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Ways of Thinking in Mathematical Problem Solving Based on Mathematical Critical Thinking Skill

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Abstract: The purpose of this study is to describe the analysis results of Ways of Thinking (WoT) in solving ratio and comparison problems based on critical thinking skills. The WoT in question is a way of thinking in the category of problem solving approaches, and proof schemes. The ways of thinking analyzed were the problem-solving approach and the proof scheme. The subjects in this study were junior high school students in grade VII in one of the schools in Bandung city. This research uses qualitative research with the data collection process through tests and interviews. The results found that students' Ways of Thinking are still mostly on Result Patter Generalization (RPG) and still few who use Procces Patter Ganeralization (PPG). The way students think is correct in solving the problem then the way to understand the concept is also correct. There are several indicators of critical thinking skills in the way of thinking, namely interpretation, analysis and evaluation.

Keywords: Ways of Thinking, Mathematical Problem Solving, Critical Thinking Skill

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Introduction

The education implemented in schools seems to limit students to a set curriculum. Preparing students to face an increasingly complex and uncertain future requires rethinking their learning experiences, in particular, the need for more relevant and innovative challenging problems, and importantly education can facilitate adaptive learning and problem solving (McKenna, 2014). Failure to provide opportunities such as these can later have a detrimental impact on students' learning and their future achievement (Engel et al., 2016). For this reason, students need to be given a basic foundation, namely mathematics.

Mathematics in schools generally places more emphasis on the use of calculation formulas, and does not emphasize students' thinking process abilities (Suryadi and Suratno, 2014). Thus, this can make students more likely to memorize formulas and problem solving steps without understanding them. Based on research conducted by Nurhasanah (2019) on ways of thinking and ways of understanding students in solving problems on vektor in terms of Harel's theory revealed that the strategies used by students are generally not diverse, in fact there is only one solution and does not validate the strategy used. The strategies used tend to be about understanding of concepts by each student. In the proof scheme process, students belong the Result Pattern Generalization (RPG) way of thinking. Apart from that, students' skill in mathematics is also still low. This can be seen in the results of PISA (Program for International Student Assessment) in 2018. Student mathematics scores in PISA are ranked 72nd out of 78 countries (OECD, 2019). This low score is partly influenced by the difficulty of representing answers and designing strategies for solving problems (Prahmana, 2022).

Mathematics is foundational to other disciplines and central to STEM education (e.g., Larson, 2017; Roberts et al., 2022; Shaughnessy, 2013), mathematics is often overlooked in integrated STEM activities (English, 2016; Maass et al., 2019; Mayes , 2019; Shaughnessy, 2013). However, limited attention has been paid to how problem experiences can be developed that go beyond basic content knowledge (Anderson, 2014; Li & Schoenfeld et al., 2019), span STEM disciplines, and develop meaningful ways to address the problem. Critical thinking is part of STEM. Many other studies reveal the thinking process (Hunting, 1997; Syamsuri, 2016, 2017). The thinking abilities that are often analyzed in the field of education today are reflective, critical, creative, reasoning, metacognitive and other mathematical abilities. By using Harel's Theory comprehensively, we are able to analyze students' thinking processes in detail. This is very useful as a way of thinking that can be used by teachers when learning mathematics in class. Below is figure I of how to think in solving problems based on critical thinking skills.

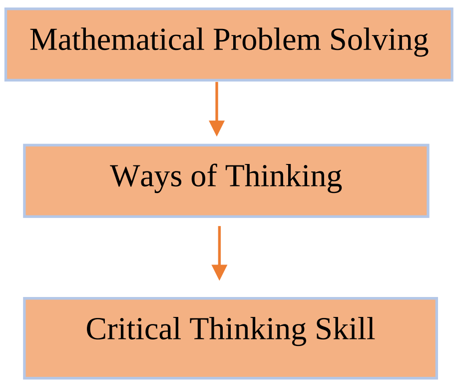


Figure 1. Way of Thinking in Problem Solving based on Critical Thinking Skills

Although it has long been recognized as an important process in various fields, research on critical thinking in education, is still limited (Aktoprak & Hursen, 2022). Critical thinking has long been associated with mathematical reasoning and problem solving, but the link between the two is still under-theorized (Jablonka, 2020). As a twenty-first century skill, critical thinking is increasingly recognized as important in mathematics (Kollosche & Meyerhöfer, 2021) but is unfortunately lacking in many school curricula (Braund, 2021). Critical thinking builds on inquiry skills (Nichols et al., 2019) and entails evaluating and assessing problem situations including statements, claims, and propositions made, analyzing arguments, inferring, and reflecting on solution approaches and conclusions drawn. While critical thinking can make significant contributions to other ways of thinking, its application is often overlooked. For example, critical thinking is on the rise.

A comprehensive review by O'Reilly et al. (2022) identified pedagogical approaches to improving early critical thinking skills including inquiry-based learning using classroom dialog or questioning techniques. These techniques encourage children to construct, share and justify their ideas about a task or investigation. Based on this, this research focuses on how to think in mathematical problem solving based on critical thinking skills.

Method

This research is qualitative descriptive research. The subjects of this study were 4 students of class VIII 3 in one of Senior hight School in Bandung City who were randomly selected. To collect research data, the data collection techniques were carried out as follows:

1. Individual written test consisting of 3 questions about ratio and comparison. The instrument was designed based on ways of thinking in problem solving.
2. Interviews were conducted with students to analyse students' ways of thinking in solving problems based on the ways of thinking instruments in problem solving.

Results

The first question given to the students is that it is known that in a Midterm Assessment (PTS) 60% of students passed in English, 52% of students passed in math, 32% of students failed in both English and math. If there are 220 students who passed in both subjects, determine the number of all students who took the PTS!

The second question given to students was given x is $\frac{5}{7}$ of 490, y is $\frac{2}{3}$ of 327, find $x + y$!

The third question given to students is as follows table presents the distance traveled by 3 types of trucks that are the same but of different brands.

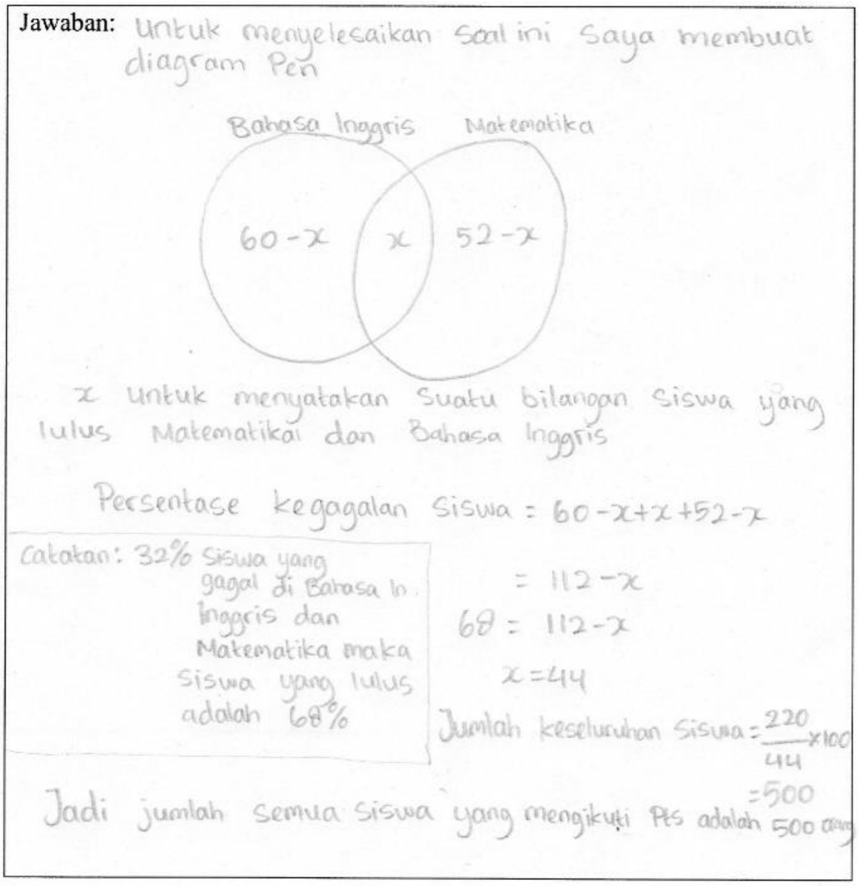
Table 1. Fuel and Mileage of Each Truck

	Truck A	Truck B	Truck C
Distance traveled (KM)	140	340	425
Fuel (Liter)	10	20	25

Which truck is the most fuel efficient?

Discussion

Analyzing the First Question


Jawaban: Untuk menyelesaikan Soal ini Saya membuat diagram Pen

Bahasa Inggris Matematika

60 - x | x | 52 - x

x untuk menyatakan Suatu bilangan siswa yang lulus Matematikai dan Bahasa Inggris

Persentase kegagalan Siswa = 60 - x + x + 52 - x

Catatan: 32% Siswa yang gagal di Bahasa In. Inggris dan Matematika maka siswa yang lulus adalah 68%

= 112 - x

68 = 112 - x

x = 44

Jumlah keseluruhan Siswa = 220/44 x 100

= 500

Jadi jumlah semua siswa yang mengikuti PTS adalah 500 orang

Figure 1. Student’s PPG Answer for Number 1

The way of thinking in the category of students' problem solving approach The way of thinking of students has a variety of strategy approaches and chooses the most effective and efficient strategy and leads to the correct solution. This means that students have a good problem solving approach. Furthermore, the proof schemes category is included in the Process pattern generalization (PPG). PPG is a way of thinking in solving problems by paying attention to the concepts and processes carried out. Students are able to complete a logical, systematic process in accordance with the concept. The following is the result of the interview.

R: Why did you make a Venn diagram in your answer?

S: Because to find out the percentage of failure, I made a Venn diagram by assuming x is a number that passed math and English.

R: referring to the problem I gave you before, are there any mistakes?

S : No.

R : Why is that?

S: Because to find out the total number of students I made a ven diagram and summed up the percentage of failures, then I made the percentage of failures equal to the total number, namely 112-x, then I could find the total number of students.

R : Why did you choose this concept?

S : Because this concept is what I know

R : Do you understand this concept?

S : Yes

R : Based on the answer you gave, what can you conclude?

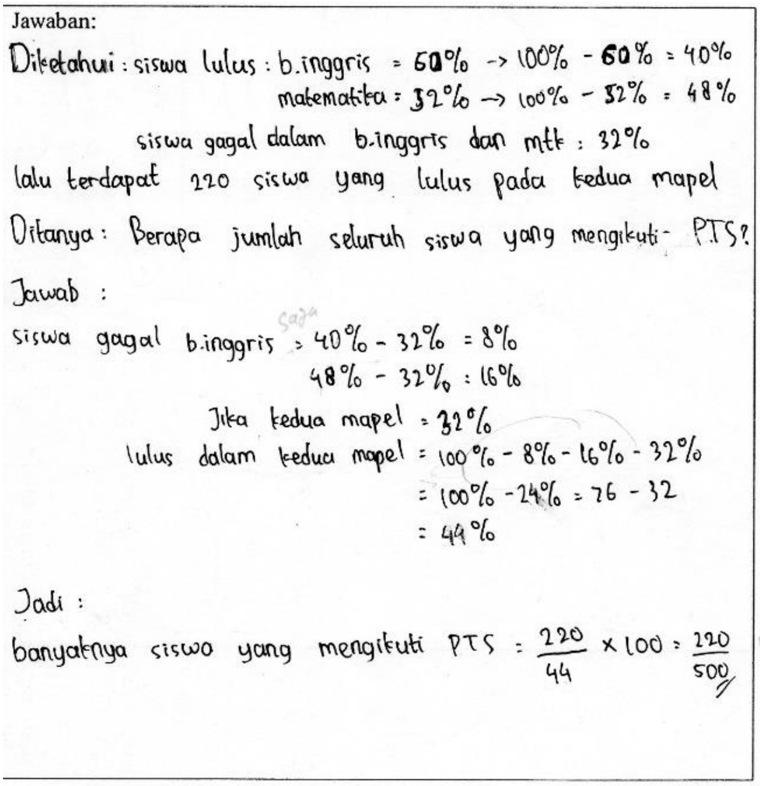
S : To solve this problem, we can use ven diagram.

R : Is there anything interesting that you found?

S : Yes, that is adding up linear equations of one variable.

R : Thank you for your cooperation.

This shows that students have critical thinking skills based on inference indicators, students are able to show evidence of the ideas they have.


Jawaban:

Diketahui : siswa lulus : b.inggris = 60% -> 100% - 60% = 40%

matematika = 32% -> 100% - 32% = 48%

siswa gagal dalam b.inggris dan mtk : 32%

lalu terdapat 220 siswa yang lulus pada kedua mapel

Ditanya : Berapa jumlah seluruh siswa yang mengikuti PTS?

Jawab :

siswa gagal b.inggris saja = 40% - 32% = 8%

48% - 32% = 16%

Jika kedua mapel = 32%

lulus dalam kedua mapel = 100% - 8% - 16% - 32%

= 100% - 24% = 76 - 32

= 44%

Jadi :

banyaknya siswa yang mengikuti PTS = 220/44 x 100 = 220/500

Figure 2. Student’s RPG Answer for Number 1

The way of thinking in the category of problem solving approaches students make problem solving plans that can be applied but may not get the appropriate or wrong results. The way students think in the proof schemes category is included in the Result pattern generalization (RPG), which is a way of thinking of someone in solving problems that focuses on results without knowing the meaning or process or limited to substituting answers. students are able to solve problems by linking known concepts, but students experience problems regarding errors, where at the end of the solution students make mistakes. Thus, the results obtained by students are less precise. The following is the result of the interview.

R: why did you write "It is known that students passing English equals 60%, then there is an arrow 100%-60%=40%?

S: because to find out the students who passed in English 100%-60%=40%, because 60% are students who passed in English so 100%-60%.

R: Why don't you look again, is it really the students who passed or the students who failed?

S: It turns out that after I pay attention, these are students who failed, not those who passed.

R: Why did you write that the failing students in English are 40%-32%=8%?

S: Because students who failed in English alone means 40% of students who failed in English alone. While 32% is obtained from students who failed in math and English so it must also be calculated and the result is 8%.

R: why is the final result 220/500?

S: I wasn't careful enough so the result is 500.

R : Why did you choose this concept?

S : Because this concept is easy for me to understand

R : Do you understand this concept?

S : Yes

The way of thinking of students based on critical thinking skills is classified in the interpretation indicator with moderate ability, because students only formulate a problem or identify it, but have not been able to propose conclusions logically.

Analyzing the Second Question

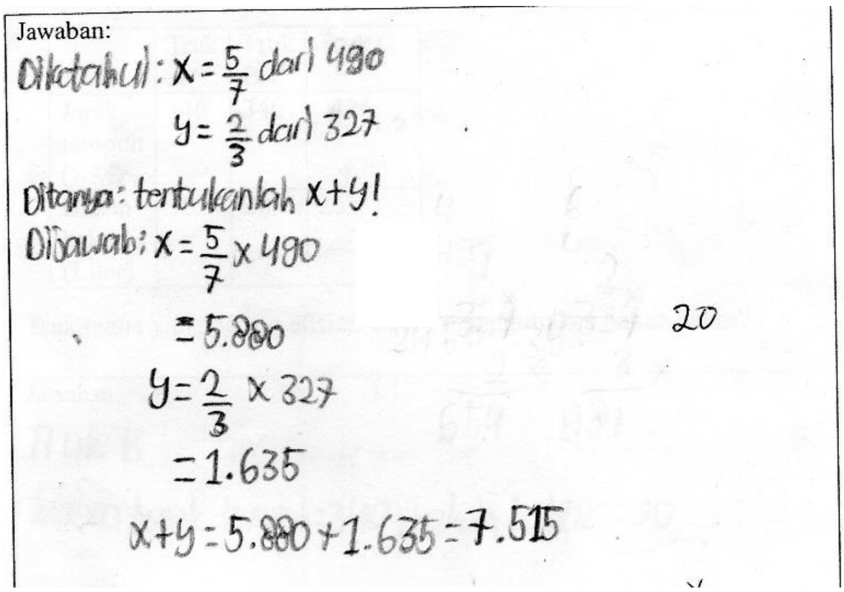


Figure 3. Student's RPG Answer for Number 2

The way of thinking in the category of problem solving approach students make a problem solving plan that can be applied but it is possible not to get the appropriate results or wrong. Students' way of thinking in the proof schemes category is included in the Result pattern generalization (RPG). students are able to solve problems by linking known concepts, but students make several mistakes so that they do not get the results correctly. Students' way of thinking is not yet based on critical thinking skill.

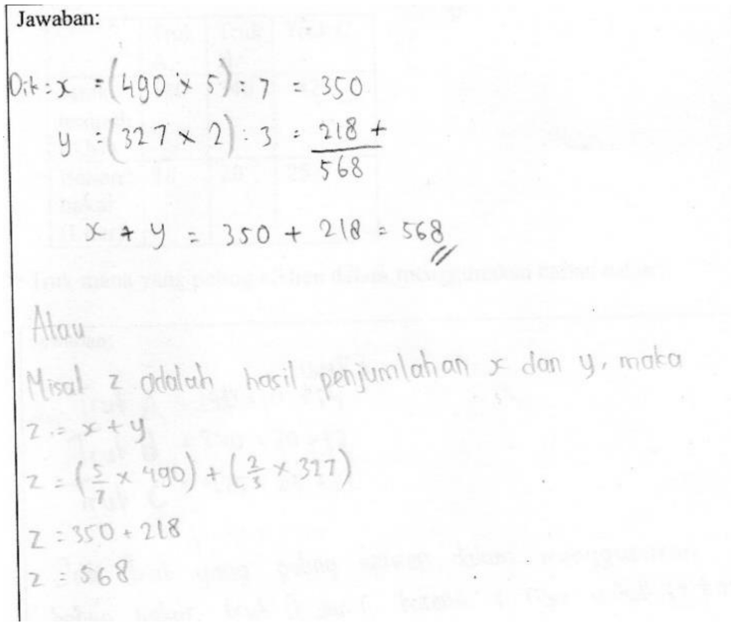

Jawaban:
Dit: x = (490 × 5) : 7 = 350
y : (327 × 2) : 3 = 218 +
568
x + y = 350 + 218 = 568 //
Atau
Misal z adalah hasil penjumlahan x dan y, maka
z = x + y
z = (5/7 × 490) + (2/3 × 327)
z = 350 + 218
z = 568

Figure 4. Student’s PPG Answer for Number 2

The way of thinking in the category of student problem solving approaches has a diverse strategy approach and chooses the most effective and efficient strategy and leads to the correct solution. the way of thinking of students in the proof schemes category is included in RPG and PPG. Students solve problems logically, systematically, in accordance with concepts and solve problems by paying attention to concepts. The way of thinking of students based on critical thinking skills is included in the indicator of analyzing.

Analyzing the Third Question

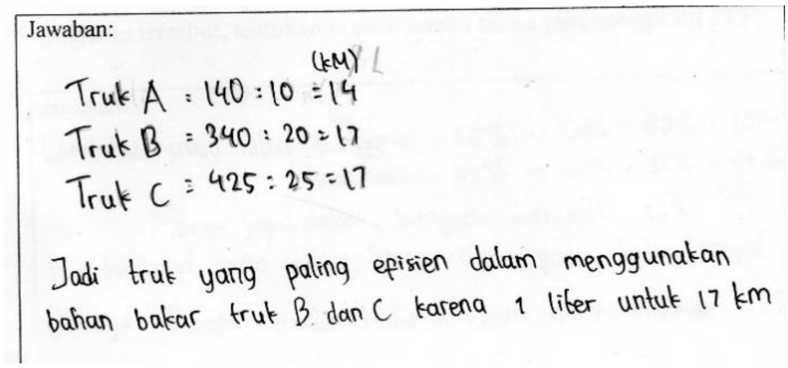
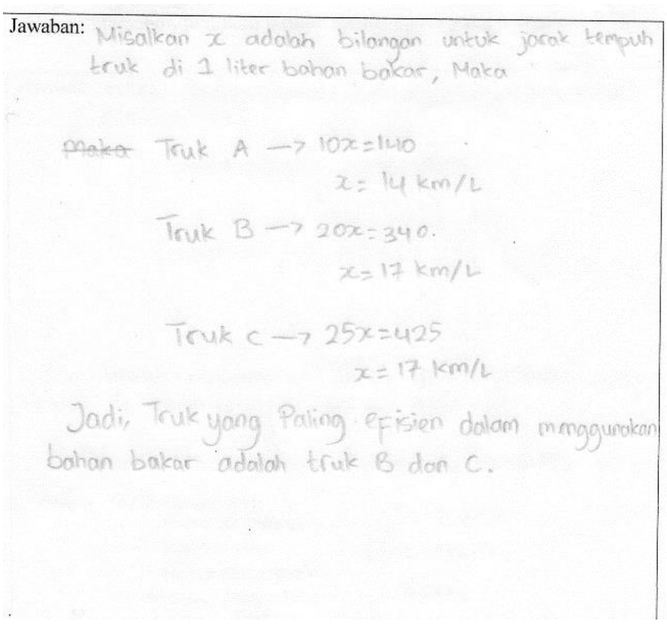

Jawaban:
(KM) L
Truk A : 140 : 10 = 14
Truk B = 340 : 20 = 17
Truk C = 425 : 25 = 17
Jadi truk yang paling episien dalam menggunakan bahan bakar truk B dan C karena 1 liter untuk 17 km

Figure 5. Student’s PPG Answer for Number 3

The way of thinking in the category of student problem solving approaches makes the correct plan and leads to the correct solution. the way of thinking of students in the proof schemes category is included in RPG. students are able to solve problems by linking known concepts, but there are some mistakes made. The way of thinking of students based on critical thinking skills is included in the interpretation indicator with a moderate level, however, students understand and express the questions given but students have not been able to make clarifications about the words or phrases applied.


Jawaban: Misalkan x adalah bilangan untuk jarak tempuh truk di 1 liter bahan bakar, Maka

~~Maka~~ Truk A → $10x=140$
$x=14$ km/L

Truk B → $20x=340$.
$x=17$ km/L

Truk C → $25x=425$
$x=17$ km/L

Jadi, Truk yang Paling efisien dalam menggunakan bahan bakar adalah truk B dan C.

Figure 6. Student's PPG Answer for Number 3

The way of thinking in the category of students' problem-solving approaches has a diverse strategic approach and chooses the most effective and efficient strategy and leads to the correct solution. Students solve problems logically, systematically, in accordance with concepts and solve problems by paying attention to concepts. The following is the result of the interview.

R: Why do you suppose x is a number to represent the distance the truck travels in one liter of fuel?

S : Because I want to answer this question using a linear equation with one variable, I let x be the number to represent the distance the truck travels in one liter of fuel.

R: Why is truck a 10x =140?

S: because 10 liters of fuel is equal to 140 KM so to get 1 liter of fuel I made 10 x = 140 so that one liter is 14 KM so we get 14 KM/L

R: why are trucks B and C the most efficient?

