina, 2020; Blanton et al., 2017; Pinto et al., 2022). Moreover, some studies focus on designing the early algebra lesson to foster FT in elementary school students (Stephens et al., 2017; Wilkie, 2016b). Although these studies significantly contributed to mathematics learning, few addressed the FT on secondary school students. İndeed, early algebra is intended to be introduced and has been implemented at the elementary school level in some developed countries (Pinto & Cañadas, 2021; Watanabe, 2011). Nevertheless, early algebra is not yet presented in Indonesian elementary school mathematics, resulting in students lacking preparation in learning formal algebra in high school. Another research gap is that existing studies focus their analysis on students' FT, with less attention to the sources of why they only reach a certain level of FT. We regard the sources as learning obstacles.

Considering the essential role of FT in mathematics learning, students' difficulties with FT, and the research gap, there is a need to conduct a study to investigate high school students' FT further. Therefore, this study aims to describe secondary school students' learning obstacles in solving early algebra problems whose solutions require FT ability. Two questions are addressed in this study: 1) How is the students' FT level in solving early algebra problems? And 2) How are the learning obstacles experienced by the students in solving the problems? Analyzing these aspects of students' FT can aid other researchers, curriculum developers, and teachers. For researchers, the recent study might provide a new perspective on different learning obstacles that students experienced in early algebra learning, focusing on FT. For curriculum developers, it gives suggestions on how early algebra should be presented for curriculum design. For teachers, it provides suggestions to teach their students about early algebra and perhaps more broadly.

Method

Research Design

The purpose of this study was to investigate students' learning obstacles in solving early algebra problems whose solution requires FT. Therefore, this study was conducted under the interpretive paradigm with a qualitative method. By tracing students' prior learning experiences in early algebra, particularly algebra as the study of functions, the study aimed to decipher all of the meanings of what causes them to encounter learning obstacles.

Participant and Data Collection

The participants in this study were 39 ninth-grade students and a mathematics teacher, and the concept of functions was the subject under investigation. The selection of this topic was driven by the absence of explicit early algebra lessons in the Indonesian curriculum. Typically, formal algebra is taught in junior high school. Nonetheless, we selected the concept of functions as a part of early algebra because it is related to the FT.

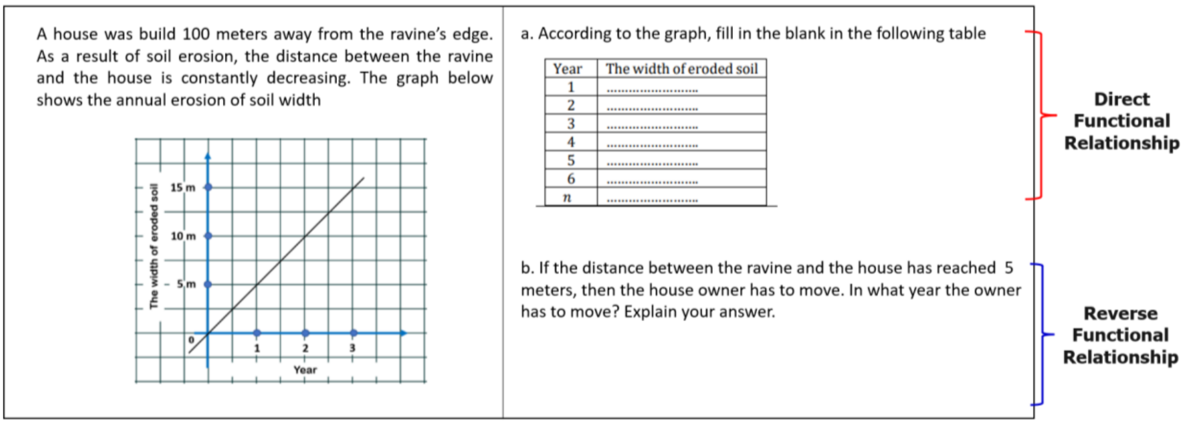


Figure 1. The Example of Problems in the Student's Written Test

Furthermore, written tests, interviews, and documentation studies were used to collect data for this study. The written examination consists of three problems in early algebra focusing on FT. Each question consists of two parts: (a) students are asked to generalize a pattern (direct functional relationship), and (b) students are asked to determine a specific value from a given output (reverse functional relationship). Specifically, each question was designed based on all levels of FT, so students answering the same question could reveal different levels of FT. Figure 1 depicts an example of questions given to the student. In addition, the interview included ten representative students and the math instructor. A documentation study was conducted to analyze the teaching and learning documentation, such as the class's mathematics textbook.

Data Analysis

The data analysis used qualitative data analysis techniques containing three stages: preparing, managing, and interpreting the data.

Preparing the data

At the stage of primary data analysis, all collected information was gathered for analysis. The data prepared for analysis in this study are the results of students' written tests, students' and the teacher's interview transcripts, and a documentation study on the series of mathematical textbook tasks.

Managing the data

We attempted to analyze the data from the written tests of the students. We categorized the students' written test responses based on FT levels in each type of problem (direct and reverse functional relationships) as the point in obtaining additional information about their learning obstacles. The interview results of the students were also classified based on their FT levels. It was meant to explore more about why the student chose a particular strategy to solve the problem. The results of the teacher's interview regarding how he designed and implemented the learning of the concept of function were also included, as the purpose of this study was also to determine the impact of students' prior learning experiences. Since the teacher stated that the majority of students' learning paths for the concept of function were based on the textbook, the analysis of tasks presented in the math textbook on the related topic was also considered.

Interpreting the data

The final stage of analysis is data interpretation. This stage was done by matching each data with a connection or an explanation of the other data. For instance, the teacher's interview supported the outcome of a student's interview regarding their previous learning activity in class, which explained the rationale for their chosen strategy in problem-solving. At this stage of the analysis, all interconnected data will be interpreted and categorized based on three types of learning obstacles experienced by students: ontogenic, didactical, and epistemological.

Results

The results of this study will be presented in accordance with the proposed research questions from the previous section. First, this section will discuss the students' FT level in solving early algebra problems. Following that discussion, the students' learning obstacles identified in solving the problems will be explained.

Students' Functional Thinking in Solving Early Algebra Problems

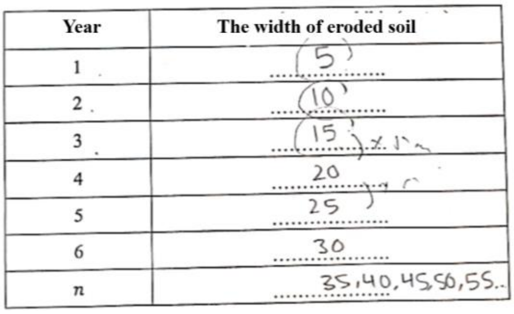
In investigating students' FT, they were asked to solve three problems which implicitly used three different types of functions, that is $y=ax$ (question number 1), $y=ax+b$ (question number 2), and $y=ax-b$ (question number 3. Each question consists of two parts, namely direct and reverse functional relationships (FR). From 39 participating students, the result shows that most students are in the recursive level of FT. The description of students' written test and FT level categorizations are described in Table 1 as follows.

Table 1. Description of Students' FT in Solving Early Algebra Problems

Problem	Type of function	Type of functional relationship (FR)	Num. of students evidenced for FT (Total students: 39)			Num. of students who are not evidenced for FT
			Recursive Patterns	Covariation	Correspondence	
1.	$y=ax$	Direct FR	32	-	7	-
		Reverse FR	6	3	7	23
2.	$y=ax+b$	Direct FR	35	-	3	1
		Reverse FR	23	3	2	11
3.	$y=ax-b$	Direct FR	20	-	5	14
		Reverse FR	8	4	3	24

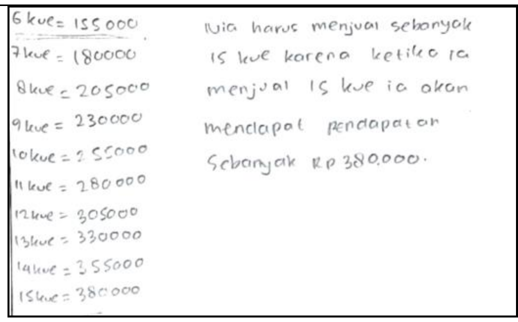
Table 1 shows that students' way of solving all three problems is categorized into the recursive patterns level in FT, followed by the correspondence and the covariation. In addition, we have observed that the number of students who solve direct FR problems is always greater than the number of students who solve reverse FR problems. These results indicate that students found it more difficult to solve reverse FR problems than direct ones. A further explanation of how students solve the direct FR (generalize the patterns and determine the formula) and solve the reverse FR problems are described below.

Students who demonstrate recursive pattern level in FT always use a similar method to solve problems, according to our investigation. In order to solve direct FR questions, they determined the value of each dependent variable by adding the same number to the previous term's value. Similarly, recursive patterns level students also count the number in consecutive terms when solving reverse FR problems. Figure 2 below illustrates examples of student responses at this level



Year	The width of eroded soil
1	5
2	10
3	15
4	20
5	25
6	30
n	35,40,4550,55..

(a)



6 kue = 155000
7 kue = 180000
8 kue = 205000
9 kue = 230000
10 kue = 255000
11 kue = 280000
12 kue = 305000
13 kue = 330000
14 kue = 355000
15 kue = 380000

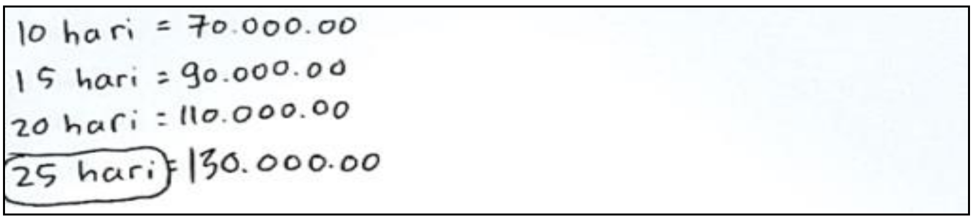
Wia harus menjual sebanyak 15 kue karena ketika ia menjual 15 kue ia akan mendapat pendapatan sebanyak Rp 380.000.

(b)

Figure 2. Examples of Students' Answers in Recursive Pattern Level: Direct FR (a) and Reverse FR (b)

In Figure 2a, students could find the width of eroded soil in the fourth, fifth, and sixth years by adding 5 meters to the previous year. As a result, students wrote 35, 40, 45, and so on to indicate the width in the nth year instead of 5n. In solving reverse FR (Figure 2b), similar to solving direct FR, the student listed one by one until he found that profit would reach 380,000 rupiahs if the seller sold 15 cakes (*kue* in Indonesian).

Furthermore, students that reach the covariation level of FT can be evidenced by their way of solving the reverse FR problems. In their strategy of finding the independent variable value from the given dependent variable value, they used trial-and-error as their solution. For instance, in Figure 3, to find how many days are needed for the boy to save 130,000 rupiahs money, the students chose to *guess* the amount of money collected on certain days. Although this strategy is also valid, their answer indicates that they cannot reverse the relationship and opt for working from the input to the output (direct FR). In Figure 3, the function type is $y=ax+b$, and the students cannot do the reverse calculation, $x=(y-b)/a$.



10 hari = 70.000.00
15 hari = 90.000.00
20 hari = 110.000.00
25 hari = 130.000.00

Figure 3. An Example of The Student's Answer in Covariation Level (Hari means day in Indonesian)

Students with the highest level of FT, namely the correspondence, managed to identify the relationship between independent and dependent variables, symbolize the relationship, and do the reverse calculation. In Figure 4 below, students with a correspondence level of FT can determine the width in the nth year as *5n* instead of stating the exact value in Figure 2a. They understand that the width is 5 times a year and not merely *add 5* to each width. Likewise, in the reverse problem (Figure 1), the students understand that if the width is 5 times a year, then the year is one-fifth the width. So, they used the formula instead of listing one by one to find the year when the width reached 95 meters.

Year	The width of eroded soil
1	5 m
2	10 m
3	15 m
4	20 m
5	25 m
6	30 m
n	5 n

Figure 4. An Example of The Student's Answer in Correspondence Level

Nevertheless, not all students who solve direct FR problems with correspondence can solve reverse FR problems at the same level. Despite being categorized with the correspondence level in solving direct FR, some only reach the covariation or recursive patterns level in solving reverse FR ones.

Students' Learning Obstacles in Solving Early Algebra Problems with A Focus on Functional Thinking

Based on the previous section, this study highlights two significant issues that students deal with when solving early algebra problems. Those three issues came from students who (1) applied the recursive pattern strategy to solve direct FR problems, thus, did not make it to the algebraic expression of the generalization, and (2) managed to work on direct FR problems but not with reverse FR ones. As a further investigation, this study explains the reasons for the three existing issues. This study considers the reasons as students' learning obstacles (LO).

As the primary stage of students' LO identification, the researcher (R) interviewed two representative students with the first issue. One student (S1) guessed the n symbol as the pattern, while the other one (S2) worked on the n symbol as the next term. The interview of both students is transcribed as follows.

Transcript 1: The interview with S1

R : When you solve question 1A, can you see the pattern in this problem?