S: Because by comparing 14 KM/L, 17 KM/L and 17 KM/L, the most efficient is 17 KM/L, which is trucks B and C.

R : Thank you for your cooperation.

The way of thinking of students based on critical thinking skills is included in the indicators of analyzing, identifying and evaluating relevant arguments.

Conclusion

The ways of thinking analyzed were problem-solving approaches and proof schemes. Some students can create a problem-solving strategy and lead to the right solution. The problem solving approach is based on the knowledge possessed. In the proof scheme, students are more inclined to the RPG way of thinking. The way students think is correct in solving the problem, so the way to understand the concept is also correct. There are several indicators of critical thinking skills in the way of thinking, namely interpretation, analysis and evaluation.

Recommendations

Based on these results, the researcher suggested that students be trained in PPG to develop their way of thinking so that students pay attention to the concepts and processes carried out. The learning process in the classroom should be focused on concepts and processes, not on formulas so that students can still use their prior knowledge even if they forget the formula.

Acknowledgements

The researcher would like to thank the students from one of the junior high schools in Bandung City who have participated in solving problem ways of thinking and thank you to The Indonesia Endowment Funds for Education (LPDP) for supporting the funding of this research through Postgraduate Scholarship Program.

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Detection and Diagnosis of Crusher Failures by Vibration Analysis (Case of the Elmalabiod Cement Plant)

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Abstract: Conditional maintenance by vibration analysis, domain of activity which constitutes an increasingly important part of the provisions allowing to make the instrument of industrial production profitable. Vibration analysis is a methodology experimental aid for the detection and vibration monitoring of faults in rotating machines. Experience has shown that vibration analysis is the most reliable tool that gives the state of deterioration of a rotating machine early and in the best way. It allows efforts to be identified as soon as they appear, before they have caused irreversible damage. Real measurements were analyzed by the vibration indicator, leading to satisfactory results.

Keywords: Conditional maintenance, Defects, Vibration, Analysis, Crusher

Citation: Taleb, M. & Ghoudelbourk, S. (2023). Detection and Diagnosis of Crusher Failures by Vibration Analysis (Case of the Elmalabiod Cement Plant). In A. A. Khan, E. Cakir, & M. Unal (Eds.), *Proceedings of ICSEST 2023-- International Conference on Studies in Engineering, Science, and Technology* (pp. 12-21), Antalya, Turkiye. ISTES Organization.

Introduction

Predictive maintenance for industry is a method to prevent equipment failure by analyzing production data, identifying machine operating modes and predicting problems before they occur. The main benefit of predictive maintenance is to minimize unscheduled and curative maintenance. Indeed increased efficiency by reducing unnecessary maintenance prolongs the life of equipment (Hotait, H. (2020). Rotating machinery is commonly used in modern engineering to generate power and production. The continuous operation of rotating machinery produces vibrations by its nature. Vibration phenomena affect machine performance and lead to component failure.

Monitoring the condition of rotating machine components is an important aspect to consider in the various management policies of any production system, in order to minimize the risk of failure, by identifying the state of health of the machine at through early detection of defects (Jardine, A. K et al, 2006). The objective of this study is to implement vibration analyzes for industrial maintenance purposes, in particular to diagnose and identify faults that may impact the various components of the system using vibration analysis.

Case study

In our study we are interested in the rotor A1MO1 limestone crusher of the raw zone of the cement production line of Elma Labiod located 35 km from the city of Tébessa. (see fig 1).

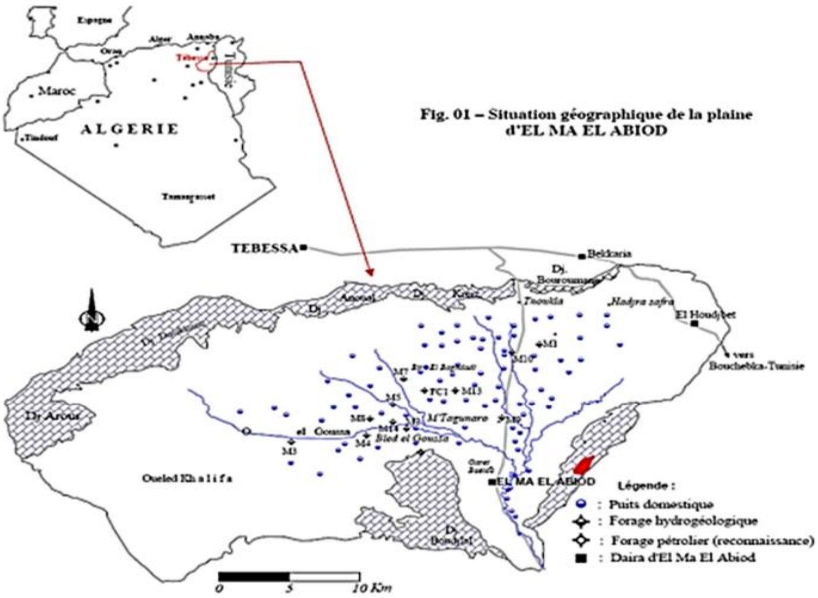

Figure 1. Geographical location of the Elmalabiod cement plant in Tébessa

The monitoring of the machine concerns the control components of the crusher, namely: Motor, gearbox and bearings (see fig 2)

Figure 2. Crusher A1MO1 control equipment

Methods

In this study, we are interested in monitoring rotating machinery while using vibra-tion analysis. This maintenance mode in machinery vibration analysis can better man-age failures, detecting defects at an early stage, before they become critical (Bertrand, R. 2000) achine monitoring is not just limited to detecting the presence of a defect, but it is also necessary to be able to carry out an in-depth diagnosis to locate it precisely and quantify its severity. Vibration analysis is a technique that makes it possible to carry out this diagnosis (Chevalier, R. 2001) For more precision, diagnosis by vibration analysis requires studying the values of the overall vibration level, the frequency content of the signals using sophisticated signal processing tools (spectrum, cepstrum, envelope analysis, etc.) (Djebili, O. 2013) Note that the main technical data are required for classification of the equipment, and determining the alarm thresholds for the establishment of the vibration signature crusher (Belhour S., 2008).

The vibration analysis equipment used in this study is:

- An analyzer collector: Portable called “movilog2” which presents a very ad-vanced synthesis of research, especially in computer science and advanced electron-ics. This type of hardware has great performance thanks to its connection to a com-puter equipped with software called “Diva”(Figure 3)

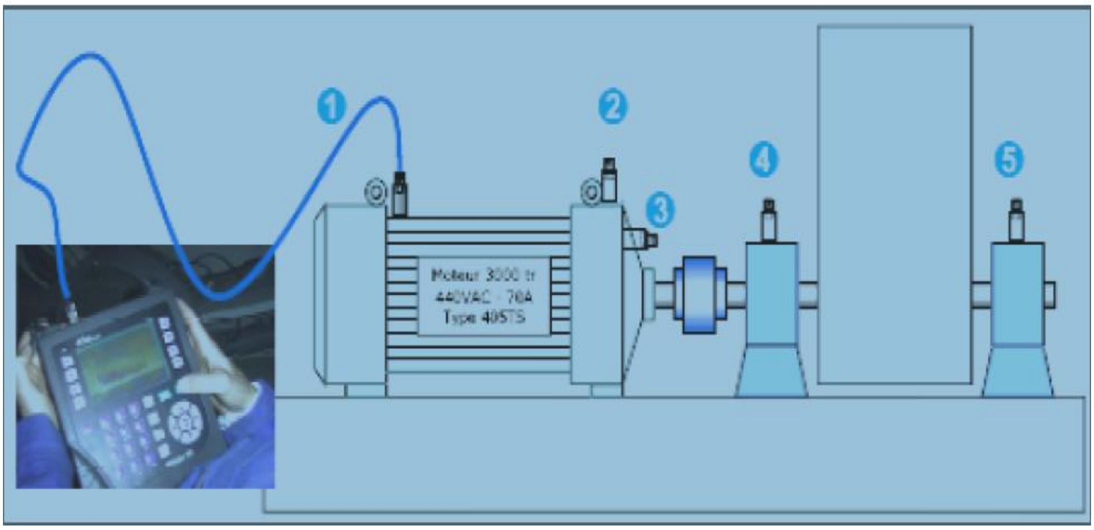

Figure 3. Continuous monitoring [6]

- An Accelerometer: They are sensors used to ensure the vibration readings of a various measuring points.
- A Vibration Analysis Software DIVA**:** This software is designed especially for conditional and predictive maintenance, for the processing of the signals emitted by different types of vibration The application of the monitoring technique by vibration analysis allowed us, after analysis, to deduce the origin and to estimate the risks of failure of the equipment which represents one of the links

constituting the cement production line, from the extraction of the limestone to the shipping of the cement. We configured eight measuring points to detect weaknesses generating when there is a machine malfunction (Figure 4).

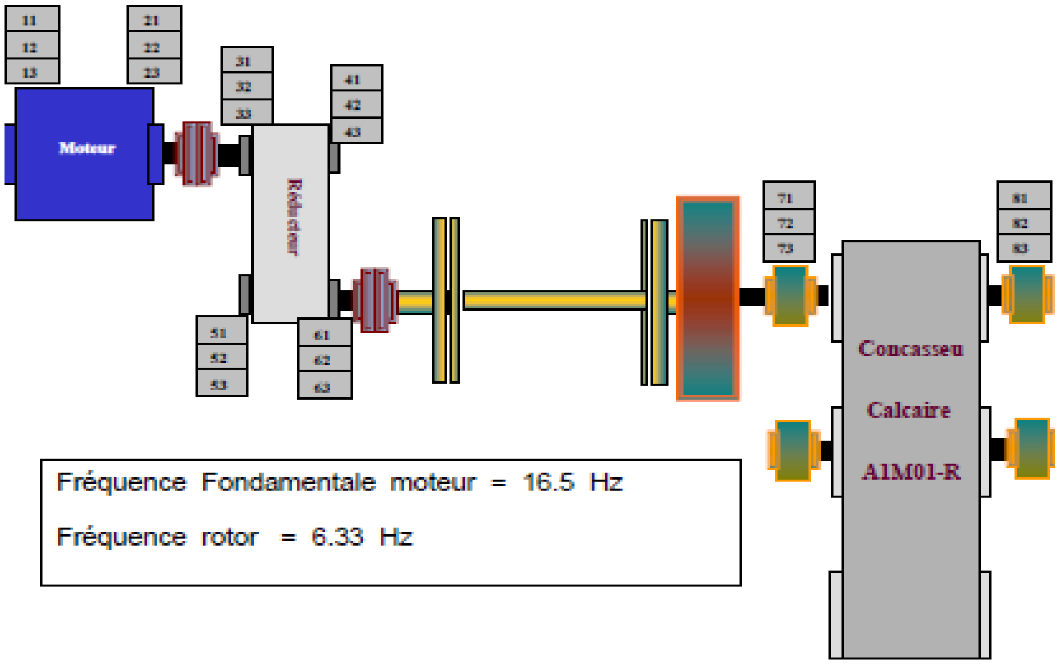

Figure 4. Synoptic diagram of the A1MO1 rotor limestone crusher

Results

Based on the vibration measurements made on the motor, the reducer; we have drawn the trend curves of the global level in speed and acceleration as follows:

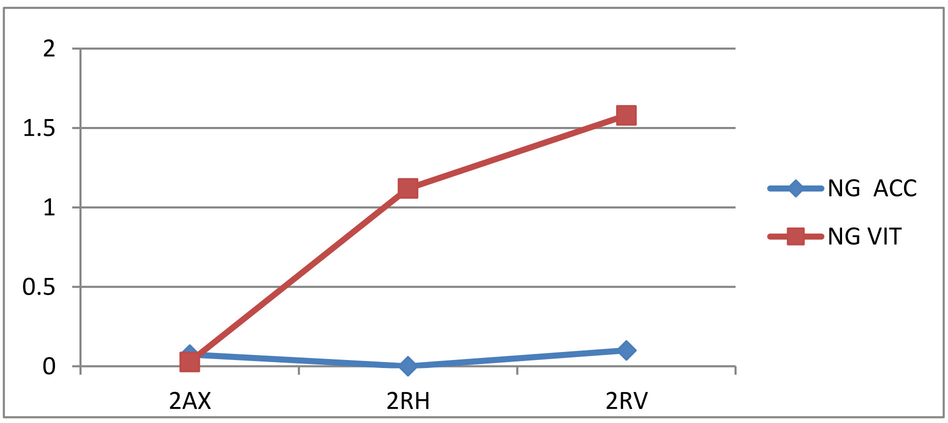

Figure 5. Trend curve of NG acceleration and motor speed

For more precision we pass to the spectral analysis

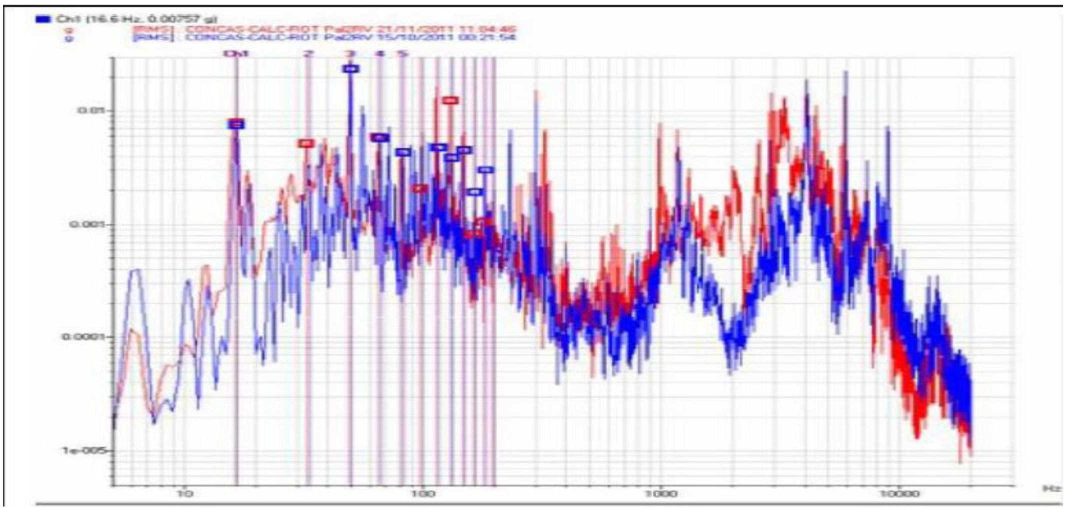

Figure 6. Engine spectral analysis

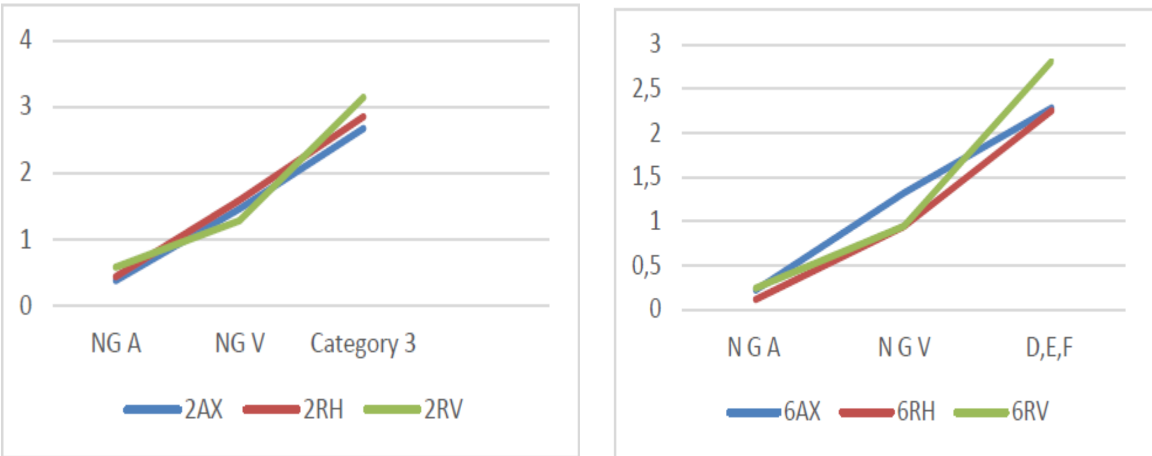

Figure 7. Trend curves of the NG speed at the gearbox input and output.

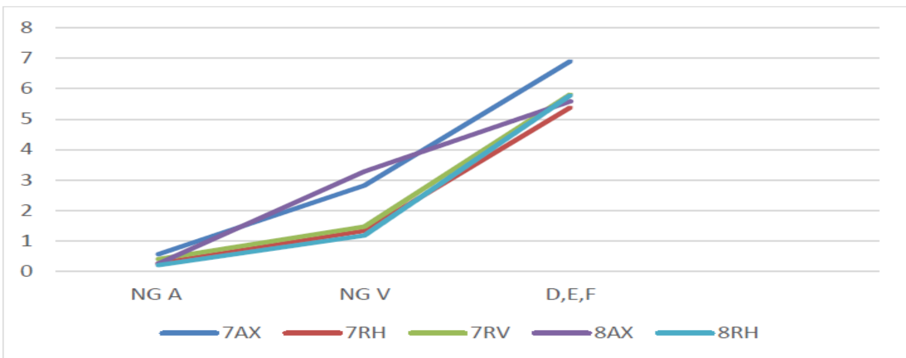

Figure 8. Tendency curve of the NG speed in axial of the cylinder bearings.

A second measurement highlighted the slight change in overall vertical speed levels, the threshold of which remains acceptable. To better understand the phenomenon and to have more information on the dysfunction, we moved on to spectral analysis (Figure 9).

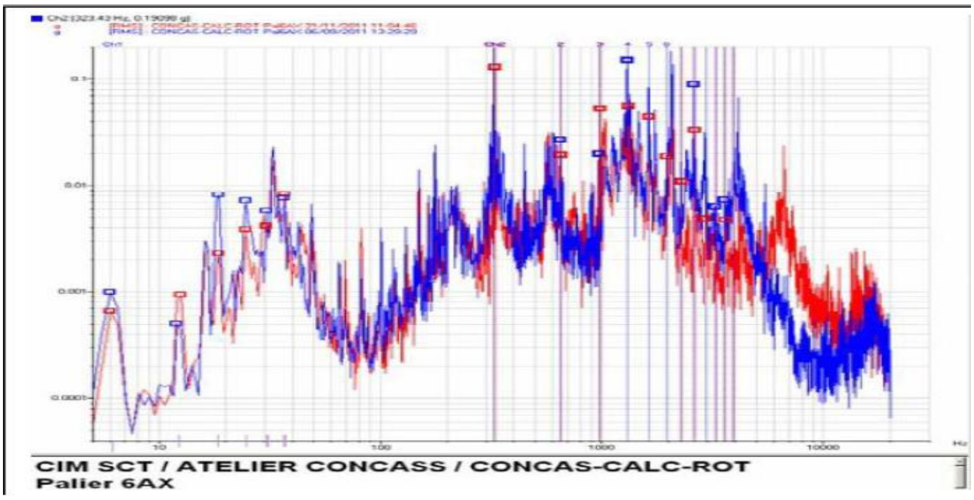

Figure 9. Spectral analysis of reducer October 2019

Global level analysis of crusher bearings

Evolution of the overall vibration levels recorded on the bearings of the crusher rotor, especially axially compared to the previous measurement on the inertia wheel side from 3.98mm/s to 4.79mm/s.

After changing the inertia wheel + the bearing sleeve, the overall level analysis showed the evolution of the overall vibration levels recorded on the bearings of the crusher rotor, especially axially compared to the previous measurement on the inertia wheel side from 3.98mm/s to 4.79mm/s.

Spectral analysis of crusher bearings

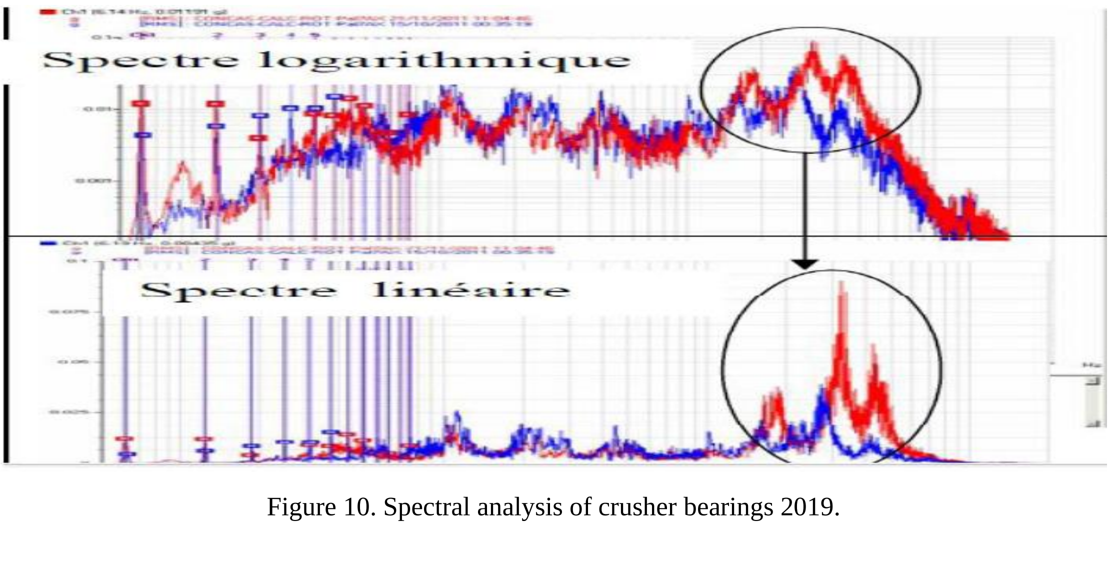

Figure 10. Spectral analysis of crusher bearings 2019.