S1 : Yes, it is 5 meters (*the width of eroded soil always increases by 5 meters per year*)

R : Right. Can you tell me how you find the width in the fourth until the sixth year?

S1 : I just added 5 to the previous width.

R : Do you understand the meaning of the nth year here?

S1 : I do not miss.

R : Okay, what do you mean 5 in the width for the *n*th year you wrote here?

S1 : I just thought *n* was the pattern, so I wrote 5.

Transcript 2: The interview with S2

R : Okay, when you solve question 1A, can you see the pattern?

S2 : Yes, the width always adds 5 meters per year.

R : Good. How can you find the width in the fourth until the sixth year?

S2 : Adding 5, so 20 is from 15 plus 5, 25 is 20 plus 5, 30 is 25 plus 5.

R : Do you understand the meaning of the nth year here?

S2 : It is the width of the following year.

R : So, you mean that n is the width of the seventh year? That is why you wrote 35?

S2 : Yes.

According to the interview transcribed above, there are two ways of students' understanding about the *n* letter. First, the student's answer in Transcript 1 indicates that neither S1 knows about the letter *n* referring to nor does S1 know that *n* is a variable. The student's lack of understanding of variables resulting S1 producing incomplete solutions. The fact that the problem requires the student to have a sufficient understanding of the variable, which S1 has not, according to Brousseau (2006), is categorized as having an *ontogenic obstacle*. Unlike S1, who does not know what the *n* stands for, S2 sees the *n* as a single value. Thus, S2 has a limited understanding of a variable representing a *specific unknown* but not with *things that vary*. According to Brousseau (2006), having a restricted image of a concept that is only useful for specific problems but not for others is categorized as having an *epistemological obstacle*.

Furthermore, the researcher managed to dig for more explanation from a representative student (S3) with the second issue (solved direct FR but did not solve reverse FR problems. An example of an interview transcript with S3 is described below.

Transcript 3: The interview with S3

R : Do you understand the problem in question 1B?

S3 : No, Miss.

R : Okay, look. The starting distance between the ravine and the house is 100 meters. In this question, the distance becomes 5 meters. How much is the width of eroded soil?

S3 : It is 95 meters, Miss.

R : How can you find the year when the width reaches 95 meters?

S3 : Just add 5 meters one by one.

According to the interview, S3 did not understand what to do with the reverse FR problem on his first attempt. However, with a bit of help from the researcher, S3 solved the problem. Moreover, notice that even S3 make it to solve the reverse FR problem; he treats the reverse FR like the direct one. Instead of using the shorter way, namely, 95 divided by 5, he chooses to add 5 in consecutive terms until he finds 95. According to Brousseau (2006), this type of student who has the inability to do the inverse operation of the variable relationships indicates that he has an *ontogenic obstacle*.

Besides the finding of two types of students' learning obstacles, namely ontogenic and epistemological, how students solve the problem might be influenced by their previous learning activity. The students' FT is highly related to how they construct and understand the concept of function. Therefore, this study seeks to investigate how students previously learned this topic by interviewing the teacher and analyzing the tasks given to the students during the learning. The researcher conducted an interview with the students to obtain information about the learning implementation of the function's concept. The interview is shown as follows.

Transcript 4: The interview with the teacher (T)

R : How is the learning process in the concept of function before?

T : At that time, we still implemented online learning due to Covid-19. Consequently, not all lessons about the function were learned by the students. For the concept of function, the students were only expected to know the function's definition, identify function and non-function, represent a function with a Venn diagram, an algebraic symbol $f(x)=y$, and find the image of a function from a given function's equation.

R : Okay. Also, if you introduced the students to $f(x)=y$ as the function notation, did you mention using other letters as the variables?

T : We did not have much time, so I focused on using $f(x)=y$ as the formal way to represent the function.

R : You said that the students learned about finding the image of a function. Did you also mention how to find the x when $f(x)$ is given?

T : No, only until the image of a function.

The interview result with the teacher gives more insight into the possible reasons why several students have ontogenic and epistemological obstacles. According to Transcript 4, three main points should be underlined regarding the prior learning implementation: the learning of function focuses on definition and representations, the students are only taught $f(x)=y$ as the only algebraic symbol to express a function, and the learning ends with finding the function's image.

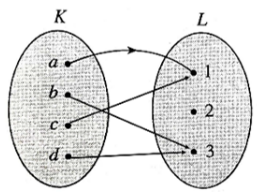
These points obtained from the teacher's interview come up with different connections with the identified LO of the students. As the result of learning the function's symbol $f(x)=y$ as the only way to represent a function algebraically, the students could not understand n as a variable in direct FR problems (ontogenic) and had a restricted image of n as a specific unknown, not a variable (epistemological). Since the teacher only taught how to find the image of function (direct FR), it is understandable that students encountered greater difficulty when solving problems involving reverse FR (ontogenic). Students' limitation in understanding the function concept correctly because of the teaching material implemented by the teacher, according to Brousseau (2006), is categorized as a *didactical obstacle*. Nevertheless, this teaching and learning limitation happens due to the pandemic, where the teacher has no other option but to conduct the learning activity in a short time frame.

Furthermore, this study also analyzes the tasks used during the learning activity to help students construct knowledge about the function's concept. According to the teacher's interview, the student's mathematics textbook is the primary source for learning the concept. Therefore, the student's learning obstacle analysis proceeds to the series of tasks presented by the textbook in function.

Based on the analysis, the textbook begins the introduction of function by its definition in terms of pairing between sets: *a function from Set A to B is a unique relation that pairs each element in Set A to only one element in Set B.* Following this definition, the textbook presents tasks that help students learn different representations of a function. However, we identify that the textbook does not provide connections between the representations, that is, to understand that a function is an object whose values remain the same (across its domain) despite its representation changes. In this case, the textbook does not provide how the operational conception of function (as the input-output process) can lead to the structural conception (function as an object). The missing task to link these dual concepts of a function is depicted in Figure 5.

Given a set $K = \{a, b, c, d\}$ and a set $L = \{1, 2, 3\}$. Make an arrow Venn diagram to represent a function f, if $a \to 1, b \to 3, c \to 1$, and $d \to 3$

Answer:



Example of function on the left side cannot bridge students to learn about function on the right side

Given a function $f: x \to 3x - 1$, determine the function formula and the image of function for $x = 4$.