A second measurement made it possible to obtain the following spectrum

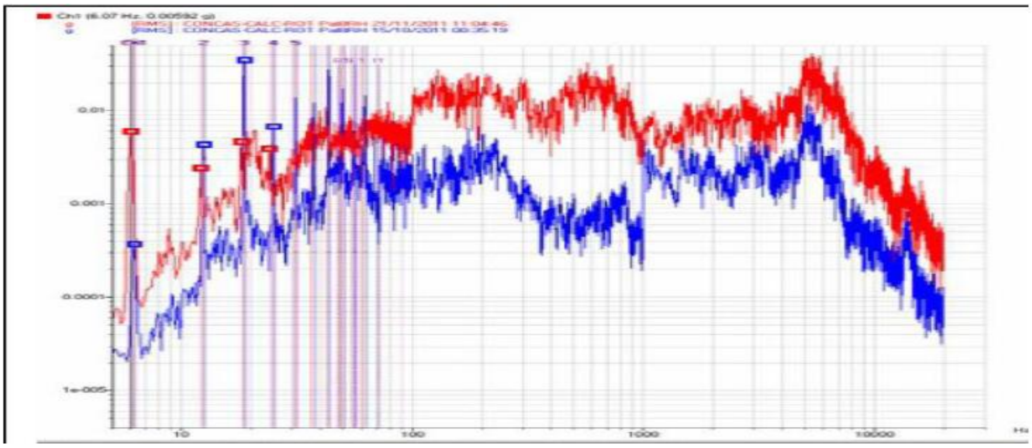

Figure 11. Spectral analysis November 2019

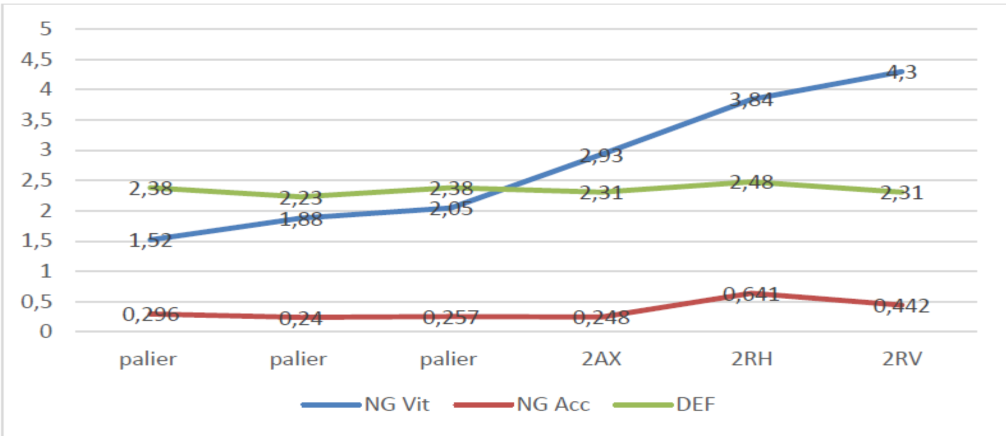

Figure 12. Trend curve in overall speed level 2022

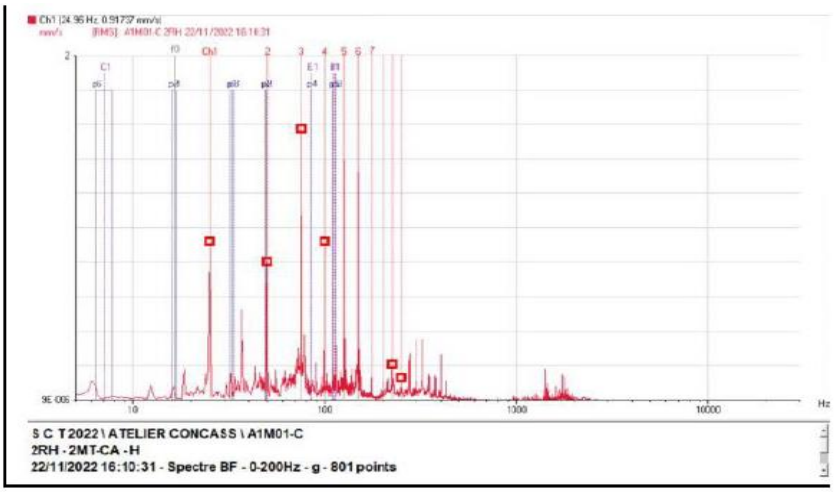

Figure 13. Motor Spectral Analysis 2022.

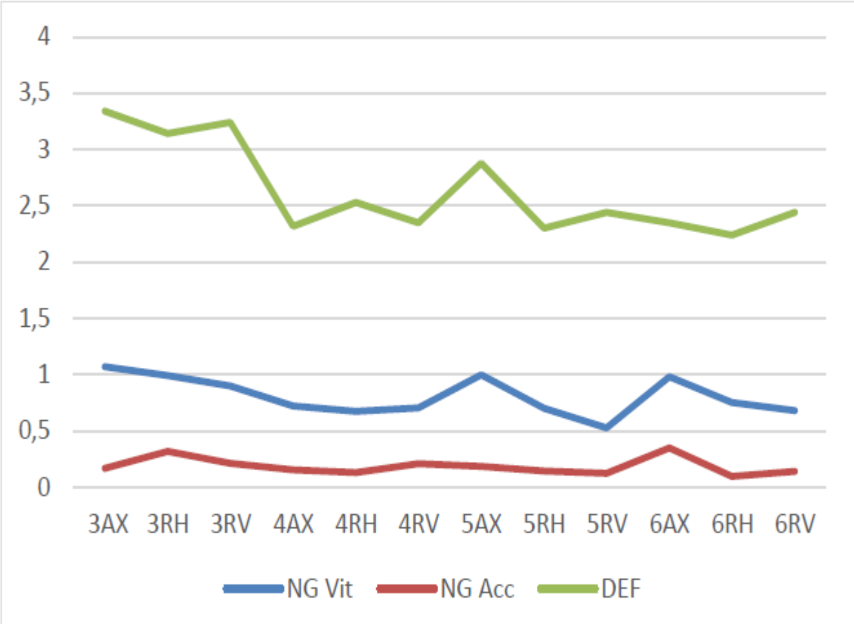

Figure 14. Trend curve in overall gear reducer level 2022.

Reducer spectral analysis

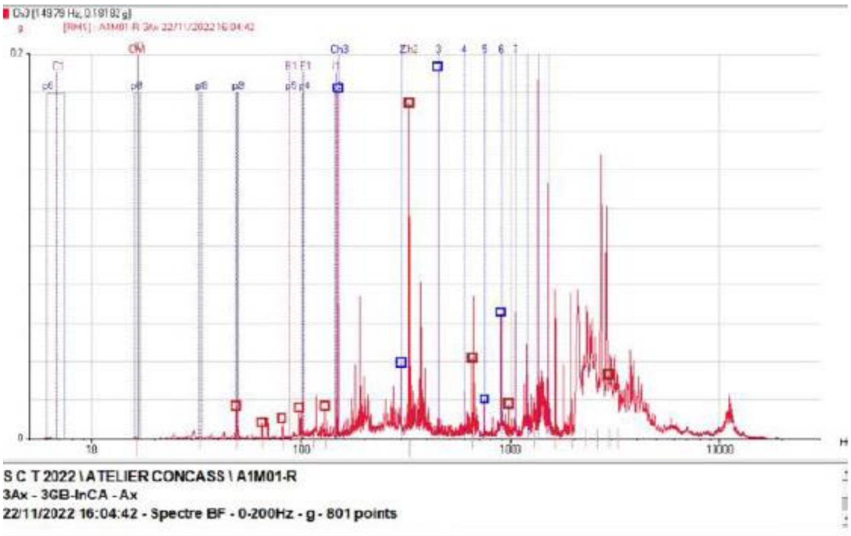

Figure 15. Analyse spectrale réducteur 2022.

Discussion

Selon la (figure 5) on constate une faible évolution des niveaux vibratoires globaux vitesses en vertical des points de mesure du moteur, dont le seuil reste acceptable.

L'analyse spectrale (figure 6) nous a permis de constater que l'amplitude est acceptable à la fréquence de rotation du moteur 0.008g à 16.24Hz, une évolution avec de l'énergie suite à l'augmentation de la charge. Une évolution du NG vitesse en vertical à l'entrée du réducteur a été mise en évidence dont le seuil reste acceptable 1.54mm/s (augmentation de la charge de 340T/H à 500T/H) avec l'atténuation des niveaux vibratoires globaux vitesses à la sortie du réducteur dont le seuil est acceptable L'analyse du deuxième composant du système de commande, qui est le réducteur à l'entrée et à la sortie en analyse globale sont représentées dans la (figure7). Montre une faible atténuation des niveaux vibratoires globaux à l'entrée et à la sortie du réducteur dont le seuil reste acceptable. Etat des roulements acceptables Pour la courbe de tendance du niveau global vitesse en axial, elle met en valeur une atténuation du NG vitesse en axial sur le palier libre dont le seuil reste tolérable (Atténuation de la charge).

L'analyse spectrale du réducteur de l'année 2019 (figure 9) a montré des amplitudes acceptables à la fréquence d'engrènement réducteur 0.13g à 325.91Hz.

Le problème réside dans la roue d'inertie à cause de l'évolution de l'énergie suite à l'augmentation de la charge, ce qui a nessecité le changement de la roue d'inertie. Après changement de la roue d'inertie+ manchon du roulement du palier 7, Selon la (figure 10) on constate une évolution des amplitudes de la 1^{ére} et 2^{éme} harmonique de la fréquence de rotation du rotor concasseur par rapport à la dernière mesure de 0.004g/6.19Hz à 0.011g/6.14Hz, avec l'évolution de l'énergie en hautes fréquences qui correspond à l'apparition d'un défaut de roulement du palier coté roue d'inertie et qui nécessite d'autre mesure pour confirmer le défaut. Plus une évolution de l'énergie sur toute la gamme de fréquence suite à l'augmentation de la charge de 340T/H à 500T/H. Une évolution de l'amplitude de la fréquence de rotation du rotor par rapport à la dernière mesure de 0.0003g/6.26Hz à 0.005g/6.07Hz a été enregistrée.

La dernière mesure représentée par le spectre (figure 11) a montré l'évolution de l'énergie sur toute la gamme de fréquence suite à l'augmentation de la charge de 340T/H à 500T/H, avec l'évolution de l'amplitude de la fréquence de rotation du rotor par rapport à la dernière mesure de 0.0003g/6.26Hz à 0.005g/6. 07Hz.le résultat de cette étude a poussé au changement de l'arbre du rotor et le suivi du défaut de roulement palier rotor concasseur.

Les mesures en niveau global sur le moteur des années 2022/2023 ont montré que les niveaux vibratoires globaux relevés en vitesse sur le moteur (figures 12and13) sont tolérables et que le facteur défaut roulement est acceptable.

L'analyse spectrale (figure14) coté réducteur montre une stabilité au niveau des niveaux globaux vitesse et un facteur défaut roulement stable.

Pour la partie palier concasseur (figure 15) les niveaux vibratoires globaux relevés en vitesse sont tolérable et le facteur défaut roulement acceptable.

Conclusion

In ils most general sense, maintenance is not limited to corrective actions carried out on equipment, such as repair or replacement, but it aims to ensure that machines are always able to perform the function expected of them. them, in good conditions of safety and profitability

The objectives set and traced in our work plan have been achieved since we were able to detect the fault caused in the crusher using vibration analysis.

It must be said that vibration analysis alone makes it possible to detect practically all the faults likely to appear in rotating machines. Unbalance, play, misalignment or worn bearing... resulting in a variation of the internal forces to which the machine is subjected and leading to a modification of its vibration behavior.

The spectral analysis clearly demonstrates the typical vibration signature of a defect just at the level of the inertia wheel because of the increase in the load, which had to be changed before the break.

Following the measurements taken on the engine using the global level analysis, it was found that the global levels recorded in acceleration, speed and the bearing defect factor are acceptable, however the spectral analysis made it possible to give more information on the state of health of the control equipment of our machine (limestone crusher) and the determination of the original cause of the defect.

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PISA Mathematics Problem Solving Strategies of Secondary Students in Vietnam

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Abstract: Vietnam as a Southeast Asian country which is also a developing country has made efforts to improve the mathematical literacy skills of their students as evidenced by the high PISA scores. Teachers and students in Indonesia need to know the strategies of students in Vietnam in solving PISA mathematics problems. This research aims to describe the strategies of Vietnamese students in solving PISA mathematics questions so that Indonesian teachers and students can learn from these strategies and apply these strategies to the appropriate questions. The method used was a descriptive qualitative approach, and the subjects of this study were 30 students of grade IX. Data collection used was the PISA mathematics question test and interviews, and the results were obtained by analyzing students' strategies in solving PISA mathematics questions. The results of this study shows that 13.4% of students used the finding patterns strategy, 18% of students used the calculating all possibilities strategy, 44.8% of students used identifying results strategy, and 6.8% of students used the writing open sentences strategy. PISA problem-solving strategies of secondary students in Vietnam produce the correct answers. Therefore, the PISA mathematics problem-solving strategies of secondary students in Vietnam can be implemented and adapted in Indonesia.

Keywords: PISA, Problem Solving, Strategy

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Introduction

Mathematical literacy plays an important role in life. By having the ability of mathematical literacy, we can solve math problems in real life. A student can understand the benefits of mathematics in real life by having mathematical literacy skills, that is the ability to analyze, give logical reasons, and communicate answers to the problems faced (OECD, 2010). Mathematical literacy skills are also very important for students who want to prepare themselves to study at university. Because, students will find problems that require the ability to read and obtain more complex information, such as mathematical problems that require students to have a good understanding of concepts, processes, and strategies for solving problems, and logical solutions (Hill et al, 2016). Mathematical literacy is seen as the role of mathematics in real life. Mathematical literacy competence enables a person to remember and use mathematical concepts more accurately. For this reason, to have mathematical literacy competence, basic concepts, and mathematical skills must be gained (Ilhan et al, 2019). The ability to formulate, use, and interpret mathematics as a component in solving everyday problems is known as mathematical literacy skills (Johar, 2012).

Mathematical literacy is a person's ability to compile several questions, formulate, solve, and describe an existing problem (Suryaningrum, 2018). Basically, mathematics does not depend on the ability to memorize, but mathematics is related to the ability to understand the concepts. The definition of mathematical literacy does not only stop at cognitive abilities, but mathematical literacy also requires students to apply concepts to problems in everyday life.

Mathematical literacy is considered to be an important issue. It is competed globally through the Program for International Student Assessment (PISA). PISA is organized by the Organization for Economic Cooperation and Development (OECD). The purpose of the PISA is to measure students' abilities in aspects of reading, mathematical literacy, and scientific literacy (OECD, 2018). Most of the PISA questions in the mathematical literacy category are problems that we find in life, so the students' ability to answer the PISA questions reflects the student's ability to solve problems in real life.

The ability to solve problems is needed to compete in several international competitions, such as PISA which is held by the OECD. Solving math problems requires higher order thinking skills, because students will face all challenges in the 21st century that require collaboration, communication, critical thinking and creative thinking skills. Questions that require critical thinking skills measure students' understanding, knowledge and application (Meryansumayeka, et al., 2021).

The OECD conducts assessments of reading, math, and science skills every three years for students aged 15 from participating countries. Based on the results of PISA, from 2000 to 2018, Indonesia has always been in the 10th lowest position. The results have not made any significant progress. (Poernomo et al, 2021). The low scores of PISA results in Indonesia are because students are not used to solving non-routine problems. Non-routine problems are more complex than routine problems. In contrast to routine problems often used as examples in explanation, non-routine problems are problems that are rarely shown or discussed on how to solve them. Because problems in non-routine questions are more complex, problem-solving strategies cannot come spontaneously. Therefore, teachers and researchers need to find ways to improve students' ability to solve non-routine mathematical problems (Putri, 2018).

Compared to other countries, Vietnam has participated in the PISA competition since 2012, becoming a concern of other countries because it was in 12th place and then increased to 8th place in the 2015 PISA (OECD, 2016). Indonesia and Vietnam have several things in common. The similarities that can be seen that the geographical location which is the same in Southeast Asia, Indonesia and Vietnam both stipulate a rule of 20% of government spending in the education sector. Indonesia's Human Development Index (HDI) is also not much different, which shows that the level of welfare between the two countries is almost the same (Nasruddin et al., 2022).

The HDI figures for Indonesia and Vietnam are not much different, showing that the Indonesian economic sector is slightly better than Vietnam, and the Indonesian Education Sector has shown progress in equal distribution of education. However, what remains an unresolved problem is literacy rates. literacy ability is one of the considerations for increasing the HDI which is the basic reference in assessing the level of welfare of a country.

Vietnam's success is related to the hard work of Vietnamese students who spend extra time studying than students in seven other developing countries, Albania, Colombia, Indonesia, Jordan, Peru, Thailand, and Tunisia (Dang et al., 2021). Students who study hard show that their efforts are great at achieving goals. Spending time to learn math, will encourage students to find ideas and ways to solve a problem.

The problems raised in the PISA questions take advantage of a broad context. Context helps students to choose a strategy to run in solving the problem. Strategy is an important aspect in the success of answering PISA questions. Most of the questions require various solving strategies (Elentriana, 2017). Reys (1978) explains that there are various strategies that can be implemented in answering math questions, namely, acting (act in out), making pictures or diagrams, looking for patterns, making tables, calculating every possibility, guessing and testing, working backwards, identifying possible results. desired, write open sentences, solve simpler problems, and change views.

Indonesian students are weak in making mathematical models, and students' reasoning levels are poor. The questions in PISA are non-routine problems that require strategies to solve them (Halya Elentriana, 2017). Strategy is an important aspect of the success of answering PISA questions. Most of the questions require various solving strategies. Improving Indonesian students' mathematical literacy has been investigated by many researchers.

Previous research related to PISA has produced many findings, including regarding the development of PISA type questions using various life and cultural contexts (Permatasari, 2018; Murtiyasa, 2018; Nizar, 2018; Jannah, 2019; Dasaprawira, 2019; Pratiwi, 2019), the students' abilities such as students' problem-solving abilities (Bidasari, 2017), and mathematical literacy skills (Putra, 2016; Oktiningrum, 2016), argumentative skills (Fauziah, 2016), and creative abilities (Novita, 2016) . Research on the results of students' error analysis in solving PISA questions has also been conducted by Sari (2017).

Research conducted by Paul, Lee, and Vu explains how Vietnam's performance is qualified and can compete with other countries in the 2012 PISA study. The research also states that the productivity of Vietnamese students is relatively better than the productivity of students in 62 other countries participating in PISA in 2012. Subsequent research that is used as a reference is research conducted by Parandeka and Sedmik which discusses Vietnam's performance in the student assessment program at PISA 2012 by comparing it with 7 other participating developing countries. This research explains how disciplined and diligent Vietnamese students are compared to 7 other countries. Thus it is said that investment in pre-school education and in school infrastructure is higher than Vietnam's per capita income.

The Indonesian government has also made efforts to improve the mathematical literacy abilities of Indonesian students. The Indonesian government creates an assessment to assess students' mathematical literacy skills, that is Asesmen Kompetensi Minimum (AKM), the minimum competency assessment. AKM is the National Assessment consisting of character surveys, learning environment surveys, and the minimum competency assessment. However, the efforts that have been processed have not shown the expected changes. To the AKM results, the achievement of student learning outcomes in Indonesian mathematical literacy is still below the minimum competency, it was less than 50% of secondary students achieve the minimum threshold value for reading literacy as well as numeracy (Kemendikbudristek, 2022).

Other aspects need to be considered to improve students’ mathematical literacy ability, including getting students used to solving PISA questions. We can see Vietnam's success in PISA, has not been obtained. This information is important in helping Indonesian students succeed in PISA. Therefore, this research aims to describe the strategies of Vietnamese students in solving PISA mathematics questions so that Indonesian students can learn from these strategies and apply these strategies to the appropriate questions.

Method

The method used was a descriptive qualitative approach by analyzing students' answers in solving PISA mathematics questions. Furthermore, to obtain more in-depth strategy information, the researcher also conducted interviews with students so that it was hoped that accurate data will be obtained for making conclusions about the strategies used by students.

PISA (Program for International Student Assessment) is a program that organizes international competitions aimed at assessing the ability of 15-year old students in mathematical literacy, scientific literacy, and reading literacy (OECD, 2015). Therefore, the subjects of this research were 30 students grade IX10A at Kim Hong Secondary School, Vietnam. The solutions for PISA Mathematics questions that were written by the students will be analyzed and grouped based on the problem-solving strategies found by Reys.

Eleven strategies can be implemented in solving math problems found by Reys are, act in out, make figures or diagrams, look for patterns, make tables, calculate every possibility, guess and test, work backwards, identify results, write open sentences, solve simpler problems, and change views (Reys, 1978).

The researcher compiled the expected solutions from each question. This description helps the author predict the strategies that can be used for each problem. The expected strategies are the making figures and diagrams strategy, finding patterns strategy, calculating all possibilities strategy, identifying results strategy, and writing open sentences strategy.

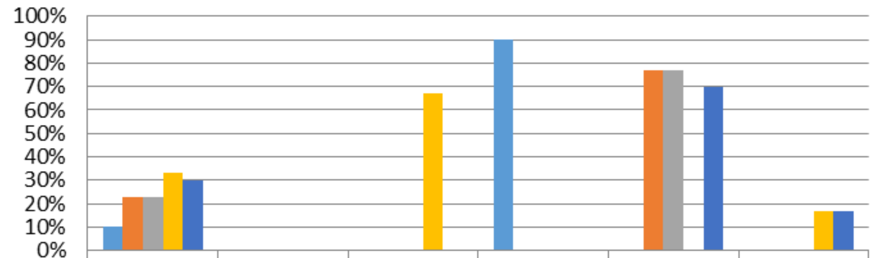
Table 1. The expected strategies in solving PISA mathematics problems

Code	Strategy	Indicator
S0	Students who do not do any strategy	Students do not write down the steps of completion
S2	making figures and diagrams	Students simplify problem solving by making figures or diagrams. A figure or diagram as an illustration of the information or data available in the problem.
S3	Finding patterns	Students find information and use it to look for relevant patterns. The intended pattern is the regularity of the information provided.
S5	Calculating all possibilities	Students calculate all possible sets of solutions to the given problem and check the possible answers.
S8	Identifying results	Students choose and use the information provided to formulate problems and find steps to solve them according to their understanding and logic.
S9	Writing open sentences	Students use variables and symbols instead of sentences in questions to formulate problems.

Results

The results of the analysis of student answers obtained clearly described. The 30 students as research subjects showed a variety of strategies used in answering PISA math questions. In simple terms, the trend of the strategies used by students in answering PISA questions is shown in Figure 1.

Based on the results of research on 30 students of Kim Hong Secondary School, it was found that three students did not write down the description of the answer in question number 1, seven students did not write the description of the answer in question number 2, seven students did not write the description of the answer in number 3, ten students did not write the description on questions number 4 and nine students did not write down the answers to the questions number 5. Students who did not write down the answers to the questions can be said that the students did not carry out any strategy (S0). The average percentage of students who do not work on any strategy is 23.8%. So that only a small proportion of students do not carry out certain strategies.



	S0	S2	S3	S5	S8	S9
number 1	10%	0%	0%	90%	0%	0%
number 2	23%	0%	0%	0%	77%	0%
number 3	23%	0%	0%	0%	77%	0%
number 4	33%	0%	67%	0%	0%	17%
number 5	30%	0%	0%	0%	70%	17%

Figure 1. Percentage of student strategies in solving PISA mathematics problems

The next strategy that might appear in student answers is to make pictures and diagrams (S2). However, no students used this strategy because some of the questions used pictures and there were also questions that already had diagrams so that students did not draw and re-diagram what was known in the problem. Therefore, the average percentage of students who do the strategy of making figures and diagrams is 0%.

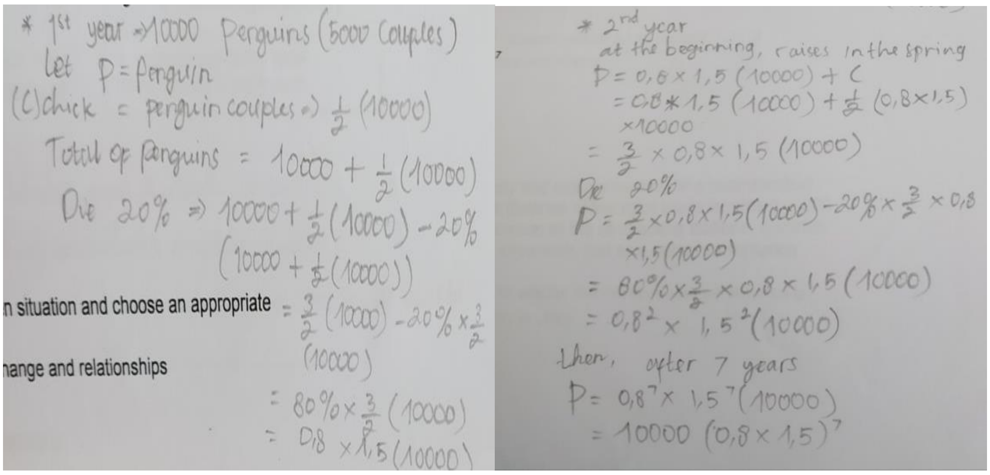


Figure 2. Number 4’s solution by subject 28

The strategy for finding patterns (S3) was used by 20 students in solving problem number 4. There were no students who worked on questions number 1, 2, 3, and 5 using the strategy of finding patterns. For this reason, the average percentage of students working on a pattern-finding strategy from the 5 questions given is 13.4%. Besides the strategy of finding patterns, there are also 5 students who use strategies of writing open sentences (S9). The following is an example of solving problem number 4 by subject 28.

The strategy of finding patterns is to look for regularities. Activities that can be applied are by looking at and identifying the characteristics that are shared by the information. In this question the information provided is interrelated, so that students can find regularities to answer these problems. To facilitate students in formulating problems, students use the S9 strategy, writing open sentence strategy. Students use variables and symbols in formulating problems and solving problems. The following are excerpts from the researcher's interview with subject 28. The researcher is coded R and subjects are coded S.

R : "What are the steps you did on number 4?"

S28 : "Okay teacher, suppose that penguin is P and chick is C, then I read all of statement at the question. At the beginning of each year, the colony consists of 5000 couples.

R : So, how many penguins in the spring of the 1st year?"

S28 : "There are 15000 penguins. Because each 5000 penguins couples raise one chick. So, P in the spring is P at the beginning add up to C. C is ½ of P. so I have 15000 penguins. So, the colony of chick is half of the penguin colony. By the end of the 1st year 20% of all penguins will die.
So, we have 10000 + 5000 – 20% (10000+5000). Because 100% - 20% equal to 80% then, at the end of the 1st year, the size of penguins couple is 80%(10000 + ½ (10000)), and equal to 0.8 x 1.5 x10000."

R : "Then, what is the next step?"

S28 : "I find it in 2nd years for the next step, and I see the pattern. It is equal to 0.8^2 x 1.5^2 x10000. So, I found that 0.8 is number of a reduction in the number of colonies due to death by as much as 20% of the colony. Then, 1.5 is number of the addition of half of the first colony. Then, 0.8 and 1.5 involve the number of colony as well as the following year, this model has the same pattern as the power of the number that increases with the turn of the year. After 7 years, the number of penguin colony is $(0.8 \text{ x } 1.5)^7$ x 10000."

Based on the results of student interviews with subject 28, it can be seen that the strategies used are looking for patterns and writing open sentences. subject 28 wrote down the variables to replace the sentences in the given statements to make it easier for him to formulate the problem.

The next strategy is the strategy of calculating all possibilities (S5). This strategy was used by 27 students in question number 1. The percentage of using the strategy of calculating all possibilities (S5) for number 1 is 90%. There were no students who worked on questions number 2, 3, 4 and 5 using the strategy of calculating all possibilities (S5). For this reason, the average percentage of students working on calculating all possibilities strategy from the 5 questions given is 18%.

There were students who completed question number 1 by mentioning 8 possibilities from the two albums that could be deleted, there were also students who wrote down the steps for solving the problem by calculating the capacity of the 2 albums that could be deleted. One of the students who wrote down the completion steps by calculating the capacity of the two albums was subject 17. The student's answer is showed in Figure 3.

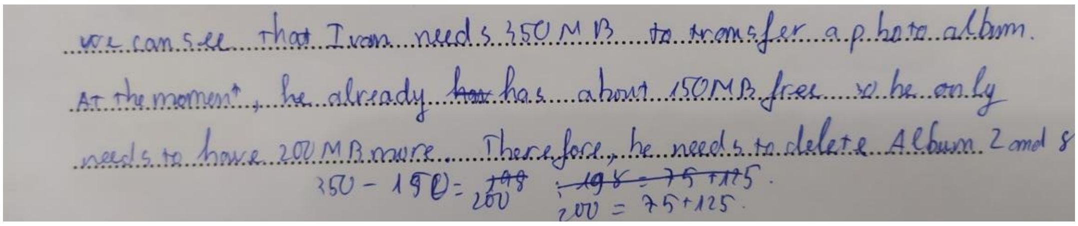


Figure 3. Number 1’s solution by subject 17

In the solution, students identify all possibilities of solution. The following are excerpts of interview with subject 17.

R : “After you read the question, what did you know from the problem?”

S17 : “I know that Ivan has 1 Gb memory stick, he wants to transfer 350 Mb photo album but there is no more space in memory stick, it is only 152 MB. He need 198 Mb more spaces.

R : “Then, how to solve it?”

S17 : “First, I tried to find two albums that have capacity more than 198 Mb. For example album 2 and 8, 75 Mb plus 125 Mb equal to 200 Mb. So I can delete album 2 and 8, but if I added up album 1 and album 2, they only have 175 Mb that less than 198 Mb. So Ivan can choose album 1 and album 8, album 2 and album 8, album 3 and album 8, album 6 and album 8, album 7 and album 9 to delete two albums.”

The following figure is the solution given from student who only wrote down 8 possibilities out of 2 albums that could be deleted without writing down the calculation of the total capacity of the two albums to be deleted.

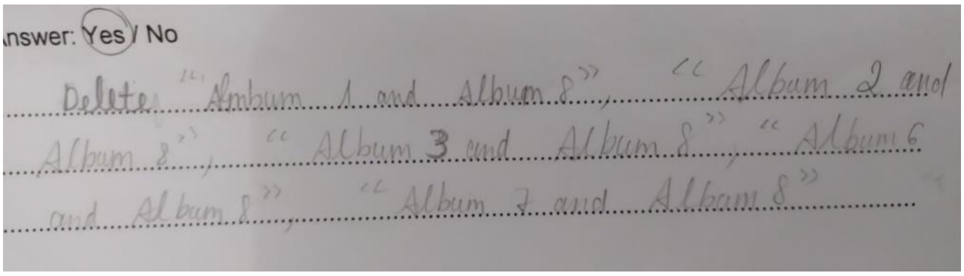


Figure 4. Number 1’s solution by subject 29

Subject 29's solution is more concise without writing down the calculations on the two possible albums to be deleted. Subject 29 listed only 8 possibilities on the two possible albums that could be deleted. In Subject 29's solution, there was no calculation process, this was because he had calculated it without writing it down. S29 chooses 2 albums that can be deleted with a space capacity of more than or equal to 198 Mb and he found 8 possibilities from the two albums that could be deleted.

The next strategy is the strategy of identifying results (S8). This strategy was used by 23 students in solving problem number 2, 23 students in solving problem number 3 and 21 students in solving problem number 5. Therefore, the average percentage of students working on calculating all possibilities strategy from the 5 questions given is 44.8%.

The result of the analysis of students' solution for question number 2 is 77% of students did the identifying results strategy. In the strategy of identifying results, students collect information, formulate problems and choose the right steps according to students' thinking in solving problems. The answer by subject 14 is showed in Figure 4.

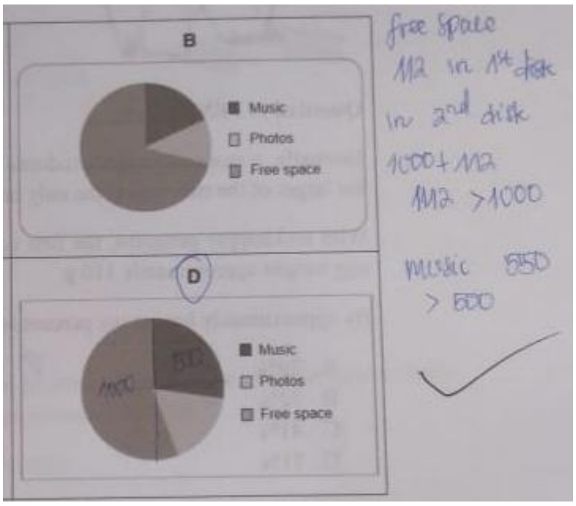


Figure 5. Number 2’s solution by subject 14

Based on interviews with subject 14, student used the Identifying results strategy in solving number 2. Subject 14 compared the pie chart of the capacity of music and photo with the capacity size of 2 GB. After that he found the correct picture to represent the new memory stick. The following are interview excerpts to support the above statement.

R : “Can you explain what is the problem in the question!”

S14 : “It asks me to choose which picture is suitable for that case, 1st memory stick has 1 Gb include musics 550 Mb, Photos 338 and free space 112 Mb. Then, Ivan has 2nd memory stick 2 Gb empty and he transfer content of old memory to 2nd memory.”

R : “Then, what do you do to solve it?”

S14 : “I think picture D is suitable for the new memory stick, because capacity free space in new memory stick has been 1112. It is more than half of memory sticks. Then, I see 550 Mb of music is more than ¼ of memory stick. So I choose D."

Based on the results of interviews with subject 14, students used the S8 strategy to make it easier for them to complete problem number 2. This can be seen from students looking at the capacity of music and photos and then comparing it to the size of the 2 GB capacity, then finding the right picture to represent the new memory stick. So it can be seen that students have sorted some information from the problem then formulate the problem and choose the right steps according to the student's logic in solving the problem.

The description of students' solution on number 3 can be identified as a strategy of identifying results. Here is an example of solving problem number 3 by subject 4.

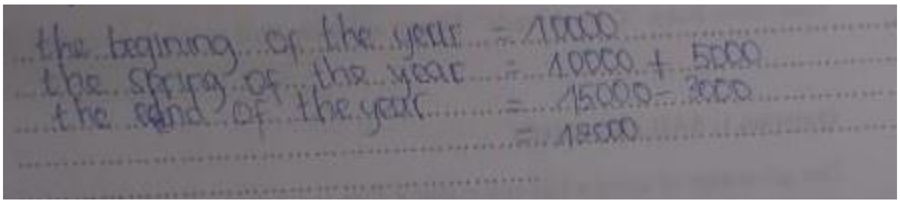


Figure 6. Number 3's solution by subject 4

The steps of this strategy are gathering information, formulating problems and choosing the right steps according to thinking in solving problems. The following is an excerpt of the researcher's interview with subject 4.

R : "Can you explain what the problem on the question is about!"

S4 : "The colony has 10000 penguins. Then, every penguin's couple raises 1 chick in the spring. Then, 20% of them are died in the end of the year. I just solve it by additing all of penguins. First, in the spring they are 10000 + 5000, cause every penguin's couple is 5000 couples. 2nd, in the end, they are died about 3000, cause 20% died of 15000. Now they are only 12000 penguins."

Students used the S8 strategy to make it easier for them to complete problem number 4. This can be seen from student reading the information provided in the questions, then adding up all the penguins at the end of the year based on the information they already know. So it can be seen that student has sorted some information from the problem then formulate the problem and choose the right steps according to the student's logic in solving the problem.

The strategies used by students in solving question number 5 are identify results strategy and write open sentences strategy. 16 out of 30 students only use identify results strategy without writing open sentence strategy, 5 out of 30 students use both of these strategies. Because in we found 5 students use the strategy 9 in solving number 4, then the average percentage of students working on a writing open sentences strategy from the 5 questions given is 6.8%. The following is the completion of question number 5 by subject 29 using the strategy of identifying the results and the strategy of writing open sentences.

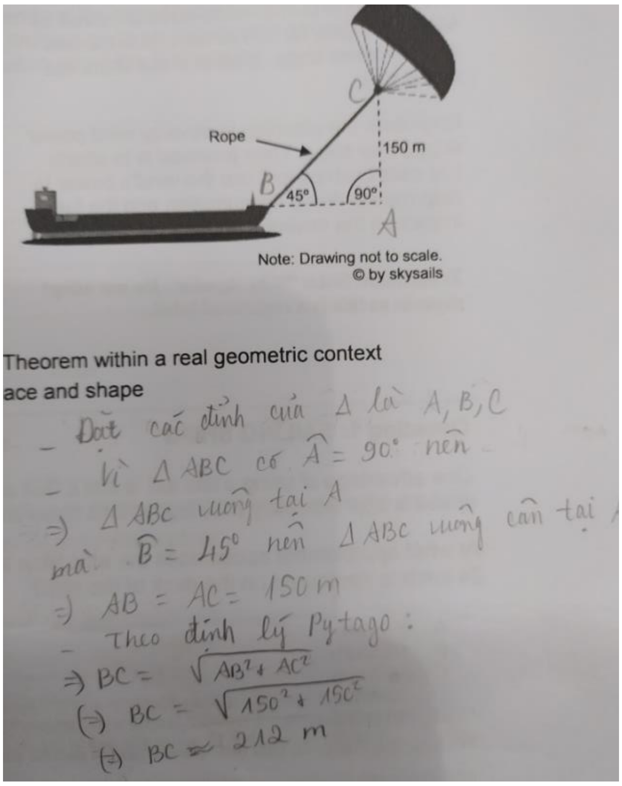


Figure 7. Number 5’s solution by subject 29

From the Figure 8, it is shown student sorted the information in the questions, chose the right steps using logic and then wrote open sentences, used variables and symbols in formulating problems and solving problems. The following is an excerpt interview with subject 29.

R : “Now, for number 5. What did you understand from the problem?”

S29 : “It is about how many the length of the rope with angle 45 and be at a vertical height of 150 m.”

R : “So, how do you solve it?”

S29 : “I suppose it is an ABC that is a right triangle for that picture. And BC is the rope. So I find BC by using phytago. cause angle B = 45º of course angle C=45º and that is make AC equals AB. So, the length of the rope is about 212”

Based on the results of student interviews, it appears that the strategy used is to write open sentences and identify results. Students process the information contained in the problem, then look for solutions with logic and existing concepts after that, for example, the statements in the problem with variables then perform mathematical operations using symbols, then use the Pythagorean theorem to solve the problem.

Discussion

The results of the analysis on the student test result sheet showed that students used the finding patterns strategy, the strategy of calculating all possibilities, the strategy of identifying the results and the strategy of writing open sentences. It was found that three students did not write down the description of the answer in question number 1, seven students did not write the description of the answer in question number 2, seven students did not write the description of the answer in number 3, ten students did not write the description on questions number 4 and nine students did not write down the answers to the questions number 5. Students who did not write down the answers to the questions can be said that the students did not carry out any strategy. The average percentage of students who do not work on any strategy is 23.8%, So that only a small proportion of students do not carry out certain strategies. However, no students used the strategy of make pictures and diagrams because some of the questions used pictures and there were also questions that already had diagrams so that students did not draw and re-diagram what was known in the problem.

Students used the strategy of identifying results on several questions, namely question number 2, question number 3, and question number 5 with an average percentage of 44.8%. It indicates that students can choose and use the information in the problem to formulate problems and find steps to solve them according to their understanding and logic.

Students use the pattern-finding strategy only on several questions that require pattern-finding. An example of a question that uses the strategy of finding patterns is question number 4. Out of 5 questions, only 1 question uses a pattern-finding strategy. In question number 4, 67% of students can do the strategy of finding patterns. It shows that students can look for the regularities listed in the information given in the questions. Students can identify the properties shared by the data in solving number 4. The order obtained by students can be used as the beginning of starting a solution by continuing the pattern of the order obtained.

Some students use the open-sentence writing strategy in conjunction with other strategies. Because an open sentence writing strategy is needed as a first step in formulating a problem using certain variables. The open sentence writing strategy was used by 17% of students in solving problem number 4 along with the pattern finding strategy. The open sentence writing strategy was also used by 17% of students in solving problem number 5 along with the strategy for identifying results. This strategy is seen in 2 of the 5 questions given, therefore it only has an average percentage of 6.8%. Even though this strategy is used by a small number of students, students are used to solving problems in a short time, this makes the steps for solving students short without exemplifying what is known in the problem.

Students are familiar with the questions given, students have been given questions with the same characteristics in the form of different questions. This can be seen from the students' answers during the interview which stated that the student had worked on PISA questions or similar questions given by the teacher. Students can understand what is known and what is asked in the questions, this can be seen from the answers of students when interviewed regarding what they understand in the questions, so students can determine the steps what to do to find a solution to the problem. each step of the completion steps written by the student determines what strategy is implemented, and the strategy leads to the correct and appropriate solution.

Conclusion

Based on the results and discussion, the strategies of Vietnamese students in solving PISA mathematics questions are looking for patterns, calculating all possibilities, identifying results and writing open sentences. The students solve PISA mathematics problems correctly and with appropriate strategies. Therefore, Indonesian teachers and students can learn from these strategies and apply these strategies to the appropriate questions.

Recommendations

Based on the conclusions obtained, the authors provide several suggestions. The first is a suggestion to teachers to guide students about choosing and using the right strategy when solving math problems, both PISA questions and problem solving questions that can improve students' mathematical literacy skills. Then, it is suggested to students to get used to working on PISA math problems using appropriate strategies. And, it is hoped that the next researcher will be able to conduct similar research by choosing PISA questions or making PISA equivalent questions that consider the four components of PISA.

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Developing Interactive Learning Media Based on Geogebra Classroom to Increase Students' Creativity on Learning Quadratic Functions

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Abstract: In 2021, the Ministry of Education and Culture of the Republic of Indonesia implemented a new curriculum, namely the Sekolah Penggerak curriculum. One of the main visions of implementing this curriculum is the acceleration of school digitalization, which means the need for technology-based media in each lesson. One of the lessons that require technology-based media is learning mathematics. The GeoGebra Classroom learning media can be a supporting medium for learning mathematics considering that this media supports the activities of all domains of learning mathematics and its use is easy for teachers and students. Preliminary observation results show that teachers tend to use the lecture method in class X mathematics learning activities at SMA Negeri 3 Surakarta. Students are not facilitated to develop their creativity because the learning media used is not interactive. Therefore, it is very important to develop interactive learning media based on GeoGebra Classroom so that students can develop their creativity while studying quadratic function material. After the media has been developed and declared fit for use by experts, an analysis of the increase in student learning creativity is carried out. Students' mathematics learning creativity was tested based on indicators of four main aspects: fluency, flexibility, elaboration, and originality. Based on tests of student learning creativity tested in an interactive learning media experimentation class based on GeoGebra Classroom. Obtained an average N-gain result of 0.75 with a very high improvement category. Thus, it can be concluded that it can increase student learning creativity in quadratic function materials.

Keywords: GeoGebra Classroom, Quadratic Functions, Students' Creativity, Sekolah Penggerak Curriculum.

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Introduction

In 2021, when all areas of life in Indonesia were affected by the Pandemic COVID-19, including the education sector, many new policies were implemented so that learning activities could be implemented. In response to this, the Indonesian government launched a new curriculum, the Sekolah Penggerak curriculum that focuses on developing student learning outcomes holistically by realizing the Pancasila Student Profile which includes competence and character that begins with superior human resources (principals and teachers) (Kemdikbud, 2021). One of the interventions contained in the Sekolah Penggerak program is the acceleration of school digitalization, namely the use of various digital platforms to reduce complexity, increase efficiency, add inspiration, and a customized approach (Ministry of Education and Culture, 2021). Curriculum changes often occur in Indonesia aiming to move according to the times. This can also be referred to as curriculum development, curriculum development aims to improve the evaluation of the previous curriculum so that the curriculum can become teaching materials and references used to achieve national education goals (Mu'arif et al., 2021). However, when viewed from its urgency, the Sekolah Penggerak curriculum exists because it responds to the times, namely the existence of the pandemic COVID-19 which has encouraged learning activities that have so far been carried out face-to-face in full into distance blended learning.

The launch of this curriculum was criticized because the training for teachers was considered too short, confusing teachers in designing learning scenarios and tools. The Sekolah Penggerak (SP) curriculum is still in the trial stage and has not been widely implemented in schools. One of the schools that participated in this curriculum trial was SMA Negeri 3 Surakarta with the trial class being class X. Lack of teacher readiness in preparing the recommended teaching tools the government made the learning scheme that the government hoped for did not work as it should. Obstacles related to teacher preparation resulted in the emergence of various problems in the field. Based on the results of interviews with one math teacher of class X at SMA Negeri 3 Surakarta, these obstacles resulted in learning that has been going on for approximately one semester by using the same teaching tools as the previous curriculum, namely the 2013 curriculum. The results of preliminary observations show that the mathematics learning activities in SMA Negeri 3 Surakarta, especially in Class X, teachers tend to use the direct method. The lack of use of innovative and creative learning media places students as individuals who are monotonous and less creative in their learning process. Therefore, it is very important to develop innovative learning media to increase student creativity.

Anggraeni (2021) explains that one of the learning media for mathematics material is the GeoGebra Classroom learning media. GeoGebra is a page (website) provider of math applications accessible via geogebra.org. GeoGebra was developed by Markus Hohenwarter, a professor at Johannes Kepler University Linz starting in 2001 and also an Austrian mathematician. GeoGebra is a free, dynamic, multi-platform math software. GeoGebra combines algebra, geometry, tables and graphs, statistics, and calculus in one easy package that can be used for all educational networks, according to Hidayat and Tamimuddin (in Anggraeni, 2021). GeoGebra can produce math applications through the geogebra.org page. Thus, the geogebra.org page can be used as an alternative to disseminating GeoGebra-based learning media. In addition, on the GeoGebra page, there is a GeoGebra Classroom feature that can be used to display activities created through the GeoGebra application, so students can access it without having to install the GeoGebra application on their computer. One of the Sekolah Penggerak curriculum materials that requires the help of learning media is quadratic function material. This material requires a fairly high ability to understand concepts, considering that this material is Algebraic material which incidentally is classified as abstract mathematical material, so a medium is needed to make it easier for students to visualize objects related to this material. Based on these problems, it is necessary to research and develop instructional media with specifications for developing activities on GeoGebra Classroom learning media on the quadratic function material of the Sekolah Penggerak curriculum. In addition to school digitalization, another intervention included in the Penggerak School curriculum is learning with a new paradigm designed based on the principle of differentiated learning so that each student learns according to his needs and developmental stage. Faith in God Almighty and noble character, Global Diversity, Independence, Mutual Cooperation, Critical and Creative Reasoning, this is a profile of learning Pancasila that is learned through curricular and co-curricular programs (Patilima, 2022).