Answer:
Function formula: $f(x) = 3x - 1$
The image of f for $x = 4$:
$f(4) = 3 \times 4 - 1 = 12 - 1 = 11$

Figure 5. The Examples of Tasks in the Textbook

In Figure 5, the task on the left only presents a function as pairings between sets while the task on the right side presents a function in analytical expression (algebraic). The missing link between the left and the right tasks is the function rule, which can be used to determine the image of the function. The left task does not help students to grasp an understanding that a function expresses a generality. This understanding is needed for them to solve the right task. Nevertheless, the absence of tasks linking the left and the right side might result in the students having a limited understanding of the meaning of the algebraic representation of a function. This finding supports our previous investigation about students' epistemological, ontological, and didactical obstacles; that is, all the learning obstacles experienced by the students are sourced from the textbook they use during the learning. Students' limited understanding of the function's concept due to the tasks within the textbook, which does not consider their cognitive development progression, based on Brousseau (2006), is categorized into the *epistemological obstacle.*

To conclude, Figure 6 shows the linkage between learning obstacles experienced by the students in solving the early algebra problems with a focus on FT.

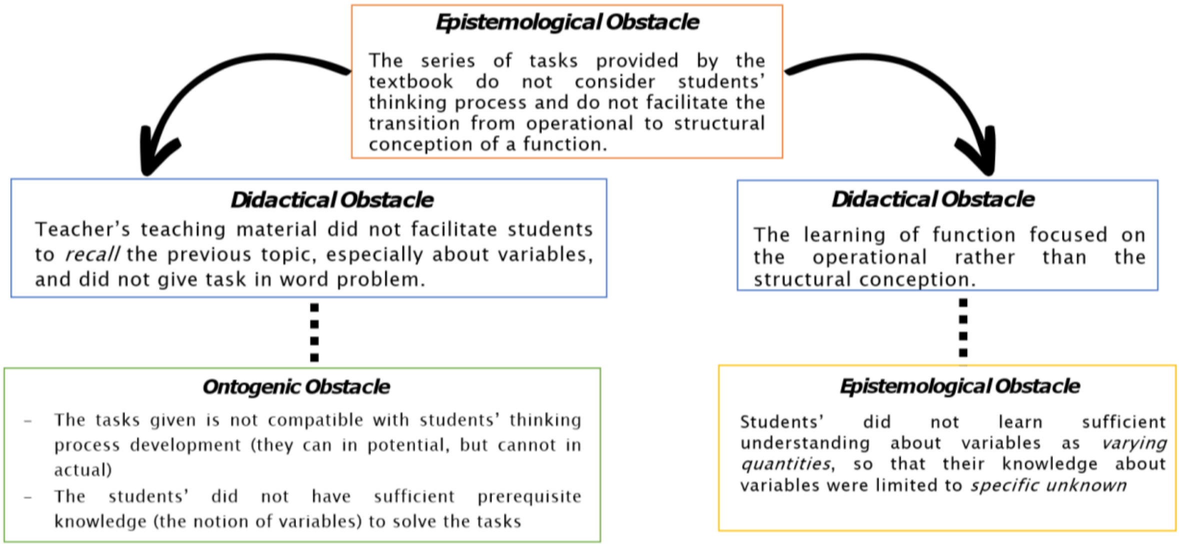


Figure 6. Students' Learning Obstacles in Solving Early Algebra Problems with a Focus on FT

Discussion

This paper refers to the FT's level proposed by Doorman et al. (2012), Smith (2008), and Wilkie (2014), namely *recursive patterns, covariation, and correspondence.* According to the finding, students who worked on the problems (direct or reverse FR) with the correspondence strategy managed to understand algebra, as a study of function, as a mathematical object (Doorman et al., 2012). Nonetheless, few of these students can symbolize the generalization due to their limitedness in identifying the patterns in word problems. This study's result complements prior research that generalizing patterns from word problems are more challenging than object configurations (Pinto & Cañadas, 2021; Ramírez et al., 2022; Wilkie & Clarke, 2016).

Unlike students who make it to the correspondence level, students with recursive pattern levels can only identify a limited variation within a sequence of numbers or objects. Doorman et al. (2012) and Lichti and Roth (2018) associate the recursive patterns level with the input-output assignment aspect, the student's ability to pair each element in the domain to only one element in the codomain; however, this pairing is local. Moreover, in identifying the pattern, previous studies explain the finding of this research that students with recursive patterns level focus on the values' change of one variable without paying attention that the values of both variables change simultaneously (Pinto & Cañadas, 2021; Wilkie, 2016a).

Furthermore, students with the correspondence level solved the reverse FR problems by performing Polya's (2004) working backward strategy. In working backwards, the student determines the primary goal and then starts working backwards to the initial condition. This problem-solving strategy suits the strategy to solve reverse FR problems by knowing the goal (the given value of the dependent variable) and beginning the reverse operation to find the value of the independent variable.

On the other hand, students who reached the recursive patterns and covariation level of FT did not work with the working backward strategy in solving reverse FR problems. Students with the recursive patterns level tend to solve the problem by repeating addition from y_1 to y_n (y_n is the given value of the dependent variable). When they find the y_n, they need to see which x's value (the independent variable) corresponds to the y_n. Another strategy was conducted by the covariation level students. They apply the trial-and-error strategy to find the independent variable's value: if x_1, then y_1; if x_2, then y_2. Indeed, this kind of strategy is often performed by students in solving problems related to pattern generalization (Malisani & Spagnolo, 2009; Radford, 2010).

Moreover, this study also reports that students find solving the reverse FR problems more challenging than the direct FR ones. According to the study of Callejo and Zapatera (2017), elementary school students found difficulties in solving reverse problems, even though they met no challenges in solving the direct ones. In fact, the study of Wilkie (2016a) that was conducted a year before revealed that even solving the reverse problems still exists as an issue for secondary school students. Therefore, this study complements the previous research that in solving reverse FR problems, not only do students complicate it, but also they tend to downgrade their FT level from solving the direct FR problems. For instance, some students show the corresponding level in solving direct FR but only reach the recursive patterns level in solving reverse ones.

This study also put efforts into investigating the possible students' learning obstacles. We refer to the three learning obstacles stated by Brousseau (2006), namely ontogenic, didactical, and epistemological. According to the finding, two main issues experienced by the students are categorized into having ontogenic obstacles. First, their insufficient understanding of variables affected their strategy in solving the problems given; they recursively determined the value of each term without being able to represent the generality with algebraic symbols. Second, their unfamiliarity towards working on a reverse operation to the functional relationship between variables. Based on Brousseau (2006), students with ontogenic obstacles encounter an imbalance between the given task and their existing knowledge or cognitive development.

In addition to students' ontogenic obstacles, students with the epistemological obstacle, who reach the recursive patterns or covariation level, have a restricted image of variables. Küchemann (1978) and Usiskin (1988) stated that judging from its usefulness, a variable exhibits different meanings: generalized number, specific unknown, and varying quantities. In a function, students should understand a variable representing varying quantities. However, the students have not yet reached this level of comprehension and still depend on a variable representing a specific unknown. Likewise, some students consider x the only letter to denote a variable and have difficulties when the problem requires them to use n as the variable. These findings support the prior study, which reported that the number of students who obtain knowledge of a variable as varying quantities is low, and the students' possibility of denoting a variable with x might be caused by their unfamiliarity with using another letter except x (Sajka, 2003; Trigueros & Ursini, 1999). According to Brousseau (2006), students with epistemological obstacles construct a limited understanding of knowledge, which may be affected by their previous learning experiences, so their obtained knowledge is only helpful for specific problems.