Creative Reasoning is one of the profile learning of Pancasila. Mel Rhodes (in Fatmawiyati, 2018) argues that creativity is a phenomenon, in which a (person) communicates a new concept (product) obtained as a result of a mental process (process) in generating ideas, which is an attempt to fulfill a need (press). affected by ecological pressure. In discussing creativity, it contains four things, namely person, process, press, and product. Stenberg, Kaufman, and Pretz define creativity as the ability to produce new, appropriate, high-quality products, which most researchers eventually use as a general definition of creativity. Creativity can also be seen in how individuals attach importance to a process in solving problems and recent research states that creativity must be developed in solving problems in the context of real world Basadur's (in Fatmawiyati, 2018). Fatmawiyati (2018) concluded that creativity is an individual's intellectual ability to create and develop something new from a collection of experiences, knowledge, and concepts that have been obtained. Creative individuals are open-minded people so they can develop their imagination. From the opinions of Mel Rhodes, Stenberg, Kaufman & Pretz, and Fatmawiyati regarding the notion of creativity, the authors conclude that creativity is an individual's intellectual ability to create and develop something new that is obtained as a result of mental processes in solving problems in the real world. Guilford (in Fatmawiyati, 2018) states that creative products need to have; fluency, namely the capacity of a person to be able to produce many ideas given in a certain period that are relevant to the existing situation; flexibility, namely someone who has flexibility in thinking, for example making many categories of ideas that have been raised, or in creating new ideas one needs to think flexibly in finding a way out; originality, namely the authenticity of someone's idea that is different from others. Munandar (in Fatmawiyati, 2018) states that creative products have the following characteristics: fluency refers to several ideas.

The researcher use the GeoGebra Classroom because the GeoGebra Classroom can help students in learning mathematics. Based on the results of previous research related to GeoGebra Classroom. Research conducted by Sutopo, Ratu (2022) with the research title "Development of GeoGebra Classroom Learning Media as Strengthening Conceptual Understanding of Translation Material for Grade IX Junior High School Students" shows that the validity of the learning media developed is included in the good category with an average validity value of 4.35 and has an average media practicality score of 4.35 which is included in the practical category. The results showed that there was an increase in test results after students used the GeoGebra Classroom media with a learning result of 63.33 and a posttest learning result of 95.93 so this media was included in the effective category. In another study conducted by (Septian et al., 2022) with the research title "Development of GeoGebra Classroom on Geometry Transformation MaterialDevelopment of GeoGebra Classroom on Geometric Transformation Material" the results that GeoGebra Classroom on geometry transformation material developed very valid with a percentage of 93.00% and very practical with a percentage of 85.87%. Following up on the findings in this study, the GeoGebra Classroom is suitable for use as a medium for learning mathematics in the classroom and for independent learning of students. This result was supported by (Badriyanto & Qohar, 2022) in their research about " Developing Interactive Learning Media of Worksheets based on Geogebra Classroom" with the result that the developed learning media has been validated and obtained a media validation score of 3.49 and material validation 3.45 which indicates that this media is valid. The results of the practicality test obtained from the questionnaire distributed to students got a score of 3.24. As for the effectiveness of getting a score of 3.25 and helping 78% of all students reach a KKM. This shows that the media developed is both practical and effective. Based on the results of validation, effectiveness, and practicality, the developed digital worksheet based on the GeoGebra classroom can be used to study the topic of set operations. 45 which indicates that this media is valid. The results of the practicality test obtained from the questionnaire distributed to students got a score of 3.24. As for the effectiveness of getting a 234 score of 3.25 and helping 78% of all students reach a KKM. This shows that the media developed is both practical and effective.

Besides that, the researcher assumed that the GeoGebra Classroom can develop students' creativity through the research that has been conducted. "Development Of Junıor Hıgh School Mathematıcs Teachıng Materıals Assısted By Geogebra Software Wıth A Contextual Approach To Improve Mathematıcal Creatıve Thınkıng" that conducted by (Setiawan et al., 2022), the results obtained from this study are the validity of teaching materials that are declared very valid with teaching materials that have been developed using GeoGebra assistance produces valid and practical teaching materials for the learning process with the results of an average validity value of 96.93% and an average practicality value of 94.6%. Another research conducted by Pianda, Rahmiati (2020) with the research title "Increasing Student Creativity in Learning Mathematics with Google Classroom as a Digital Class Assisted by the GeoGebra Application" shows that the average score of student creativity in cycle I is 56.11 with the low category and cycle II 83.22 with high category. The average score of student learning outcomes in cycle I was 69.72 out of an ideal score of 100 in the moderate learning outcome category, while in cycle II it was 81.22 out of an ideal score of 100 in the high learning outcome category. (Kurnia, 2022) also doing similar research with the title "Development Of Student Worksheets Usıng Geogebra Classroom To Improve Creatıve Thınkıng Skills There Are Topıcs Of Quadrılateral And Trıangular Class VII Junıor Hıgh School", the result is The LKPD was categorized as quite effective with an average score of 46.87% in the pre-test and 66.67% in the post-test so it can be concluded that the LKPD or worksheet using Geogebra Classroom can improve students' creativity thinking skills.

Thus, it can be concluded that the learning media developed in this study can increase students' mathematics learning creativity. From these data, it can be seen that the use of GeoGebra Classroom learning media in learning mathematics is not only effective, but also able to increase student creativity, but until now there is no research about developing GeoGebra Classroom to improve students' creativity in learning quadratic functions.

Based on that condition, the research initiated for doing the research Developing Interactive Learning Media Based on Geogebra Classroom to Increase Students' Creativity on Learning Quadratic Functions.

Method

The research method used in this research is Research and Development (R&D). Gall, Gall, and Borg (2003: 569) argue that research and development (R&D) in the field of education is a development research model resulting from the adaptation of industrial product development. The findings of this study are used to design new products and procedures that are systematically tested, evaluated, and refined so that the results meet the criteria, as viewed from the perspective of practicality and effectiveness. Fithriyah & Abdur (2013) explained the purpose of the practicality test, which is to test whether the development product is practical and easy to use by users. One of the stages of the expected and actual practicality test is carried out by asking students to fill out a user response questionnaire or a practicality questionnaire. This is in line with research that tests teaching materials on students and helps researchers determine the parts that need revision so that teaching materials can be produced that are easily understood by students (Aulia, Mochamad, & Dharmono, 2016). Meanwhile, "Tests of the effectiveness of interactive media were carried out to measure how effective interactive media can improve learning activities and student learning outcomes" (Nurzaelani & Kasman, 2019).

Twelker (1972) says that learning development is a systematic way to identify, develop, and evaluate a set of materials and strategies to achieve certain educational goals. One of the results of learning development is learning tools. There are several models of learning development, including the Kemp model, the Gerlach and Ely model, the ITS model, the Dick and Carey model, the 4-D model (Thiagarajan), and others. The development of instructional media in this study is guided by the 4-D learning device development model (four d model) developed by Thiagarajan (1974), this development model is used in designing an educational product which includes defining, planning, developing (development), and deployment (disseminate). The subjects used in the research on the development of learning media based on GeoGebra Classrom quadratic function material for the Sekolah Penggerak curriculum are as follows: the subject of analysis, namely a math teacher at SMA Negeri 3 Surakarta; learning media validation subjects, namely two media expert validators and two material expert validators; the test subjects, namely students of class X E3 SMA Negeri 3 Surakarta for the 2021/2022 academic year; learning media practicality test subjects, namely teachers and students of class X E3 SMA Negeri 3 Surakarta for the 2021/2022 academic year; learning media effectiveness test subjects, namely students in class X E3 and X E8 SMA Negeri 3 Surakarta for the 2021/2022 academic year; the test subjects for increasing learning creativity, namely class X E3 SMA Negeri 3 Surakarta for the 2021/2022 academic year.

In this study, the technique used for taking subjects which was carried out at the practicality and effectiveness testing stage of learning media was probability sampling, namely a sampling technique that provides equal opportunities or opportunities for each element or member of the population to be selected as a sample (Sugiyono, 2017: 82). Budiyono (2017) argues that cluster random sampling is simple random sampling applied successively to units or sub-populations which are then referred to as clusters. This determination was made during teacher interviews and observations at school by taking data on Semester 1 Final Assessment scores. The population used in this study were all class X SMA Negeri 3 Surakarta consisting of accelerated classes (X E1 and X E2) and regular classes (X E3, X E4, X E5, X E6, X E7, X E8, X E9, X E10, XE11, and X E12). Determination of the research sample was carried out by dividing the student population based on clusters consisting of accelerated classes and regular classes. Based on the time of the research, a regular class was chosen to serve as the research sample, then clustering was carried out again to determine the research sample in the form of a control class and an experimental class. The samples in this study were students of class X E3 as the experimental class and students of class X E8 as the control class. The selection of these two classes was based on the same curriculum, the same delivery time, the same supporting teacher, and the average learning outcomes of the end-of-semester 1 assessment which were not much different.

Data analysis techniques are used to obtain learning media products that meet the criteria of validity, practicality, and effectiveness. If these three conditions are met, a good quality learning media product is obtained. After the product is declared to be of good quality, it is followed by an analysis of increasing student learning creativity using the module. The data analysis technique used for validity analysis in this study used Aiken's Value index validity method.

$$N - Gain = \frac{Post\ Test - Pre\ Test}{Skor\ Ideal - Pre\ Test}$$

Where:
N-gain: the change that is obtained
Pre-Test: the test value before applying a method
Post Test: the test value after a method is applied
Ideal score: the ideal value expected
The results of the N-Gain analysis are then interpreted based on Hake and Richard (in Adawiyah, et al., 2018) which can be seen in Table 1.

Table 1. N-Gain Interpretation

***Gain* Skor (g)**	**Interpretation**
$(g) \geq 0{,}7$	High Increcement
$0{,}7 > (g) \geq 0{,}3$	Middle Increcement
$(g) < 0{,}3$	Low Increcement

(Source: Hake, 1998: 65)

Results

The GeoGebra Classroom-based media that has been made is then validated by each expert, both media expert and material expert. After the process has been validated, revisions are made to the parts of the media that require improvement, so that a feasible module to be tested is obtained. Media expert validators include Riki Andriatna, M.Pd., who is a lecturer in Mathematics Education at Sebelas Maret University, and Fakhi Rahmasari, S.Pd. who is a teacher of mathematics at SMA Negeri 3 Surakarta. The summary of the validation results by media experts can be seen in Table 2.

Table 2. Media Expert Validation Results

Assessment Aspects	**Aiken's Average Validity Score**	**Validity Criteria**
General Aspect	0,944	Very High Validity
Device Engineering	0,944	Very High Validity
Visual Communication	0,833	Very High Validity
Media Quality	0,833	Very High Validity
Average Total Score Validity	0,889	Very High Validity

From these results, it can be concluded that the learning media based on GeoGebra Classroom that was developed is in the "very good" criteria so the indicators of the validity of the media in this study are met.

Material expert validators include Dr. Budi Usodo, M.Pd., who is a lecturer in S1 and S2 Mathematics Education at Sebelas Maret University, and Fakhi Rahmasari, S.Pd. who is a teacher of mathematics at SMA Negeri 3 Surakarta. The recap results of validation calculations from material experts can be seen in Appendix 31. A summary of the validation results by material experts can be seen in Table 3.

Table 3. Material Expert Validation Results

Assessment Aspects	**Aiken's Average Validity Score**	**Validity Criteria**
Relevancy	0,889	Very High Validity
Accuracy	0,875	Very High Validity
Learning	0,861	Very High Validity
Learning Quality	0,861	Very High Validity
Average Total Score Validity	0,872	Very High Validity

From these results, it can be concluded that the learning media based on the GeoGebra Classroom that was developed has very high validity criteria so that the indicators of the validity of the material in this study are met. Even so, several parts still require improvement according to comments and suggestions from each media and material expert.

The practicality of interactive learning media based on GeoGebra Classroom is analyzed based on the results of user response questionnaire assessments by teachers and students. The user response questionnaire for teachers was filled in by a class X teacher, namely Fakhi Rahmasari, S.Pd., as the supporting teacher for class X E3, and user responses for students were filled out by students in class X E3. Based on the results of the user response questionnaire assessment, the following quantitative data were obtained.

Table 4. Results of User Response Questionnaire Assessment by Teachers

Assessment Aspects	**Score (%)**	**Practically Criteria**
Learning	100	Very Practical
Media Quality	100	Very Practical
Media Display	100	Very Practical
Media Function	100	Very Practical

Table 5. Results of User Response Questionnaire Assessment by Students

Assessment Aspects	**Score (%)**	**Practically Criteria**
Learning	77,5	Practical
Media Quality	77,78	Practical
Media Display	78,65	Practical
Media Function	81,13	Very Practical

Based on these results, it can be concluded that interactive learning media based on GeoGebra Classroom is practically used in learning.

The effectiveness of interactive learning media based on GeoGebra Classroom was analyzed based on the test scores of learning outcomes between the control class and the experimental class. The test scores for the control class were the test scores in class X E8 which did not use interactive learning media based on GeoGebra Classroom on quadratic function material, while the test scores for the experimental class were the test scores in class X E3 which used interactive learning media based on GeoGebra Classroom on quadratic function matter. Data on the results of the test scores for the control class and the experimental class are shown in Table 6 below.

Table 6. Student Learning Test Results

Class	**Statistics**					
	N	$\underline{X}$	σ^2	σ	X_{max}	X_{min}
Control	36	60,556	605,247	24,602	100	20
Experiment	36	72,56	335,417	18,314	100	40

The results of the one-way ANOVA test revealed that there was a significant difference in mean between the control class and the experimental class. To determine which class gives better learning outcomes, the experimental class or the control class, in terms of the mean difference, the experimental class has an average of 72.56 while the control class has an average of 60.556, which means the experimental class has a larger average than the control class so that it can it was concluded that the experimental class had the best learning outcomes. In other words, the GeoGebra Classroom learning media is effectively used in learning the quadratic function of the Sekolah Penggerak curriculum.

The application of interactive learning media based on GeoGebra Classroom for learning quadratic functions is applied to students of class X E3, totaling 36 students. Before students receive material delivery, the researcher first asks students to work on one essay question related to quadratic functions as a pre-test. After that, students get learning quadratic function material with interactive learning media based on GeoGebra Classroom. Finally, the researcher asked students to answer the questions posed in the post-test questions. The results of the assessment obtained both before (pre) and after (post) tests are calculated using the normalized gain or N-Gain test. The normalized gain test was carried out to determine the increase in student learning creativity after being given treatment. This increase was taken from the pre-test and post-test scores obtained by students, described in Table 7 below.

Table 7. Calculation of Increased Learning Creativity

Name	***Pre - Test***	***Post - Test***	**N-gain**	**Increcement Category**
Adam I R	50	75	0,5	Middle
Adelia N P S	75	100	1	High
Agatha A B	50	100	1	High
Alkhahfi D P	0	75	0,75	High
Aqilatun Nisa'	75	100	1	High
Ardia O Y	25	75	0,67	Middle
Aurellia V A	0	75	0,75	High
Aven P G	0	0	0	Low
Bagas S G	0	100	1	High
Benedictus F	0	100	1	High
Caesilia K	50	75	0,5	Middle
Christine C S	25	75	0,67	Middle
Delfieana K N	25	100	1	High
Dharu B M	75	100	1	High
Dylan A S	0	50	0,5	Middle
Farrel A S	0	75	0,75	High
Fransiska S	25	75	0,67	Middle

Gari M S	75	100	1	High
Husin Y	0	75	0,75	High
Jody J P C	25	75	0,67	Middle
Jonathan H	0	25	0,25	Low
Kamila R	0	100	1	High
Leo Agung	0	50	0,5	Middle
Margaretha S	50	75	0,5	Middle
Moh Ariel F	75	100	1	Middle
Monika F L	50	50	0	Low
Nabilla N A	75	100	1	High
Naila A Y	75	100	1	High
Nathania L	0	75	0,75	High
Noval Lexa	25	50	0,33	Middle
Olda S B P	50	100	1	High
Rachella G A	75	100	1	High
Rehuel N S	50	75	0,5	Middle
Rufaida Binti	75	100	1	High
Sulthan Rasyid	75	100	1	High
Vika Laras J S	75	100	1	High
Sum	**1325**	**2900**		
Average	**36,8**	**80,56**	**0,75**	**High**

From the results of the N-gain calculation, it can be concluded that learning using interactive learning media based on GeoGebra Classroom can increase students' mathematics learning creativity, especially in quadratic function material with an average score increase of 0.75 in the high improvement category.

Discussion

Practical implications if obtained interactive learning media based on GeoGebra Classroom that is valid, practical, and effectively used in learning quadratic function material. The results of this study in the form of interactive learning media based on GeoGebra Classroom can be an alternative learning media used by math teachers in teaching quadratic function material for class X, especially in learning with the Sekolah Penggerak curriculum. This learning media can also be used as a media for students learning independently during online learning during a pandemic. The features contained in interactive learning media based on GeoGebra Classroom help students understand the material and can increase student learning creativity in quadratic function material. The research results for schools are that interactive learning media based on GeoGebra Classroom can be one of the learning innovations in mixed learning (PTM and PJJ) to achieve optimal learning processes and outcomes during online learning activities as well as offline learning at school. The school can organize socialization and training regarding the development of learning media that are innovative, attractive, and capable of being used in various situations. This can also be a real form of school effort to implement the Sekolah Pengerak curriculum.

Theoretical implications occur when more and more research is carried out that can bridge the theory and practice of developing interactive learning media to increase student learning creativity. From the results of the research, it can be said that the GeoGebra Classroom-based interactive learning media that has been developed can complement previous studies by adding important components that do not yet exist. The results of this study can strengthen previous studies that the development of interactive learning media based on GeoGebra Classroom produces learning media that are valid, practical, and effective in learning mathematics. Not only that, but interactive learning media based on GeoGebra Classroom is also proven to be able to increase student learning creativity in quadratic function material.

Conclusion

Based on the results of research and discussion regarding the development of GeoGebra Classroom-based interactive learning media on quadratic function material, the following conclusions are obtained: The process of developing GeoGebra Classroom-based interactive learning media is carried out based on the 4D development model. At the define stage, interviews were conducted with mathematics teachers to obtain information in the form of reasons for the need for development, learning systems, and student characteristics. At the design stage, the researcher draws up a product design plan, makes the initial product, and chooses the right testing strategy. Furthermore, for the development stage, researchers carried out several activities, namely, making learning media products as a whole, conducting expert validation, revising products, and conducting trials. At the dissemination stage, limited dissemination activities were carried out, namely by disseminating and promoting the final product in a limited way to mathematics teachers at SMAN 3 Surakarta.

Based on the results of a questionnaire assessment by media experts and material experts, it was found that interactive learning media based on GeoGebra Classroom met the validity criteria. The average rating of media experts is 0.889, including the very good assessment criteria. For the assessment of material experts, an average of 0.872 was obtained, including the very good assessment criteria. Therefore, it can be concluded that interactive learning media based on GeoGebra Classroom is valid to use in learning quadratic function material.

Based on the results of user response questionnaire assessments by teachers and students, it was found that interactive learning media based on GeoGebra Classroom met the practical criteria. The average user response questionnaire rating by the teacher is 100% including the very good assessment criteria. For the user response questionnaire assessment students, obtained an average score of 78.765% included in the good assessment criteria. Therefore, it can be concluded that interactive learning media based on GeoGebra Classroom is practically used in learning quadratic function material. Based on the results of the one-way ANOVA test, Fobs

= 5.308 with DK = {F│F>3.98}. This shows the results that the average test score of student learning outcomes using interactive learning media based on GeoGebra Classroom on the quadratic function material is different from the average score on student learning outcomes that do not use interactive learning media based on GeoGebra Classroom with a mean difference of 12.004 and because the class average is using interactive learning media based on GeoGebra Classroom is higher, which is equal to 72.56 compared to the average class that does not use interactive learning media based on GeoGebra Classroom, which is equal to 60.556. Therefore, it can be concluded that interactive learning media based on GeoGebra Classroom is effectively used in learning quadratic functions. Based on the results of the pre-test and post-test the students' learning creativity was tested in a class using interactive learning media based on GeoGebra Classroom. Obtained an average N-gain result of 0.75 with a very high improvement category. Thus, it can be concluded that it can increase student creativity in quadratic function material.

Recommendations

Schools can utilize interactive learning media based on GeoGebra Classroom for use in learning quadratic functions in class X. Mathematics teachers can use GeoGebra Classroom as an alternative learning media in teaching and learning activities on the topic of quadratic functions. Regarding efforts to improve competence according to the profile of Pancasila students, teachers can review student learning outcomes based on indicators of learning outcomes assessment related to Pancasila student profiles, such as the ability to think critically and creatively. Students can take advantage of interactive learning media based on GeoGebra Classroom to learn mathematics on the topic of quadratic functions both classically and independently. This media is also able to help students improve their learning creativity through independent exploration activities by simply following the instructions given. Other researchers can implement the use of this media more broadly, for example by using more classes or even several schools. The development of interactive learning media based on GeoGebra Classroom can be used as a reference for other researchers in developing mathematics learning media. The general public can use the GeoGebra Classroom learning media for the topic of quadratic functions by selecting the Resources feature in GeoGebra Classroom and then choosing learning activities that have been provided by researchers with the trisedyafebrianti23 account.

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Teaching Computational Thinking in Mathematics Education: A Systematic Literature Review

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Abstract: This study aims to get an idea of how computational thinking should be taught in mathematics and what strategies can be used to measure computational thinking skills so that stakeholders such as mathematics teachers and lecturers get clear and detailed information about how to teach computational thinking skills in mathematics learning in various education level. The dimensions in this research are related to Computational Thinking which is analyzed based on time period, level of education, school mathematics material, and learning media used in learning activities. Overall, over the last 10 years, this research has been carried out with the highest significance being carried out in 2021. Most applications of teaching computational thinking are carried out at the junior high school level. The selection of specific school mathematics material to be used in teaching computational thinking is not an absolute rule, but the most widely used material is number patterns. The media used in teaching computational thinking can use computer network-based technology, or without using a computer network. This literature review provides information that computational thinking in mathematics education can be carried out optimally by paying attention to how teachers help students understand algorithms and data, especially in activities that utilize simulations with the help of plug-in media or unplugged-in media. We see that teaching computational thinking skills means we teach students the process of solving problems.

Keywords: Computational Thinking, Mathematics Education, Systematic Literature

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Introduction

Computational Thinking is one of the additional skills that is becoming a global trend in the world of education, culture, and science. Computational thinking has even been proposed to complement the 4 C skills (Critical thinking and problem solving, Creativity, Communication and Collaboration) issued by UNESCO as "skills" needed by digital generation. The rapid development of technology and digital culture that occurs in various lines of human life, requires us to have the ability to be able to overcome these difficulties and challenges, one of which is the ability to think computationally (Subramaniam et al., 2022). Computational thinking is an important thinking skill and even a compulsory lesson in school (Maharani et al., 2020). Adopting the 21st century curriculum until 2030, all countries in ASEAN must integrate the 5C skills into their respective national curricula.

The integration of computational thinking in the national curriculum in ASEAN countries has certainly been carried out. Several ASEAN countries, such as Malaysia (Bahrudin et al., 2022) and Thailand (Katchapakirin et al., 2022), have included computational thinking skills since early 2017 in their national curriculum. Even though Indonesia had removed ICT subjects from the curriculum since the 2013 curriculum (K-13) began to be implemented throughout Indonesia in 2014, the Indonesian government has shown its attention to fostering computational thinking skills, as evidenced by creating bebras activities since 2016. Bebras is an international initiative whose aim is to promote Computational Thinking (Thinking based on Computing or Informatics), among teachers and students starting at the elementary school level, as well as for the wider community. Apart from that, Indonesia has adopted the K12 Computer Science Curriculum to be implemented as a national curriculum for primary and secondary education, which was ratified on December 20 2018 as Minister of Education and Culture Regulation no. 37 of 2018 as an amendment to Permendikbud number 24 of 2016. Understanding the concept of informatics in the basics of Computer Science is closely related to computational thinking skills (Pertiwi et al., 2020). Therefore, in solving problems students will be trained to think computationally by using steps to develop solutions using computer science concepts. This step of thinking is further called computational thinking.

Computational thinking is a thinking skill that focuses on the skills, habits, and dispositions needed to solve complex problems with the help of computing and computers. Computational thinking includes the ability to distinguish multiple levels of abstraction and apply mathematical reasoning and design-based thinking (Maharani et al., 2020). Over the past few years, teaching computational thinking in schools, especially for K-12 schools, has seen a considerable increase in interest. Some countries such as Estonia, Israel, Finland, and the UK have integrated computational thinking education into the school curriculum because they understand the need and benefits of computational thinking in education (Angeli & Giannakos, 2020). Efforts in teaching or building Computational Thinking skills have been made in secondary school students by treating computer science as a main subject, including science, math, engineering, and robotics (Polat et al., 2021). Computational thinking can not only be introduced and developed in computer or programming lessons but can also be applied in mathematics learning (Cahdriyana & Richardo, 2020). So from this description, it can be said that computational thinking is also related to mathematics and can be applied in learning mathematics.

The idea of integrating computational thinking in mathematics learning is not new. Computational thinking emerged as an approach to problem-solving that does not only apply conceptual mathematics but to learn the true value of mathematics in everyday life (Maharani et al., 2020). The ability to think in mathematics learning which consists of a coherent process with clear steps and procedures (algorithms), calculations (computation), determining the right strategy, and oriented to problem solving requires the ability to think computationally (Cahdriyana & Richardo, 2020). If adopting the definition of computational thinking ability by Park & Green (2019) that the components of computational thinking are outlined in Table 1 below.

Table 1. Components of Computational Thinking

Component	Description
Decomposition	Solving a problem into parts
Pattern Recognition	Analyzing data, looking for patterns to make sense of the data
Abstraction	Removing unnecessary details and focusing on the important things
Modeling/Simulation	Creating a model or simulation to represent the process
Algorithms	Create a series of sequential steps to be taken to solve a problem
Evaluation	Determining the effectiveness of a solution, generalizing and applying to new problems

The six components of computational thinking skills in Table 1 are described separately to guide learning activities or assessment development but in reality, all components are interrelated. With computational thinking, a person will be easy to observe problems, find solutions to problems, solve problems, and be able to develop solutions or problem-solving. The integration of CT in mathematics learning aims to help students develop analytical, problem-solving, and critical thinking skills.

In recent years, there have been many literature review studies on computational thinking in various fields. Previous literature review studies related to teaching computational thinking skills other than in computer science disciplines have also been conducted in other disciplines such as science disciplines (Ogegbo & Ramnarain, 2021; Suharto, 2022), physics disciplines (Ifriliya et al., 2022), and mathematics disciplines (Subramaniam et al., 2022). In addition, the teaching of computational thinking skills also have been taught in early childhood education (Bati, 2022) and elementary school (Kakavas & Ugolini, 2019; Suwahyo, 2020; Montiel & Gomez-Zermeño, 2021; Li et al., 2022; Su & Yang, 2023).

Although the importance of CT is recognized, there is still a lack in the development of effective methods and curricula to teach CT in the context of mathematics education. For stakeholders such as mathematics teachers and lecturers, determining tools in the form of methods and media that are appropriate and suitable for the level of students is an important thing that must be considered as preparation before teaching so that the learning objectives are maximally achieved. As with general methods, each teaching field has its methods (Kurt &

Yavuz, 2018). This study will investigate the potential of integrating CT in mathematics learning to improve students' analytical thinking and problem-solving skills.

This study provides a systematic review of the literature on teaching computational thinking skills focusing on articles relevant to the dimensions to be studied published in academic journals, theses, and dissertations in the field of mathematics. The main objective of our research is to examine the process of developing computational thinking skills in mathematics education through an empirical study review. The dimensions in this study related to Computational Thinking are analyzed based on time period, education level, school mathematics materials, and tools used.

Method

Research Design

This type of research is descriptive research with the Systematic Literature Review method. Systematic Systematic Literature Review (SLR) is defined as the process of identifying, assessing, and interpreting all available research evidence to provide answers to specific research questions (Kitchenham et al., 2009). The stages of this research process follow the guidelines from Kitchenham & Charters (2007), namely Planning, Conducting, and Reporting. Based on the explanation from Zawacki-Richter et al. (2020), systematic literature review procedure in more detail begins with developing research questions. Furthermore, designing a conceptual framework, building selection criteria, developing a search strategy, selecting studies using selection criteria, coding studies, assessing study quality, synthesizing individual study results to answer research questions, and the final stage is reporting findings or analysis results. To obtain in-depth research results, data collection in this study used the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) method. The PRISMA method has a clear systematics by the research protocol (Stovold et al., 2014).

In this study, researchers used secondary data obtained not from direct observation. The data is obtained from the results of research that has been conducted by previous researchers. The secondary data sources used in this study are primary or original reports contained in scientific publication articles or journals obtained online. In this study, the sample is national and international research articles related to the research title published during the last 10 years.

Selection Criteria

In this process, inclusion and exclusion criteria were set based on the Systematic Literature Review protocol as shown in Table 2. Considered on research field maturity concept by Kraus et al., (2022), we was done the screening procedure and restricted to items published between the years 2013 and 2023.

The techniques for encouraging computational thinking in mathematics education were the focus of the publications in the journal (research article) or conference proceedings. The database were selected for the quality and nature of their publications, particularly in the education field. Figure 1 shows the methodical approach to answer the questions in this literature study. Furthermore, based on the results of the literature search and the inclusion and exclusion process, 24 articles were obtained for further analysis.

Table 2. The Eligiblity of An Exclusion Criteria

Criterion	Eligibility	Exclusion
Litelature Type	Journal (research article) or conference proceeding	Book, book series and chapters, or systematics review articles
Language	English or Indonesia	Non-English or Non-Indonesia
Timeline	Between 2013-2023	Before 2013

Data Analysis

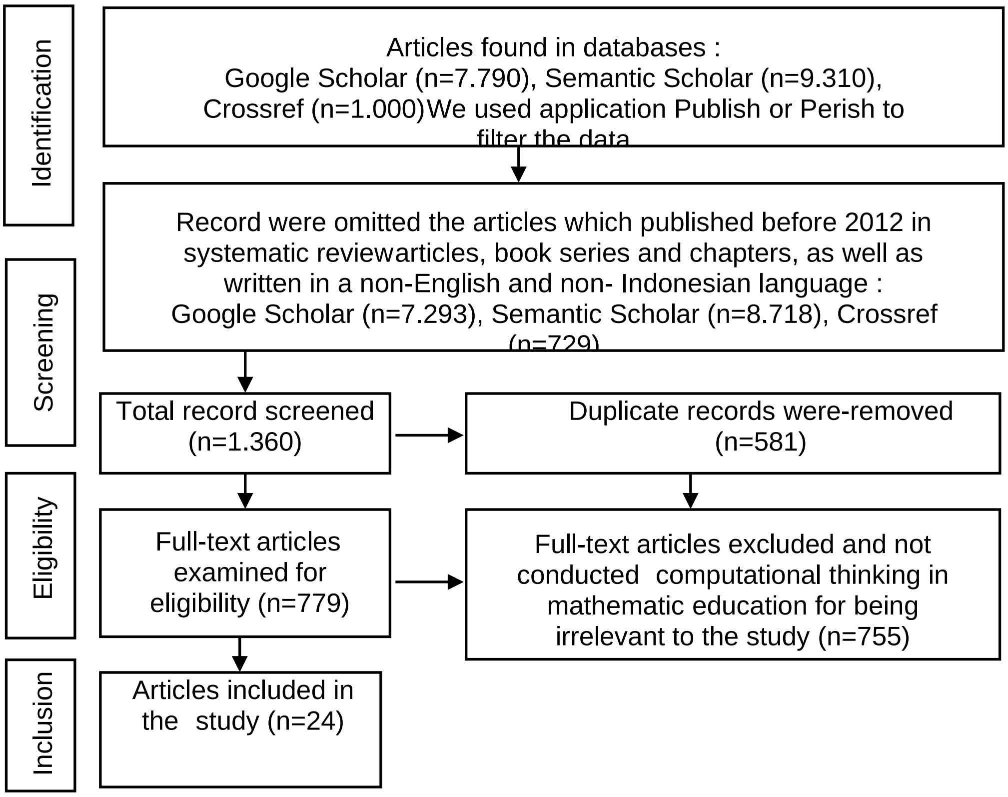

Figure 1. PRISMA Systematic Review Adapted from Page at al. (2021)

The data collected were analyzed using content analysis. Based on a preliminary search, there are 18.100 articles scattered in 48 subdiciplines. We filtered the data back using one subdicipline namely Mathematics Education. The analysis was conducted by synthesizing data and information related to Computational Thinking based on the dimensions of time period, education level, school mathematics materials, and tools or media used in learning.

Results

From the results of the manual synthesis of the selected primary studies, the author took the points or keywords used by the author in expressing the concept of the researcher. For studies conducted by the same person but published in different years, the author re-synthesized by looking at the similarities, if there are similarities then choosing one of them is the most representative, but if the content and topic are different then it will still be used as material in this study. We got twenty-four studies synthesized in this study, namely Weintrop et al. (2014), Basawapatna et al. (2014), Apriyanto (2016), Costa et al. (2017), Bati et al. (2018), Yang et al. (2018), Abdullah et al., (2019), Reichert et al. (2020), Rodríguez-Martínez et al. (2020), Sung & Black (2020), Supriyadi & Rustam (2020), Barana et al. (2020), Valovičová et al. (2020), Soboleva et al. (2021), Maharani et al. (2021), Yang et al. (2021) Van Borkulo et al. (2021), Rosali & Suryadi (2021), Andriyani, et al. (2021), Memolo (2022), Aminah et al. (2022), Maksum et al. (2022) Çiftçi & Topçu (2022), and Yasin & Nusantara (2023).

Computational thinking in mathematics education by year of publication

Over the last 10 years, the teaching of computational thinking in mathematics education began to be published in 2014. The distribution of the number of studies on teaching computational thinking in mathematics education over the last 10 years is outlined in the line diagram in Figure 2. From Figure 2, it is known that in 2013 there was no research on efforts to foster and improve computational thinking skills in mathematics education, but from 2014 to 2023 researchers' interest in teaching computational thinking skills in mathematics education began to grow, and every year there is always.

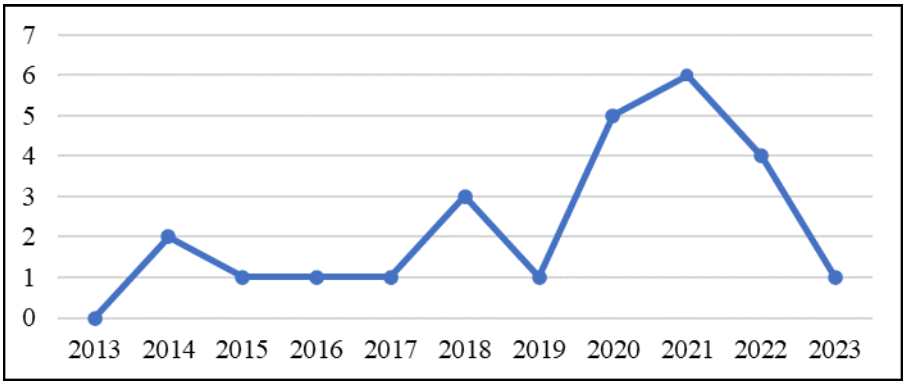

Figure 2. Distribution of the number of publications per year

The number of studies on computational thinking in mathematics education increased in 2017-2018, 2019-2021, and 2020-2021, while in 2014-2015, 2018-2019, 2021-2022, and 2022-2023 there was a decrease. A very significant increase in the number of studies on computational thinking in mathematics education occurred in 2019-2020, which was 400%. The most research was conducted in 2021. For 2023, there is 1 paper, assuming that there is still related research being conducted or in the process of publishing after this study is conducted considering that the data used in this study is limited to April 11, 2023.

Computational thinking in mathematics education by level of education

Based on the literature reviewed, research on computational thinking in mathematics education was conducted at all levels, namely elementary school, junior high school, senior high school, and university. The synthesis of the articles reviewed in this study obtained the percentage of each research on computational thinking in mathematics education at each level of education as illustrated in Figure 3.

From Figure 3, it is known that the highest percentage of research on computational thinking in mathematics education is at the Junior High School level, which is 40% or as many as 10 studies, while the lowest percentage is research conducted at universities, which is 16% or as many as 4 studies. The teaching of computational thinking at the university level is done to students majoring in mathematics as done by Aminah et al., (2022); Maharani et al., (2020); and Çiftçi & Topçu, (2022), or done to students majoring in engineering but in mathematics by Apriyanto (2016).

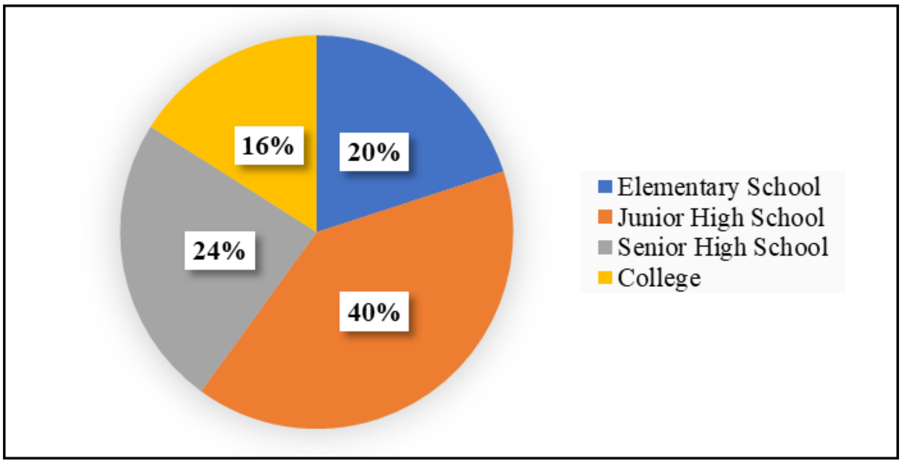

Figure 3. Percentage of Research on CT Based Education Level

Computational thinking in mathematics education based on mathematical materials or topics

Based on the results of data synthesis in this study, the content of mathematics materials used in teaching computational thinking skills was obtained, the details of the content are described in Figure 4 below. According to NCTM (National Council of Teachers of Mathematics), there are five standards of mathematics content taught in the classroom, namely number & operations, algebra, geometry, measurement, and data analysis & probability. However, in this case, the synthesized data is presented in more specific content. Number pattern is the most widely used math content to teach computational thinking skills in mathematics, namely research conducted by Abdullah et al. (2019), Rodríguez-Martínez et al. (2020), Rosali & Suryadi (2021), Memolo (2022), Çiftçi & Topçu (2022), and Yasin & Nusantara (2023). Furthermore, linear equations and geometry are the two most widely used mathematics contents in teaching computational thinking in mathematics education. For studies that use measurement, data analysis & probality, and computational mathematics materials, there is only one each.

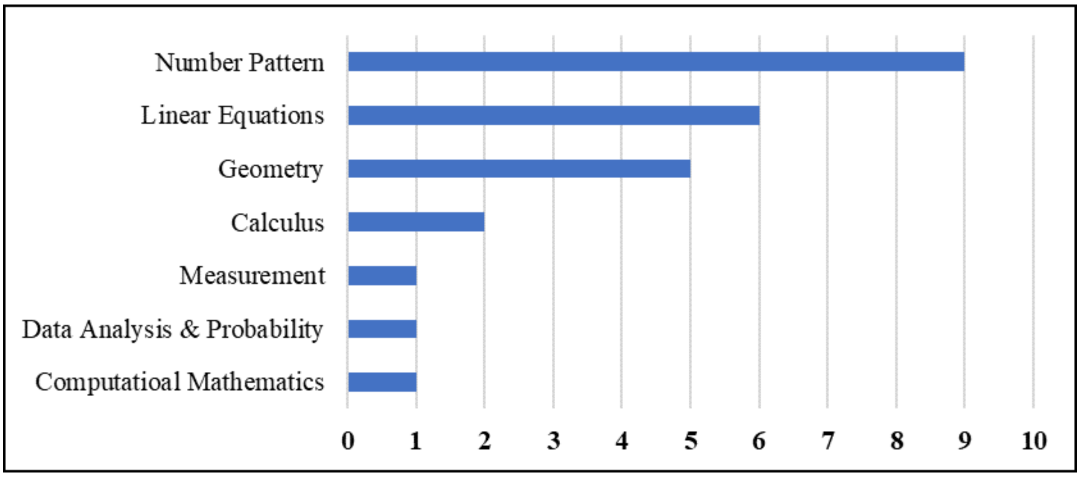

Figure 4. The Amount of Mathematics Content in Teaching CT

Teaching computational thinking in mathematics education using media

The results of the data synthesis obtained the distribution of media use in teaching computational thinking itself, which we present in Figure 5. In this study obtained data that, teaching students' computational thinking skills in the classroom can be done using learning media or without learning media. If using learning media, there are two types: first, media that requires electronic devices or digital technology when accessed or used or in this case we call it plugged-in media and second, media that does not require electronic devices or digital technology when it will be used or accessed, in this case we call it unplugged-in media.

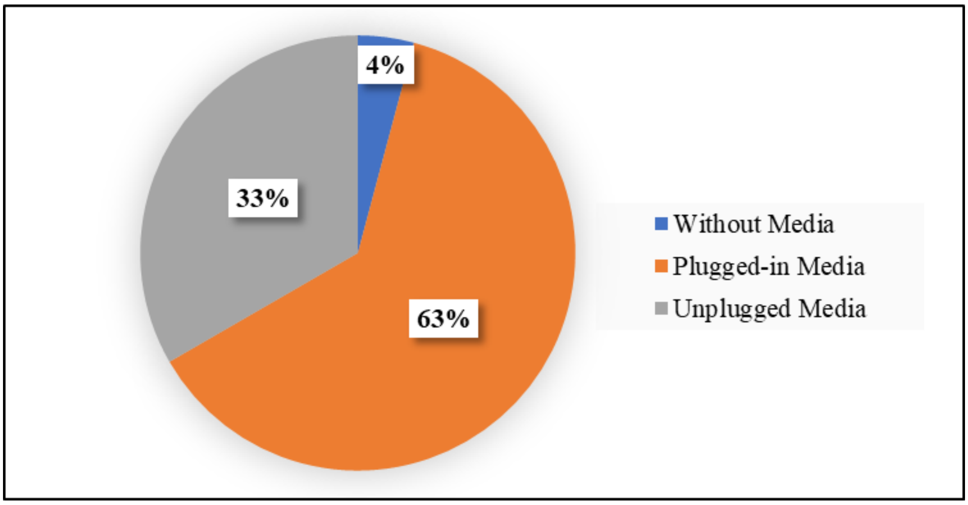

Figure 5. Distribution of Media Used in Teaching CT

Based on Figure 5, it is known that teaching computational thinking in mathematics education mostly uses plugged-in media, namely 63% or 15 studies. Meanwhile, teaching computational thinking without using media only amounted to 4% or one study.

Discussion

Our findings in this study show that there have been ups and downs in the number of studies examining the teaching of computational thinking in mathematics education over the past 10 years. The increase in the number of studies related to this issue began to increase in 2020 and continued until 2021. The most significant increase occurred in the 2019-2020 timeframe, but the largest number of studies was in 2021. The reason behind the increase in publications may lie in the fact that research with a focus on computational thinking in mathematics learning has been widely investigated due to the increasing popularity of computational thinking in general in education. This is in line with the findings of Rafiq et al. (2023) in their study, that research on computational thinking in education began to become a concern and increased since 2013. Although in our study we found different things, in 2013 computational thinking research conducted specifically in mathematics education did not find publication. In terms of the decline in the number of studies on computational thinking in mathematics education itself needs to be analyzed further. The decrease in the number of publications is due to several possibilities, for example there are still researchers who do not understand how to teach computational thinking or are not familiar with computational thinking itself, or have conducted research on it but have not been published.

In general, if you see a phenomenon where the number of research publications tends to go up and down, then of course the factors that cause it can come from internal or external researchers themselves. If described in more detail, external factors that may cause the high and low number of research on computational thinking are (1) the availability of resources and facilities, such as software and hardware, to support research, (2) the need for research to address certain problems or challenges, and (3) the availability of funds and support for research. The problems faced by researchers affect the learning process which creates a difficult stigma for teachers, so they tend to avoid these difficulties. This is supported by the results of research by Kadaria et al. (2020) where one of the factors that make teachers difficult in the learning process is limited facilities and infrastructure. However, of course there are other factors that are internally derived from the researchers themselves, such as the perceived importance and relevance of the topic as well as curiosity, motivation, and personal needs.

A researcher who works as a student, teacher, or lecturer can teach computational thinking in mathematics education at the elementary, junior high, high school, and university levels. Basically, teaching computational thinking in mathematics education has a good effect on every child at all levels of thinking. Based on Piaget's theory (in Wardani, 2022) the cognitive development level of elementary school children is at the concrete operational stage, namely ages 7-11 years, where children are able to develop logical thinking and the ability to understand concrete concepts and classify objects and understand the concept of conservation. Whereas at the age of 12 years and above, for junior high school to university level, children are at the formal operational stage where children are able to develop abstract thinking and the ability to reason logically and can think about hypothetical situations and engage in deductive reasoning. This means that at whatever level of education computational thinking is taught in metamatics education, cognitive development in the form of thinking and reasoning skills will develop with age. Any learning obtained by the child will have an impact on the child's actual abilities to help him in undergoing further development at a higher level.