Relating to the students' ontogenic and epistemological obstacles, this study also reveals that during the learning process in the function's concept, the teacher only introduces a function through mathematical problems with less attention to the word problems. Meanwhile, according to Wilkie (2016b), helping students to learn about functions and nurturing their functional thinking can be done by teachers through giving contextual problems. Moreover, this study also reports that learning functions emphasize the operational rather than the structural conception of a function. However, understanding a function as an analytical expression $f(x)=y$ requires students to grasp both conceptions; operational as finding the image of function (y) from specific x within the domain, and structural as knowing the formula $f(x)=y$ is valid for every x in the domain (Sfard, 1991). Thus, students' obstacles caused by their previous learning experiences, which are less effective in helping them acquire the attained knowledge, is called didactical obstacle (Brousseau, 2006).

Finally, this study reveals the primary source of all students' learning obstacles discussed above. By analyzing the series of tasks presented in the textbook used during the learning activity, this study reveals that the order of tasks within the textbook does not present connectivity between tasks and students' thinking processes. The tasks do not bridge the students to construct knowledge about functions in which algebraic symbols can represent the rule. Thus, students' restricted image of a function caused by the series of tasks provided by the textbook, according to Brousseau (2006), is called an epistemological obstacle. The tasks within textbooks are essential in shaping students' knowledge since the knowledge they learn is highly dependent on the series of tasks given to them (Fitriati et al., 2020; Henningsen & Stein, 1997; Hiebert & Wearne, 1993).

Conclusion

This study provides evidence of lower secondary school students' FT in solving early algebra problems and the types of learning obstacles they experience when attempting to solve these problems. Comparing the covariation and recursive pattern levels, the findings revealed that only a small percentage of students have already attained the correspondence level. Due to the fact that the presented problem is a word problem, this study also revealed that students find it more difficult to generalize patterns in word problems than in object configurations or geometrical shapes. This study also determined how the type of functional relationships affected students' ability to solve problems. According to the test answers, direct functional relationship problems are easier to solve than reverse ones.

Furthermore, three types of students' learning obstacles were identified. The ontogenic obstacle experienced by the students as a result of the assigned tasks is incompatible with their existing knowledge, both in the notion of variables and the concept of functions. The didactical obstacle is found due to the teacher's teaching material and implementation of the concept of function, which did not focus on the role of variables in functions and only attained the operational rather than structural conception of a function. The epistemological obstacle is identified based on the series of tasks in the students' textbook as their primary sources of learning, which failed to take into account the students' thought process during the transition from an operational to a structural conception of a function. Existing studies have made significant contributions to the examination of students' FT in different types of problems; however, this study explains why students only attain a certain level of FT by analyzing their learning obstacles.

Recommendations

Based on these findings, we recommend that the development of students' FT be taken into account when designing early algebra learning activities for students. Similarly, considering the students' learning obstacles in that topic should be taken into consideration in the learning design so that the design can overcome those obstacles and meet the student's needs.

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Game Addiction Level of Turkish University Students Who Play Digital Games Regularly

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Abstract: With the development of technology, people's gaming tools and practices have also changed. While games are an activity that people need to have fun, they are also important for their cognitive and affective development. Today, digital games have largely replaced traditional games and become popular among children and young people. This situation has brought the game addiction, which has become a public health problem all over the world. Therefore, this study aimed to explore game addiction level amongst the university students who play digital games. It was designed as a cross-sectional survey within the quantitative research paradigm. The sample was made up of 164 Turkish university students who are interested in digital games and play them regularly. Data were collected through an online questionnaire including demographic information form and a 7-item game addiction scale. The findings indicated that League of Legends, Counter Strike Global Offensive, GTA San Andreas, GTA 5 were the most frequently games played by the participants. Most participants play games on a daily basis. The game addiction level was fond to be moderate on average and independent of gender, major of study, GPA and year of school.

Keywords: Digital games, Game addiction, Demographics, University students

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Introduction

According to the dictionary of Turkish Language Society (TDK), the concept of game is defined as talent and intelligence developing entertainment with certain rules (TDK, 2023). In the relevant literature, game has been explained with various meanings including but not limited to "the most important job/occupation of children", "one of the sources of creativity", "a bridge between fantasy and reality", "a natural and active learning environment", "fun learning method" and "a voluntary activity that brings happiness" (Yalcin & Bertiz, 2019). While it is essentially a fun activity that entertains the individual, it also provides significant benefits for his/her physical, emotional, social, cognitive and linguistic development (Akandere, 2006; Yavuzer, 2001). Game playing supports burning fat, strengthening muscles; psychomotor abilities such as power-response readiness, speed, stillness, dynamic attention, coordination and flexibility; the leaning and control of emotions such as jealousy, fear, joy, pity, anxiety, friendship, enmity, love and trust; understanding socialization, respecting the rights and freedoms of others, protecting their own rights and freedoms, help, sharing and leadership; skills for sentence making, asking questions, answering and storytelling, and the development of reasoning, choosing, matching, sequencing, analysis, synthesis and problem solving (Bekmezci & Ozkan, 2015).

With the development of technology, people's gaming tools and practices have also changed (Acikgoz & Akman, 2023; Cakir et al., 2019; Ozturk et al., 2023). Today, digital games have largely replaced traditional games and become popular among children and young people. Games, which in the past were real events with friends in playgrounds and on the streets, have become online events or virtual activities performed at the computer at home or internet cafes (Horzum, 2011). While computer technologies make life easier in many aspects, they have also become increasingly popular tools of entertainment. Especially young people are interested in digital games including computer and video games that can usually played with electronic tools such as computers, tablets, mobile phones, game consoles, Playstation, Xbox and so on. These games include highly interactive and realistic virtual environment allows players to take control of a person or an object and perform functions specific to each game. They can be both online and offline and played individually or in teams. Advances in internet technologies have made them more readily available, attractive and engaging. Players can also join (inter)national tournaments (e-sports) based on mutual competition (Yesilay, 2020).

There are lots of digital games available now, which can be divided into several categories. First Person Shooter Games require players to control a character with a gun or other form of shot. They have been played mostly on computer platforms, but are being played intensively with game consoles such as Xbox, Playstation with the development of technology. Multiplayer Online Battle Arena Games are known as strategy video games and involve two teams of players competing against each other on a predefined battlefield. Massively Multiplayer Online Games are often played online with other players. Role Playing Games require the person taking control of a character in a fictional virtual setting that makes the game feel somewhat realistic (Buyukbaykal & Ili, 2020).

A growing body of literature has demonstrated both benefits and perils of playing digital games. Some suggest that recreational playing may result in enhancements in hand-eye coordination, spatial abilities, imagination, inductive reasoning, mental rotation and spatial visualization, spatial distribution of attention and visual selective attention, task switching and perceptual speed (Blumberg, Altschuler, Almonte, & Mileaf, 2013; Horzum, Ayas & Cakir-Balta, 2008). On the other hand, some indicate that high involvement in these games may lead to deterioration of social relations and communication with family and friends, failures in school and work, tending to aggressive behaviors, disrupting tasks and preferring gaming to other activities, sleep problems, and behavioral addiction (Horzum, 2011; Oztutuncu-Dogan, 2006; Yalcin & Bertiz, 2019).

Game addiction is currently one of the most discussed psychosocial aspects associated with playing digital games. Addictive behavior refers to behavior that is excessive, compulsive, uncontrollable, and psychologically or physically destructive. Accordingly game addiction can be defined as uncontrollable compulsive and excessive gaming that result in social and/or emotional problems. There is considerable disagreement among clinicians and researchers about the use of terminology to describe the addictive gaming behavior. When we look at the related literature, the most prevalent term is game addiction and other terms used include problematic game playing, pathological gaming, and obsessive-compulsive gaming (Yalcin-Irmak & Erdogan, 2015). Regardless of the terminology used, researchers agree that overuse of gaming can lead to a behavioral addiction (Eker & Taş, 2022; Griffiths, 2005; Koc & Tanrikulu, 2021;). Lemmens et al. (2009) defined game addiction as a continuation of excessive and compulsive computer or video game playing even though it causes social and/or emotional problems. American Psychiatric Association (APA) defines this problem as internet gaming disorder in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) which is used by mental health professionals to diagnose mental disorders and recommends conducting further research to support clinical diagnostics (APA, 2013). In 2018, the World Health Organization (WHO) included the category of "gaming disorder" in the forthcoming International Classification of Disease Manual (ICD-11). Both DSM-5 and ICD-11 provide diagnostic criteria for game addiction, which is used by mental health professionals. According to DSM-5, the diagnostic criteria of game addiction include the following nine clinical symptoms (APA, 2013):

- Preoccupation with playing games
- Experiencing unpleasant emotions when playing is reduced/stopped
- Need to spend an increased amount of time in gaming
- Failed attempts to control participation in playing games
- Losing interest in past hobbies and entertainment
- Continue to play games despite having knowledge of psychosocial problems
- Deceiving family members, therapists or others regarding the amount of gaming
- Playing games to escape or eliminate negative feelings
- Harm or lose relationships, work, or education or significant career opportunities because of gaming.

The related literature relieves that young people university students in particular are more vulnerable than other populations because of easy and free access to digital tools, more spare times and less parental/family control. The global prevalence rate ranges from 0.2% to 57% in general population and 0.3% to 90% in clinical populations (Darvesh et al., 2020). The differences in prevalence rates can be attributed to differences in study population, cultural factors, and assessment or diagnostic criteria. Some studies show that game addiction is associated with anxiety, depression, attention deficit hyperactivity disorder (ADHD) symptoms, problematic social media use as well as stress, sleep problems and autistic traits (Mestre-Bach, Fernandez-Aranda & Jimenez-Murcia, 2022). Therefore, depressed and lonely individuals are more likely to become addicted to games. Age and gender is not a significant moderator in most studies (Chiang, Zhang & Ho, 2022).

The majority of the research comes from the Asian and Western countries and little is known about Middle East. The following is the summary of the some research conducted in Turkey that has been reviewed at the beginning of this study. Horzum (2011) examined primary school students' computer game addiction levels according to various variables and found that males, those in the upper economic class and 4th grade students were more game addicted than their counterparts. Yalcin and Bertiz (2019) conducted a qualitative study with interview data in order to investigate the consequences of game addiction on university students. They concluded that time spent on playing games was related to the level of face-to-face communication with family and friends and game addiction had effects such as associating digital games with real life, preferring playing digital games to other activities, and disrupting tasks due to playing digital games. Balikci (2018) researched the relationships between online game addiction and aggressive behaviors in children and adolescents and indicated that online game addiction was associated with aggression; those who preferred online games exhibited more aggressive behaviors, and males were more addicted and aggressive to online games than females. Ayhan and Koselioren (2019) investigated online game addiction of students studying in high schools and found that 1.8% of the participants showed signs of online game addiction while 36.7% were at risk of addiction. It is noteworthy that one fifth of the participants in the study increase the risk of addiction by playing online games for at least two hours a day; the level of addiction increases as the education level of the mother decreases; the participants spend money on playing online games and males are more dependent than females.

Aydogdu (2018) explored whether various variables were effective on the digital game addiction levels of secondary school children who play digital games. As a result, he showed that age and mother's game play status made a significant difference on children's digital game addiction levels whereas gender, number of siblings, father's game playing status, mother and father's education level, and the type of digital game played had no significant effect. Cakici (2018) investigated the relationship between digital game addiction and anger expression styles in adolescents. Males compared to females, 9th and 10th grade students compared to 11th and 12th grade students were found to be more addicted to digital games. She also found a low-level positive correlation between digital game addiction levels and anger expression. Odabasi (2016) studied the relationship between university students' online game addiction levels and subjective happiness levels. She found that both were negatively correlated and males compared to females, freshman compared to junior students were more addicted to online games. Kucuk and Cakir (2020) examined the relationship between digital game addictions and aggression behaviors of secondary school students and whether this relationship differed according to demographic characteristics. They demonstrated positive association between the two variables and males and 8th grade students were more game addicted than their counterparts. Bingol and Eker (2022) showed that competence as a sub-dimension of boredom was a significant predictor of digital game addiction among adolescents. Moreover, digital game addiction levels of boys are higher than girls; adolescents who think that they are raised with an authoritarian attitude are higher than those who think that they are raised with a democratic attitude, and adolescents with low academic achievement are higher than those with medium and high academic achievement.

The purpose of the present study is to investigate game addiction level amongst the university students who play digital games and compare it across some demographics. In order to fulfill this purpose the following research questions were formulated:

- What is the level of participants' game addiction?
- Do their addictions differ with regards to gender, major of study, GPA, and school year?