This study found that research at the junior high school level was most prevalent. This is partly because middle school students are at a critical stage of cognitive development, where they are developing logical thinking and the ability to understand abstract concepts. In addition, middle school is the transition period of students from childhood to adolescence, which may make them more interesting subjects to research. As for the lowest level of research on computational thinking in mathematics education, it is conducted at the university level. Research at the university level is most likely to be carried out by a lecturer, because of the ease of access to licensing and scientific competence, but according to Alwiyah et al. (2016) several reasons exist that hinder lecturers in conducting research, including high teaching loads and structural duties. Furthermore, Iqbal & Mahmood (2011) added that the reason why research studies at the university level are less common is the lack of research competence among researchers. This research competence can be in the form of teaching materials or materials that will be used in the learning itself. So that this affects the low interest in research among students.

In teaching computational thinking, teachers can use various topics or mathematical materials contained in the mathematics education curriculum. If we look at Figure 4, we know that the most commonly taught topic is Row Patterns. The row pattern itself is a school mathematics material that begins to be taught at the junior high school, high school, and university levels. According to Memolo (2022), learning mathematical material of number pattern is very relevant in teaching students computational thinking. This is because the concept of computational thinking itself includes the ability to recognize patterns and formulate algorithms, which are skills developed through learning number patterns.

However, this does not mean that other materials in mathematics are not suitable for use in building students' computational thinking. As shown in Figure 4, the second most used material is linear equations. The linear equations material is identical to various numbers, symbols, graphs and others that are very close indicators of numerical skills. These numerical skills include accuracy in performing arithmetic operations by understanding the concept of numbers and initiating information obtained from the understanding process. This requires computational thinking skills, so that directly in the learning process can teach and foster students' computational thinking skills. The third most common material used to teach computational thinking skills in mathematics is geometry. This material can be found in the curriculum in junior high school and senior high school. The development of computational thinking skills that have pattern recognition and abstraction is close to geometry material that has special characteristics or patterns in its shape and abstraction that is in two dimensions and 3 dimensions and with the context of student life.

Teaching computational thinking skills in learning can be started by giving problems. According to Yasin & Nusantara (2023), teaching computational thinking as an activity can be built by giving problems that are designed in such a way that students can read patterns in finding solutions to problems. This means that computational thinking is an ability that can make it easier for someone to solve a simple or complex problem. There are several characteristics of computational thinking as a problem-solving process described by Bocconi et al. (2016), namely (1) formulating problems that can make someone use computers and other tools to help find solutions, (2) managing and analyzing data logically, (3) representing data through abstractions such as models and simulations, (4) automating solutions through algorithmic thinking (a series of sequences of steps), (5) identifying, analyzing, and implementing all possible solutions to achieve the most efficient and effective steps from existing resources, and (6) generalizing and transferring the problem-solving process to various problems.

If teaching computational thinking skills means teaching students to solve problems with computational thinking processes, it means that we need to pay close attention to the delivery process, the teaching process, and the results received by students. Just like teaching other thinking skills, computational thinking skills can be taught directly without the need for media or with the help of media. The media here is not only used by the teacher, but can also be used by students in the thinking process of finding a solution to a problem. If teaching computational thinking in mathematics education without using media certainly requires direct instruction to students so that students can have an idea of what to do in order to solve the problem given. Especially if the students are at the elementary school level, with a low level of thinking ability, students need direction or instruction in order to provoke students to think and perform the stages of computational thinking. In this case, students are given problems without any discussion in groups. This makes all students have to actively think with computation to solve a problem. In essence, students can use the basic knowledge they already have to solve math problems through computational thinking. This is in accordance with the expression of Ojose (2008) that one of the important challenges in teaching mathematics is to help students make connections between mathematical concepts and their activities. So of course they need direction and assistance from their teachers. Children may not automatically make the connection between the work they do with manipulative materials and the corresponding abstract mathematics (Burns & Silbey, 2000).

In the learning process, of course, the use of media is one of the alternatives that can help the learning process itself to be easier to convey, easier to accept, and easier to understand by students. The media used can be plugged-in media or unplugged-in media. Each type of media has different characteristics, plugged-in media utilizes technology and internet access and tends to be interactive. Plugged-in media is able to present information with various multimedia formats such as text, images, audio and video. This is able to maximize student understanding in the learning process because interactive media with technology can provide personalized learning for each student according to their ability level. According to Sung et al. (2017) and Markandan et al. (2019), teaching computational thinking using technology can be an effective way to engage students and enhance their learning experience. Here are some ways technology can be used to teach computational thinking in mathematics. By using programming tools, online platforms and educational games, teachers can engage students and help them develop important computational thinking skills. In addition, the use of technology can help students visualize and understand mathematical concepts, thus enhancing their learning experience.

Furthermore, for unplugged-in media that are conventional without requiring an internet connection and can be used without dependence on electronic devices such as wireless games or in student activity sheets as used in studies such as those conducted by Maharani et al. (2021), Maksum et al. (2022), Aminah et al. (2022), and Yasin & Nusantara (2023). The use of this student worksheet creates student activities that stimulate their computational thinking skills in solving a problem. This unplugged activity requires technology but is still effective in teaching computational thinking. Considering the advantages and limitations of these two types of media, in the context of teaching computational thinking, a combination of these two types of media is highly recommended to provide a balanced and holistic learning experience.

In classroom learning activities, plugged-in media and unplugged-in media can be given to students without instructions or using direct instructions or indirect instructions. Student learning activities can be maximized by using the discussion method, although there are weaknesses in the discussion method because usually only a few students are active, but the discussion method can stimulate students to provide creative ideas or ideas and can exchange ideas so that computational thinking activities in an effort to solve problems feel easier.

However, it does not rule out the possibility that the learning process can still learn well and learning objectives can still be achieved without using media, only by giving problems and then asking students to discuss, such as research conducted by Rosali & Suryadi (2021). According to Ahn et al. (2021) step-by-step instructions through oral instructions given by teachers can make students actively involved in thinking which will develop their computational thinking skills.

Conclusion

Computational thinking is a must-have skill for students, so it is important to teach and improve through mathematics learning. This has been realized by researchers, educators and all educational stakeholders. Efforts to develop these skills have been made by researchers, educators and all educational stakeholders over the past 10 years at every level of education from elementary, junior high, high school to university. The selection of specific school mathematics materials to be used in teaching computational thinking is not an absolute requirement, meaning that any mathematics material in the curriculum can be used to teach computational thinking skills. The literature review that has been conducted provides information that computational thinking in mathematics education can be done optimally by paying attention to how teachers help students to understand algorithms and data, especially in activities that utilize simulations using both traditional and technology-based media.

We see that in teaching computational thinking skills, we are teaching students the process of problem solving. This adopts the operational definition of computational thinking described by Barr et al. (2011) as it supports the idea of developing computational thinking skills in every curriculum across all levels and content. Furthermore, Barr et al. (2011) said that computational thinking as a problem solving process is (i) Formulating problems that can be done using media to help solve them, (ii) Analyzing data logically, (iii) Creating abstractions such as models and simulations, (iv) Automating solutions through algorithmic thinking, (v) Identifying, analyzing, and implementing the most efficient and effective solutions, and (vi) Generalizing and transferring these problem solving processes to a wide variety of problems.

Recommendations

The results of this literature review show that some dimensions have been fully studied but there are still some that are limited, for example, studies on the dimensions of teaching methods used in teaching computational thinking in a learning activity. Future research is recommended to add these dimensions or focus on how to develop a practical framework that can be used to teach computational thinking skills to students at various levels and in various subject areas, especially mathematics education.

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Experimentation and Analysis of a Multistage Full Bridge Regulator

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Abstract: The Full Bridge Rectifier is a widely recognized type of a rectifier, and it is expected to outperform a half-bridge rectifier due to its ability to convert negative signals oscillating between 180 and 360 degrees into positive signals. You can derive the design formulas for a full bridge regulator from the circuit diagram by applying Kirchhoff's voltage law with two loops. The innovation introduced in this paper involves adding a parallel capacitor alongside the load resistor between four diodes. To improve the reduction of output ripple voltage and facilitate the step-down of a high supply voltage from an unknown line voltage, we propose a cascaded multistage full bridge regulator. When measuring the output voltage ripples, we observed values ranging from 80 mVpp to 120 mVpp with input frequencies of 50 Hz and 10 kHz, as well as input amplitudes of 5 Vpp and 20 Vpp. These measurements were conducted using the same capacitor, a function generator, and an oscilloscope.

Keywords: Full Bridge Rectifier, Full Bridge Regulator, Multi-Stage Full Bridge Regulator

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Introduction

The full bridge rectifier maintains a positive signal during the first half of the period through dynamic biasing of two diode loops (D1 and D2). Simultaneously, it inverts a negative signal into a positive signal during the second half of the period through the forward biasing of the other two diode loops (D3 and D4) from the differential signal. Upon analyzing the full bridge regulator, it becomes evident that during the first half of the output voltage, a double-pole frequency occurs due to the D1 and D2 diodes in the Kirchhoff's Voltage Law (KVL) loops if Equation (2.3) has a second-order term. Similarly, during the second half of the output voltage, a two-pole frequency arises due to the D3 and D4 diode loops.

The output voltage can be expressed as a function of the voltage drop across the diodes. The pole frequency can also be expressed as a function of the capacitive and resistive loads, which can be derived accordingly. In a full bridge diode regulator, there are two distinct loops to consider. The first loop begins with a signal source connected to the negative terminal (phase-shift 90 degrees compared to the positive terminal). It encompasses the voltage drop across diode D1, the voltage drop across the resistor and capacitor, and finally, the voltage drop across diode D2. This loop can be represented by the following equation.

$$-V_{in} + V_{D1} + V_{out} + V_{D2} = 0 \qquad (1)$$

The diode current equation can be expressed as an exponential function of the voltage drop and thermal voltage as follows.

$$I_{D1} = I_{S1} e^{\frac{V_{D1}}{V_T}} \rightarrow V_{D1} = V_T \ln\left(\frac{I_{D1}}{I_{S1}}\right)$$
$$I_{D2} = I_{S2} e^{\frac{V_{D2}}{V_T}} \rightarrow V_{D2} = V_T \ln\left(\frac{I_{D2}}{I_{S2}}\right) \qquad (2)$$

Kirchhoff's current law can be applied at the cathode terminal of a diode D1. The current flowing through the diode enters node V2 and is equal to the sum of the capacitive current flowing through the capacitive load and the resistive current flowing through the resistive load.

$$I_{D1}(t) = I_{C_L} + I_{R_L} = C_L \frac{dV_{out}}{dt} + \frac{V_{out}}{R_L} \qquad (3)$$

This equation can be transformed into the frequency domain using Laplace's transform.

$$I_{D1}(s) = V_{out}\left(sC_L + \frac{1}{R_L}\right) \qquad (4)$$

The equation below, shows similar application of Kirchhoff's current law at the cathode terminal of diode D2. The current flowing through the diode enters node V3 and is equal to the sum of the capacitive current flowing through the capacitive load and the resistive current flowing through the resistive load.

$$I_{D2}(t) = I_{C_L} + I_{R_L} = C_L \frac{dV_{out}}{dt} + \frac{V_{out}}{R_L} \qquad (5)$$

Similarly, this equation can equally be transformed into the frequency domain using Laplace's transform.

$$I_{D2}(s) = V_{out}\left(sC_L + \frac{1}{R_L}\right) \qquad (6)$$

Equation (2) can be substituted into equation (1) as follow

$$-V_{in} + V_{D1} + V_{out} + V_{D2} = 0 \rightarrow -V_{in} + V_T \ln\left(\frac{I_{D1}}{I_{S1}}\right) + V_{out} + V_T \ln\left(\frac{I_{D2}}{I_{S2}}\right) = 0$$
$$V_T \ln\left(\frac{I_{D1}}{I_{S1}} \times \frac{I_{D2}}{I_{S2}}\right) = V_{in} - V_{out} \rightarrow I_{D1} \times I_{D2} = \left(I_{S1} \times I_{S2}\right) \exp\left(\frac{V_{in} - V_{out}}{V_T}\right) \qquad (1.2)$$

An arrow, pointing from the left-hand side of the first line of equation (1.2), signifies that it can be substituted into the equation to impact the result on the right-hand side. In the second line of equation (1.2), the expression within the logarithm's bracket can be multiplied according to the rule of converting the addition of logarithms into the multiplication of the two expression within the bracket. Subsequently, the parameter known as the thermal voltage, which is the natural logarithm of the product of two diode current values divided by the product of two saturation current values of a diode, can be divided on both sides of the equation. This allows a group of physical parameters within the natural logarithms' bracket to emerge on the right-hand side of the second line of equation (1.2) after exponentiation of a group of normalized voltages. These normalized voltages are functions of the input signal, DC output voltage, and thermal voltage.

Substituted an equation (4) and an equation (6) into an equation (2.2) as following

$$I_{D1} \times I_{D2} = (I_{S1} \times I_{S2})\exp\left(\frac{V_{in} - V_{out}}{V_T}\right)$$

$$\left(V_{out}\left(sC_L + \frac{1}{R_L}\right)\right)^2 = (I_{S1} \times I_{S2})\exp\left(\frac{V_{in} - V_{out}}{V_T}\right) \qquad (2.3)$$

$$V_{out}^2 = \frac{(I_{S1} \times I_{S2})}{\left(sC_L + \frac{1}{R_L}\right)^2}\exp\left(\frac{V_{in} - V_{out}}{V_T}\right)$$

The third line of equation (2.3) involves taking the square root of the output voltage of the full bridge diode regulator, which allows for the utilization of this output voltage in various design tasks.

$$V_{out} = \pm \frac{\sqrt{I_{S1} I_{S2}}}{C_L\left(s + \frac{1}{C_L R_L}\right)}\sqrt{\exp\left(\frac{V_{in} - V_{out}}{V_T}\right)} \qquad (2.4)$$

Equation (2.4) represents a frequency domain equation. Additionally, the input voltage, originating as a signal source, can be transformed into a sinusoidal signal in the frequency domain and can be expressed as follows.

$$V_{in}(t) = A\sin(\omega t) \rightarrow V_{in}(s) = A\left(\frac{\omega}{s^2 + \omega^2}\right) \qquad (2.5)$$

While this function is not dependent on time, it is, however, a transformation of the function described in equation (2.4) using a single pole transformed pair.

$$V_{out}(t) = \pm \frac{\sqrt{I_{S1} I_{S2}}}{C_L}\sqrt{\exp\left(\frac{V_{in} - V_{out}}{V_T}\right)}\exp^{-\frac{t}{C_L R_L}} \qquad (2.6)$$

If the function in equation (2.6) is used to calculate the derivative with respect to time, it could represent a real frequency or a pole frequency.

$$\frac{dV_{out}(t)}{dt} = \pm \frac{\sqrt{I_{S1} I_{S2}}}{C_L}\sqrt{\exp\left(\frac{V_{in} - V_{out}}{V_T}\right)}\left(-\frac{1}{C_L R_L}\right)\exp^{-\frac{t}{C_L R_L}} \qquad (2.7)$$

The exponential function of the input voltage minus the output voltage, divided by the thermal voltage, can be approximated using an infinite series of the exponential function. In practical applications, it's often sufficient to consider just three or four terms of this series for comparison with experimental results.

$$\exp\left(\frac{V_{in}-V_{out}}{V_T}\right)=1+\left(\frac{V_{in}-V_{out}}{V_T}\right)+\left(\frac{1}{2}\right)\left(\frac{V_{in}-V_{out}}{V_T}\right)^2 \qquad (7)$$

$$\exp\left(\frac{V_{in}-V_{out}}{V_T}\right)=1+\left(\frac{V_{in}-V_{out}}{V_T}\right)+\left(\frac{1}{2}\right)\left(\frac{V_{in}-V_{out}}{V_T}\right)^2+\left(\frac{1}{6}\right)\left(\frac{V_{in}-V_{out}}{V_T}\right)^3 \qquad (8)$$

The derivative of the output voltage from equation (2.4) can be obtained by applying the chain rule, allowing both the input and output to be graphically represented without the need for an oscilloscope.

$$\frac{dV_{out}}{dV_{in}}=\pm\frac{\sqrt{I_{S1}I_{S2}}}{\left(sC_L+\frac{1}{R_L}\right)}\left(\frac{1}{2}\right)\left(1+\left(\frac{V_{in}-V_{out}}{V_T}\right)+\left(\frac{1}{2}\right)\left(\frac{V_{in}-V_{out}}{V_T}\right)^2\right)^{-\left(\frac{1}{2}\right)}\frac{df\left(V_{in}\right)}{dV_{in}}$$

$$\frac{dV_{out}}{dV_{in}}=\pm\frac{\sqrt{I_{S1}I_{S2}}}{\left(sC_L+\frac{1}{R_L}\right)}\left(\frac{1}{2}\right)\frac{\left(\left(\frac{1}{V_T}\right)+\left(\frac{V_{in}-V_{out}}{V_T^2}\right)\right)}{\left(1+\left(\frac{V_{in}-V_{out}}{V_T}\right)+\left(\frac{1}{2}\right)\left(\frac{V_{in}-V_{out}}{V_T}\right)^2\right)^{\frac{1}{2}}} \qquad (2.8)$$

$$f\left(V_{in}\right)=1+\left(\frac{V_{in}-V_{out}}{V_T}\right)+\left(\frac{1}{2}\right)\left(\frac{V_{in}-V_{out}}{V_T}\right)^2$$

$$\frac{df\left(V_{in}\right)}{dV_{in}}=\left(\frac{1}{V_T}\right)+\left(\frac{1}{2}\right)\left(\frac{2V_{in}-2V_{out}}{V_T^2}\right)=\left(\frac{1}{V_T}\right)+\left(\frac{V_{in}-V_{out}}{V_T^2}\right)$$

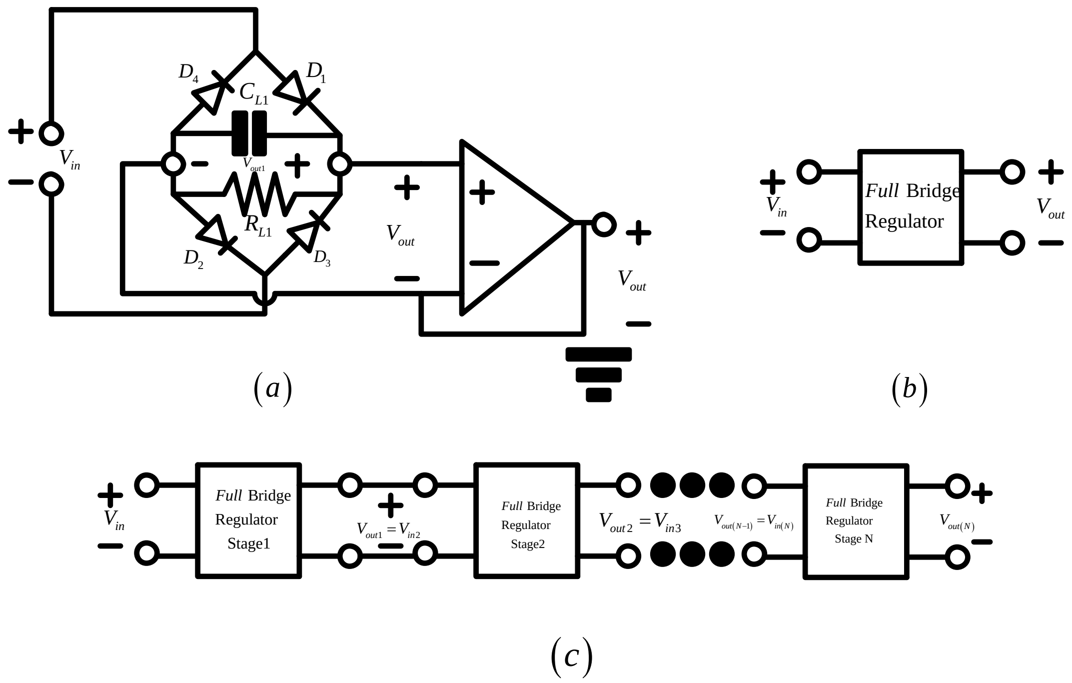


Figure 1. A Diagram of a Full Bridge Regulator and N Stage Full Bridge Regulator
(a) Circuit Diagram of a Full Bridge Regulator (b) Block Diagram of a Full Bridge Regulator
(c) Block Diagram of a Multi-Stage Full Bridge Regulator

The slope of the input and output voltage in a single-stage full-bridge regulator is not constant, it varies. This variation implies that the output voltage can be optimized through the design of the regulator, involving the selection of different types of diodes (each with varying saturation current values), as well as adjusting the resistive and capacitive loads.

A Minimum Step Down of a Multi-Stage Full Bridge Regulator

The minimum step-down of a multi-stage full bridge regulator, which is measured by the number of times the current is passed through a cascade of full bridge regulators, can be visualized in the block diagram shown in Figure 1a. Typically, diode conduction is associated with a current flow greater than one microampere. However, if it falls below this range, such as within the range of 1 picoampere to 1000 nanoamperes, the voltage drop across the capacitive load and resistive load can be less than the input voltage minus the voltage drops across two diodes ( ) which is clearly defined by the voltage drop from the anode to cathode terminals of diode D1 and D2, respectively.

Furthermore, the diodes connected in the circuit diagram in Figure 1a do not have a DC bias but exhibit time-varying voltage drops as a function of the input signal voltage source. Figure 1b represents a block diagram of a full bridge regulator, while Figure 1c illustrates the cascading of multiple bridge regulators in a block diagram format.

Advantage of a Full Bridge Regulator

Compared to a half-bridge regulator, a full bridge regulator utilizes three times more diodes per stage. It may not be immediately evident that the output voltage ripple of the full bridge regulator is superior to that of a half bridge regulator when they both employ the same capacitor values. Intuitively, the output of a half-bridge regulator exhibits a signal that can sag during the off phase (between 180 and 360 degrees) in comparison to a full-wave regulator. Therefore, one might expect that the output voltage ripple of the half-bridge regulator is not better than other circuit configurations.

An Angle of a Diode Conduction

An angle of a diode conduction is directly dependent on the input signal voltage. For example, if the input signal voltage is typically 1.2 volts peak to peak, the diode’s conduction angle would be around 90 degrees. As the signal’s amplitude varies over time, the diode gradually conducts less and less current in response to the alternating voltage drop, until it reaches a point where the diode no longer conducts because the voltage drop falls below a certain threshold. The most recent diode datasheet from Diotec Semiconductor specifies that diode conduction commences when the current reaches or exceeds 1 microampere. Understanding the diode’s conduction angle is essential for deriving the output ripple of the full bridge regulator, as demonstrated in textbook examples. It’s important to note that the conduction angle can shift based on the input signal voltage sources, particularly when dealing with office signals that have a substantial amplitude, such as 220 volts.