Method

Since this research explores the current state of game addiction level of a specific population, it was designed as a cross-sectional survey. Using a convenience sampling to overcome time and financial limitations, the sample comprised 164 volunteer and easily accessible Turkish university students who are interested in digital games and play them regularly. To collect data, an online questionnaire was developed through Google Forms and shared with players on the related forums and social media platforms. The first part of the questionnaire included a personal information form and the second one included the Digital Game Addiction Scale (DGAS) adapted to Turkish language by Yalcin-Irmak and Erdogan (2015). The DGAS is unidimensional scale and involves seven 5-point Likert-type items (1=never, 5=always). A composite variable is calculated by summing item scores, which ranges from 5 to 35 with higher scores indicating severe addiction. The Cronbach alpha internal consistency coefficient for this study calculated as 0.79 indicating reliable measurement.

Results

The demographic variables were analyzed using frequency analysis. Regarding gender of the participants, 77% were male and 33% were female. Of the participants, 38% were freshman, 29% were sophomore, 20% were junior and 13% were senior university students. Their area of program of study was distributed as follow: science and engineering (46%), social science (43%), and fine arts and sports fields (11%). Participants reported playing a large number and variety of digital games. The most frequently played games were League of Legends (28%), Counter Strike (20%) and GTA San Andreas/GTA 5 (15%). Time spent daily on gaming was distributed as 1-4 hours (48%), 5-8 hours (28%), 9-12 hours (18%), and 13 hours above (6%).

Table 1 presents the descriptive statistics for the scores that participants obtain from the DGAS. As can been seen, game addiction scores range from 7 to 33 with a mean score of 19.53, just above the midpoint of its scaling range. The standard deviation value is 6.70, which shows moderately narrow dispersions of the data, suggesting that participants' scores are closely clustered around the mean.

Table 1. Descriptive Statistics for Game Addiction Score

Variable	Minimum	Maximum	Mean	SD	Skewness	Kurtosis
Game addiction score	7	33	19.53	6.70	0.04	-1.01

An independent-samples t-test was conducted to compare participating game addiction scores across gender (Table 2). There was no significant gender difference [$t_{(162)}$=.24, p>.05] in game addiction scores.

Table 2. Comparison of Game Addiction Scores by Gender

Gender	N	Mean	SD	t	p
Male	127	19.60	6.86	.24	.81
Female	37	19.30	6.19		

A one-way between-groups analysis of variance (ANOVA) was conducted to explore school year differences in participants' game addiction scores (Table 3). There was no significant difference [$F_{(3, 160)}$=.27, p>.05] in game addiction scores among participants with different years of school. Another ANOVA test was conducted to explore major differences in participants' game addiction scores (Table 4). There was no significant difference [$F_{(2, 161)}$=1.74, p>.05] in game addiction scores among participants with different majors.

Table 3. Comparison of Game Addiction Scores by School Year

School year	N	Mean	SD	F	p
Freshman	62	19.74	7.02	.27	.85
Sophomore	48	19.60	6.31		
Junior	33	18.64	6.82		
Senior	21	20.14	6.77		

Table 4. Comparison of Game Addiction Scores by Major

Major	N	Mean	SD	F	p
Science and engineering	75	18.59	6.62	1.74	.18
Social sciences	70	20.01	6.68		
Fine arts and sports	19	21.47	6.81		

One another ANOVA test was conducted to explore grade point average (GPA) differences in participants' game addiction scores (Table 5). There was no significant difference [$F_{(3, 160)}$=2.37, p>.05] in game addiction scores among participants with different GPA.

Table 5. Comparison of Game Addiction Scores by GPA

School year	N	Mean	SD	F	p
0.01 – 0.99	32	21.59	6.68	2.37	.07
1.00 – 1.99	62	20.06	6.50		
2.00 – 2.99	43	18.51	6.41		
3.00 – 4.00	27	17.48	7.13		

The last ANOVA test was conducted to explore daily time spent differences in participants' game addiction scores (Table 6). There was no significant difference [$F_{(3,\ 160)}$=1.03, p>.05] in game addiction scores among participants with different GPA.

Table 6. Comparison of Game Addiction Scores by Daily Time Spent

Daily time spent	N	Mean	SD	F	p
1 – 4 hours	79	19.09	6.79	1.03	.38
5 – 8 hours	45	19.16	6.61		
9 – 12 hours	30	21.47	6.53		
13 hours and above	10	18.90	6.89		

Conclusion

University students in this study mostly prefer multiplayer, action-based, thriller or war themed games. As far as the average of daily time spent on gaming is concerned, they take a quarter of the day playing. On average, they seem to be moderately addicted to digital games, indicating a higher prevalence compared to previous studies. This may be due to the COVID-19 pandemic. More people especially in Asian countries are showing behaviors associated with gaming disorder and online addiction amid the COVID-19 pandemic. Another reason could be the sample. Most studies in the literature used general populations regardless of whether they are playing or not. But this study explored only regular players. Research regarding game addiction is a rapidly evolving field and findings may change with new studies being conducted. Further studies may focus on comparing cohorts in different regions, countries or cultures. Universities can raise awareness of the condition amongst their students as well as offer cognitive behavioral therapy as a first-line therapy to improve addiction symptoms.

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A Case Study of Junior High School Teachers' Opinions and Experiences about the Use of Smart Boards

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Abstract: Turkey started an innovative education reform called FATIH Project in 2010 in order to increase the equity of opportunity in education, enhance the technological infrastructure of the schools and ultimately improve teaching and learning processes. Smart boards were distributed to each classroom within the scope this project. Although these tools have the potential for student motivation and learning, it is also important to know what teachers think about and how they incorporate them in instruction. Therefore, this research aims to investigate teachers' opinions and experiences about the use of smart boards in their lessons. It was designed as a case study within the qualitative research paradigm. The participants were 11 teachers working at a junior high school located in a western city of Turkey. Data were collected through semi-structured interviews and analyzed using descriptive qualitative data analysis methodology. Teachers' responses were categorized under three main themes as potentials of smart boards in learning and teaching, problems encountered in the use of smart boards, and suggestions for improving the use of smart boards in the schools.

Keywords: Smart boards, Teachers, Opinions, Experiences, Case study

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Introduction

As part of the effort for integrating current technologies in to educational settings, Turkey has initiated a nationwide reformist project called "The Movement to Increase Opportunities and Improve Technology" (FATIH Project) since 2010. Focusing on the technology integration and related innovative pedagogical approaches, the FATIH Project aims to increase the equity of opportunity in education, enhance the technological infrastructure of the schools and ultimately improve teaching and learning processes. It has five dimensions including providing hardware and software infrastructure, offering educational content, professional development of teachers, effective use technology in teaching and ensuring security and management in technology usage (MEB, 2011).

Within the scope of the FATIH Project, smart/interactive boards were installed in hundreds of thousands of classrooms across the country. As of April 2023, the number of smart boards installed in schools is over half a million and the installation process continues (FATIH Projesi, 2023). They were first distributed to high schools and then junior high schools and finally primary schools, kindergartens and newly built schools. The initial version smart board has emerged as the projection of the computer onto a suitable surface and evolved as a board-sized monitor integrated with a computer or directly connected to the computer (Akgun, 2014). The structure and functions of smart boards are changing depending on the advances in technology. Those being installed within the FATIH Project are touch sensitive and run off of local computer system resources without the need of mouse and keyboard. They allow students and teachers to write and manipulate things on the screen like activities, assessments, videos and digital tools.

The potentials of smart boards in education have been stated in the related literature. Smart boards provide students with the opportunity to receive information in different forms and methods (text, audio, video or combined) and thus contribute to the comprehension and synthesis of information (Akar, 2020; Demirbilek, 2022; Mert & Gunes, 2018). By encouraging interaction and cooperation in the classroom, they enable students to become active participants instead of passive receiver position (Ates, 2010). These tools allow the work on the screen to be saved as a digital file, brought back when needed, and revised through adding new content (Bulut & Kocoglu, 2012). In fact, the recording feature of smart boards allows even the students who do not come to the class to access the topics covered in the lessons. They provide audio recording for students who do not attend the class to make up for the lessons (Gundogdu, 2014).

Smart boards have functions such as marking, coloring, underlining, annotating on a text on the screen (Doger, 2021). The visualization offered by smart boards makes a great contribution to the learning process of students (Alan, 2020). Visualizing and concretizing the contents not only keep the students’ interest and attention alive and thus reduce boredom, disinterested behavior and inefficiency but also make their learning effective and permanent (Mert & Gunes, 2018). Moreover, smart boards can make an increase in teachers’ teaching time in class as they allow teachers to present the internet or other resources more effectively (Adiguzel, Gurbulak & Saricayir, 2011).

Undoubtedly, the installation of smart boards has the potential to enrich the education. However, it is also important to know what teachers think about and how they incorporate these tools in instruction in order to maximize their potential. Our research, therefore, aims to investigate junior high school teachers’ opinions and experiences about the use of smart boards in their lessons. We formulate the following research questions in order to fulfill this aim:

- What do they think about the consequences/potentials of smart board usage on students learning and development?

- What are the issues they think important about the integration of these tools?

Method

We designed our study as a case study within the qualitative research paradigm. Case study research is in-depth investigation of a particular person, group, event or organization in its natural real-world context (Crowe et al, 2011). It also helps to understand situations resulting from a new policy initiative or service development (Yin, 2009). Since the integration of smart boards in education is a part of the FATIH reformist project in Turkey, we decided that such an approach was suitable for our specific purpose of examining teachers' opinions and experiences about the use of smart boards in their lessons.

Using a convenience sampling, we selected our participants from junior high school teachers working in a western city of Turkey on a voluntary basis. The second author was doing his teaching internship in a junior high school in the city center. Therefore, the participants were 11 teachers working in his school and nearby schools. Of the participants, 7 were male and 4 were female. They have been working in junior high schools (5-8 grades) with teaching experience between 4-15 years. Their branches, the courses they are teaching, distribute as follow: Social Sciences (3), Mathematics (2), Turkish (2), Science (2), English (1) and Religion (1).

We conducted semi-structured interviews to collect the data. Our data analysis process was descriptive in nature because the interview data were not much and detailed enough to conducted deep content analysis. Therefore, we first determined a thematic framework emerged from the interview questions. Next, we carefully read interview transcripts to identify significant statements and code them by suitable concepts. Finally, we described findings under suitable themes and support them with direct quotations. Below is the framing questions used in the interviews:

- What are your experiences in the contribution of smart boards to learning and teaching activities in your lessons?
- Have you encountered any problems with the use of smart boards in your own lesson? If so, what are they?
- What are your suggestions for using smart boards for your own lesson?
- Are there any features that you would like to have or to be improved on the smart boards?

Results

We generated three major themes under which we presented our findings. The first one is related to potentials of smart boards in learning and teaching. More than half of the participants (65%) think that smart board usage improves the lectures with supportive visualizations. Almost half of them (46%) believe that smart boards provide a good preparation for the lessons through videos and solve the lack of instructional material. Other categories emerged within this theme include that smart boards help to understand abstract topics with simulations (36%), attract students' attention (18%) and make lessons fun (18%). Some representative comments include:

> *"It provides opportunities that the school cannot provide due to impossibilities…simulating experiments that cannot be done in a lab environment in a virtual lab facilitates meaningful and durable learning."*

> *"I share some visual content or multimedia applications and this helps to pass the lessons in a fun atmosphere."*

> *"Undoubtedly, it contributes positively. For example, I use visuals for the math subjects to attracts students' attention and interest."*

The second theme is germane to problems encountered during the use of smart boards. Most of the participants (73%) complaint about the insufficient content suitable for the curriculum that they can use in their lessons. A little more than one quarter (27%) experience problems with Internet connection on smart boards as well as writing difficulties on the touch screen of the boards. Few participants (18%) have concerns about the frequent touch screen calibration failures. Below are some teacher statements representing this theme:

> *"Interactive boards are inadequate and of poor quality in terms of course content. Sometimes, I am even struggling finding e-content that I can use in my lesson."*

> *"The videos are opened late from time to time due to the internet or hardware. There are limited applications on reinforcing the subjects."*

> *"Sometimes there is a problem in sensing and touch screen of the board. Also, it is not easy to write on the smart board."*

The final theme is regarding suggestions for improving the use and thus benefits of smart boards. More than half of the participating teachers (65%) want the availability of applications and materials for every branch to be increased. A little more than quarter (27%) suggest the enhancement of the sensing capability of the touch screens. They also want to be provided with professional development for effective use of smart boards for educational purposes. The following are the sample comments on this theme:

> *"The content for the branches should be increased… Experiments can be increased…Diversity of*

assignments and questions can be provided.”

“It will be beneficial if experienced trainers may given lessons on effective use smart board in instruction…perhaps they can show us best practices.”

“Easy to use calibration applications for touch screen sensitivity should be developed.”

Conclusion

The investigation of teachers’ opinions about the use of smart boards can guide the effective integration of these tools into classroom teaching. This small-scale case study concludes that participating teachers believe and experience that smart boards have the potential to enhance students’ learning process and they are quite happy to have these tools in their classrooms. However, they also emphasize that this potential is not only due to the hardware features but also the availability of software application and educational content materials in line with the curriculum. Despite the benefits of smart boards, it is important to use these tools appropriately and effectively. Teachers should be competent in using these tools, creating content, ensuring their effectiveness in the course. Therefore, they ask for more electronic content germane to their curriculum and in-service training about the use of smart boards.

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