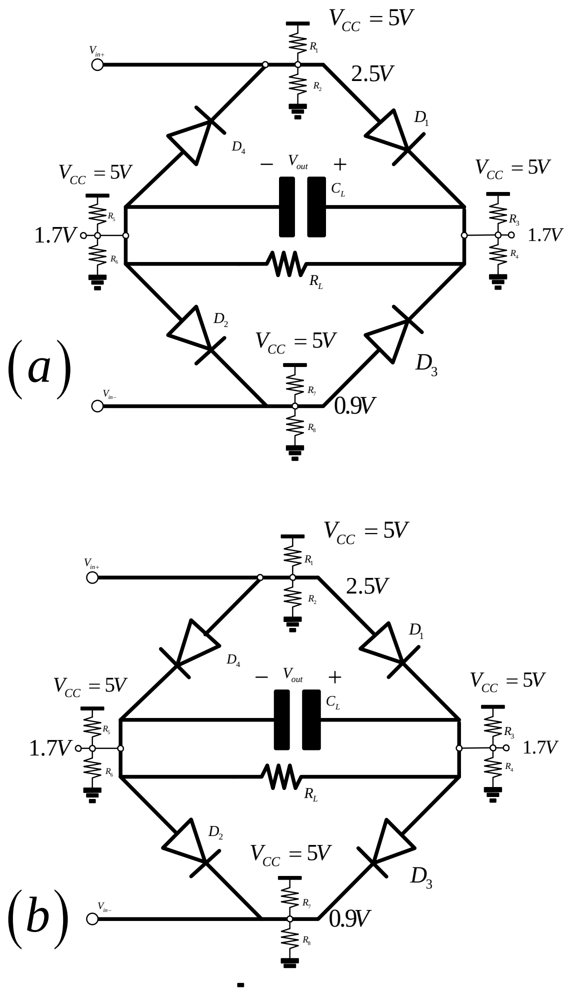


Figure 2. A Diagram of a Full Bridge Regulator with a dc Biasing

A Biasing of a Full-Bridge Regulator

In a possible circuit diagram of a full bridge regulator, there could be 16 different combination with labels that help identify the various components and their connections. To label these diagrams, you can use numbers. For instance, the positive input of the full bridge regulator can be labeled ‘1.’ The negative input as ‘2.’ The original cathode of diode D1 as ‘3’, and the original cathode of diode D2 as ‘4.’ Such numbering is essential for clear identification and understanding of the diode terminals. Figure 1 illustrates these diagrams. Figure 1a represents a modification of the original full bridge rectifier by introducing a capacitor for regulation. This is crucial because without regulation, the output voltage remains a rectified waveform. Figure 1b presents a block diagram of Figure 1a, making it easier to comprehend how to cascade multiple stages of a full bridge regulator to reduce output ripple voltage. Figure 1c displays a block diagram of a multi-stage full bridge regulator. Figure 2 shows how a full bridge can exhibit DC biasing, with the possibility of two diagrams out of the 16. Figure 2a illustrates the scenario when the two diodes (D3 and D4) are forward-biased.

PCB implementation and Measurement Results

The PCB layout was created using Visio, a computer-aided drawing program developed by Microsoft Corporation, which offers numerous advantages. One of these advantages is the ability to precisely estimate the length of components in millimeters or centimeters. You can achieve this by copying, pasting, and printing your design from Microsoft Word, which allows for measurements using a ruler on the printed paper. The copper transmission lines are drawn on a square grid with a minimum expansion factor of approximately 28 times, visually represented as 2800 percent in Visio. Afterward, the design is adjusted to account for any errors in the package diagrams of capacitors, diodes, and resistors. This involves determining the size of drill hoes and the spacing between the pins of these components Once the design is finalized, the PCB can be produced through a chemical etching process, typically carried out by PCBnow. During this process, any excess copper that is not part of the circuit layout is removed through chemical etching. Subsequently, diodes, resistors, capacitors, and wires are inserted are inserted into the PCB. These components are soldered onto the board using zinc, ensuring a secure connection between passive and active elements.

Table 1. Table of Resistor Biasing Value

$R_1 = R_L = 1M\Omega$	$R_5 = 1M\Omega$	$R_9 = 1M\Omega$
$R_2 = 500k\Omega$	$R_6 = 15.66M\Omega$	$C_L = 1\mu F$
$R_3 = 500k\Omega$	$R_7 = 1M\Omega$	
$R_4 = 2.15M\Omega$	$R_8 = 2.15M\Omega$	

Table 2. Table of Resistor Biasing Value

$R_1 = 500k\Omega$	$R_5 = 1M\Omega$	$R_L = 1M\Omega$
$R_2 = 500k\Omega$	$R_6 = 562.5k\Omega$	$C_L = 100nF$
$R_3 = 1M\Omega$	$R_7 = 11.7M\Omega$	
$R_4 = 562.5k\Omega$	$R_8 = 282k\Omega$	

Figure 3 illustrates that when the input signal has an amplitude of 5 volts peak to peak, the measured output voltage is found to be half of the maximum and minimum output voltages, which amounts to 1.42 volts. This measurement was conducted at an input frequency of 50 Hz.

Figure 4 illustrates that when the input amplitude of 20 volts peak to peak, the measured output voltage is also found to be half of the maximum and minimum output voltages, resulting in a measurement of 4.02 volts. This measurement was measured by pushing the button at the oscilloscope with the same input frequency of 50 Hz

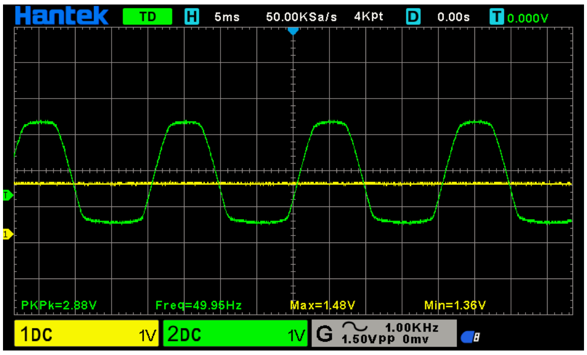


Figure 3. Measurement Results with input frequency 50 Hz and input amplitude of 5 volt peak to peak.

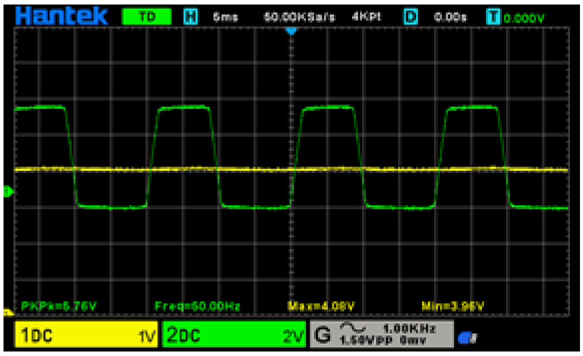


Figure 4. Measurement Results with input frequency 50 Hz and input amplitude of 20 volt peak to peak

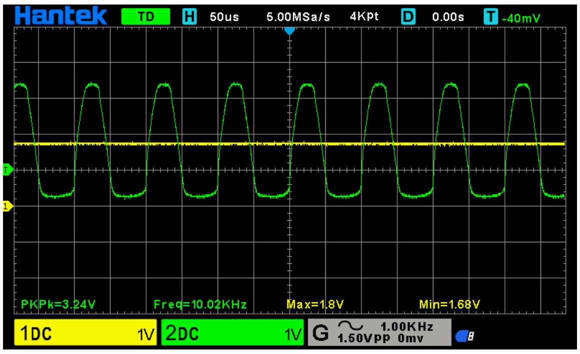


Figure 5. Measurement Results with input frequency 10 kHz and input amplitude of 5 volt peak to peak

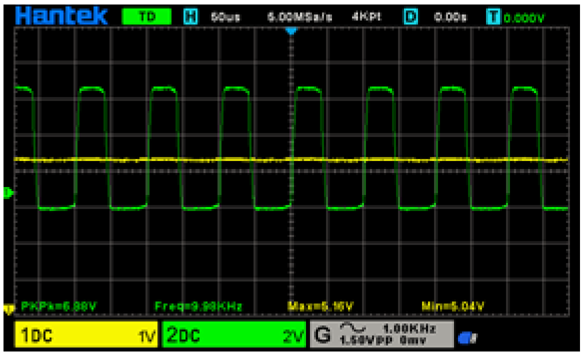


Figure 6. Measurement Results with input frequency 10 kHz and input amplitude of 20 volt peak to peak

Figure 5 illustrates that with the input signal has an amplitude of 5 volts peak to peak, the measured output voltage (depicted as the yellow line) is found to be half of the maximum and minimum output voltages, resulting in a measurement of 1.74 volts. This measurement was taken at an input frequency of 10 kHz.

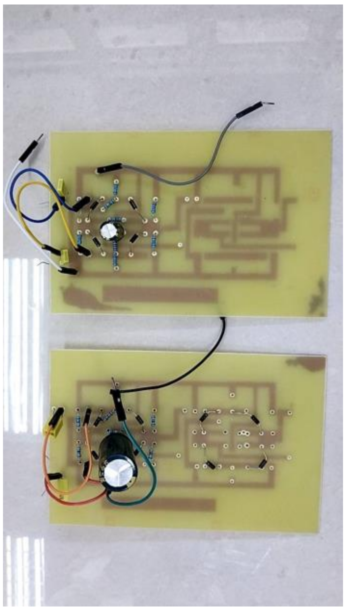


Figure 7. Printed Circuit Board (PCB) prototype of the novel full bridge regulator with different size of capacitors (Front view, with diode and passive element)

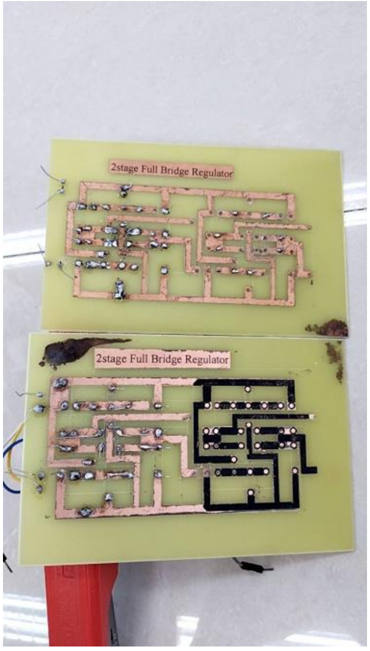


Figure 8. Printed Circuit Board (PCB) prototype of the novel full bridge regulator with different size of capacitors (Back view, with diode and passive element)

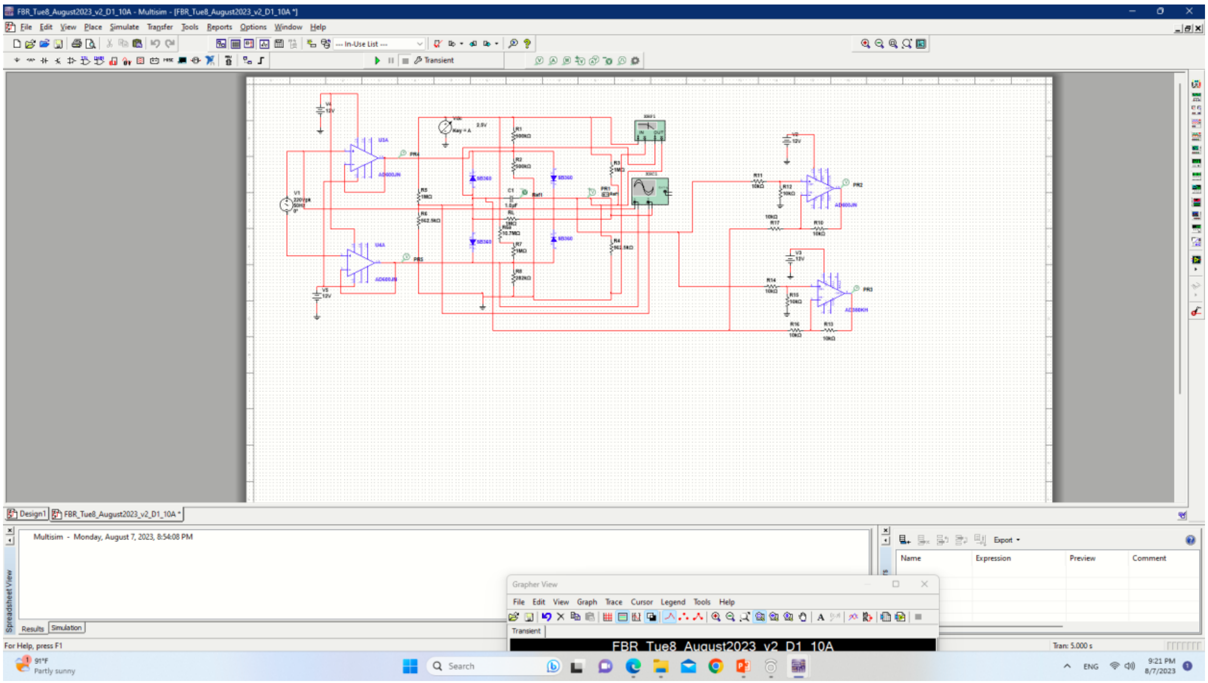


Figure 9. Schematic Diagram of the Novel Full Bridge Regulator which using Buffer op-amp to isolate full bridge regulator circuit from function generator and Difference Amplifier

The simulation results of the novel full bridge regulator, which employs two buffered op-amps to isolate the circuit from a function generator, along with two difference amplifiers, were obtained using Multisim Live Simulator from National Instruments Corps.

The simulation results, depicted in Figure 10, 11(a), and 11(b), represent the output voltage at the output node of the difference amplifier, as well as the circuit diagram of Figure 9. However, it's important to note that there are no experiment results available for the circuit in Figure 9.

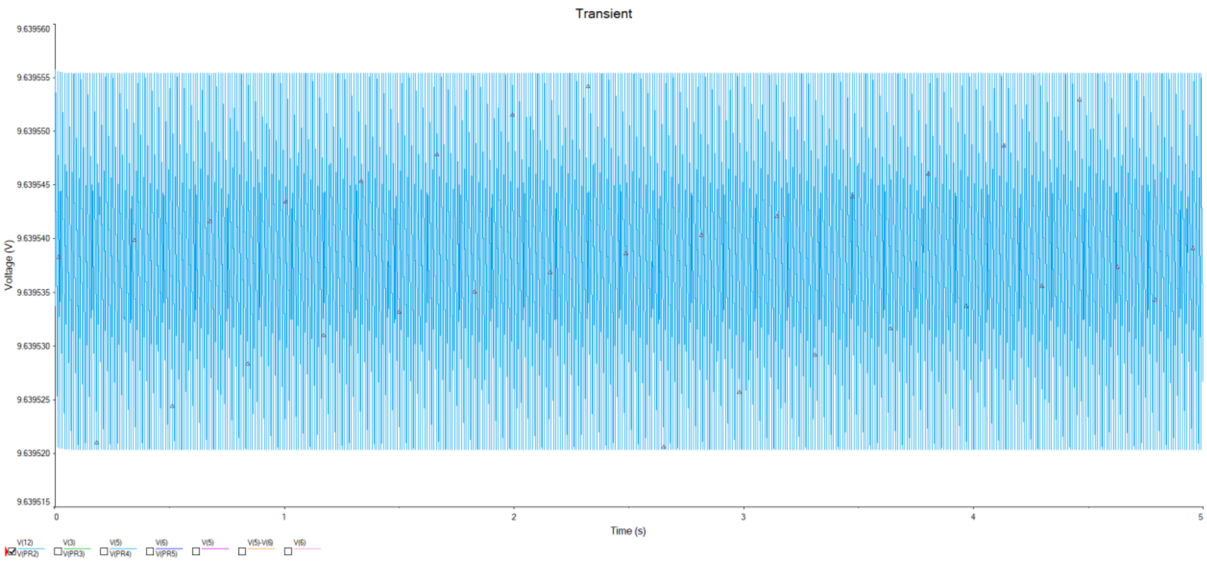
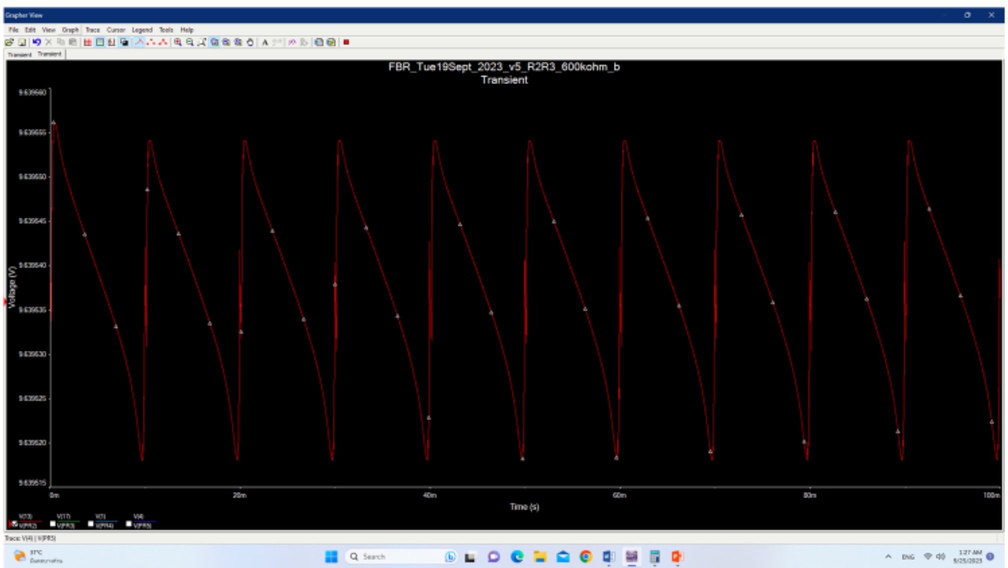
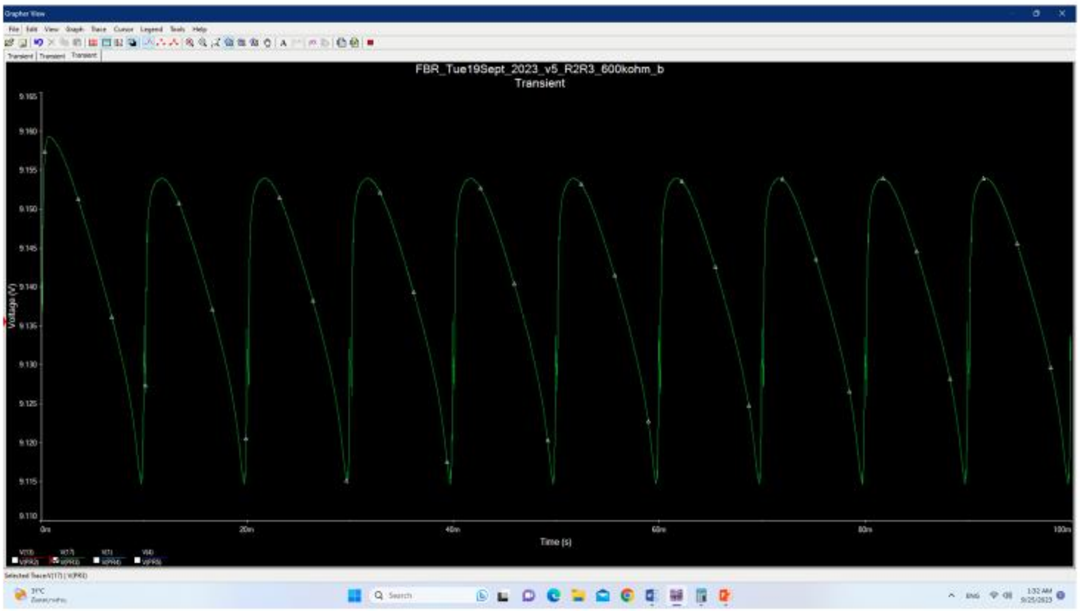


Figure 10. Simulation result of Time Domain Response of Output voltage of the Figure 9 using two Buffer op-amp to isolate full bridge regulator circuit from function generator and Difference Amplifier

The output voltage exhibits ripple, fluctuating between 9.639555 volts and 9.639520 volts. This ripple is calculated to be approximately 35 micro-volts. The efficiency of the novel Full-Bridge Regulator, incorporating buffer isolation between the function generator and load (which itself is a novel full bridge regulator), is determined to be 48.195 percent without the use of a transformer circuit.



11 (a)



11 (b)

Figure 11. The simulation results displaying an expanded view of the time domain response of the output voltage from the Difference Amplifier. This figure includes two parts (a) AD600JN (b) AD380KH

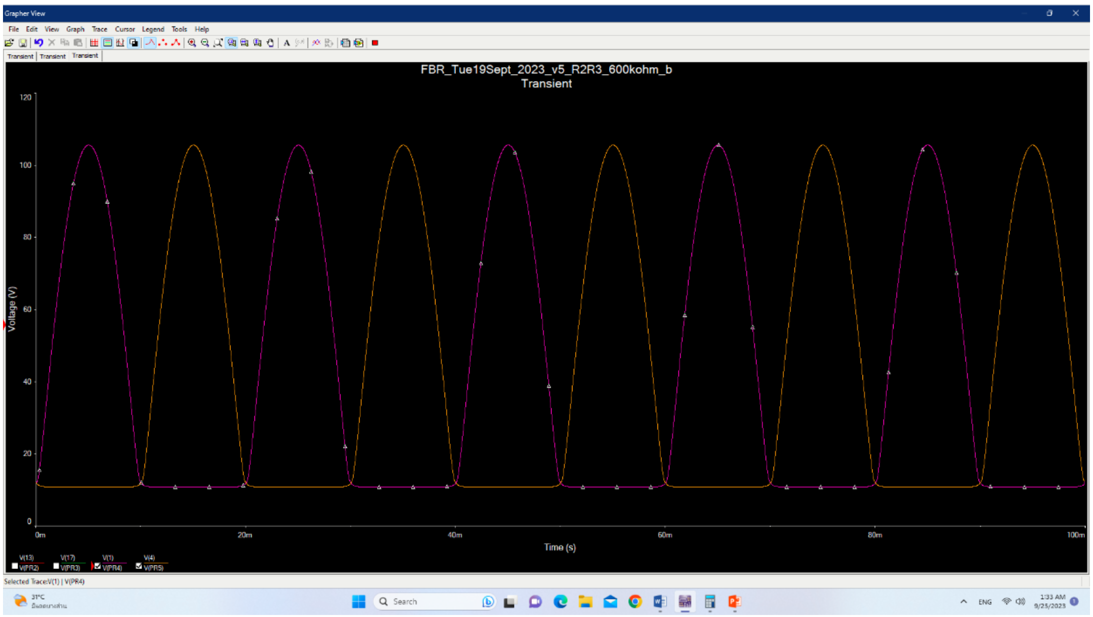


Figure 12. Illustrates the output waveform of the buffer, when connected between the function generator and the Novel Full-Bridge Regulator. The buffer is used to isolate the load from the function generator.

In Figure 10 and Figure 11(a) and 11(b) are the output voltage at the output node of the difference amplifier and circuit diagram of figure 9 which still has no experimental results. It output voltage is rippled from 9.639555 volt to 9.639520 volt. Thus, the ripple of the output voltage is calculated to have 35 micro-volt. The efficiency of the novel Full-Bridge Regulator with Buffer isolation of function generator and load (which is a novel full bridge regulator) is calculated to be 48.195 percent without a transform circuit.

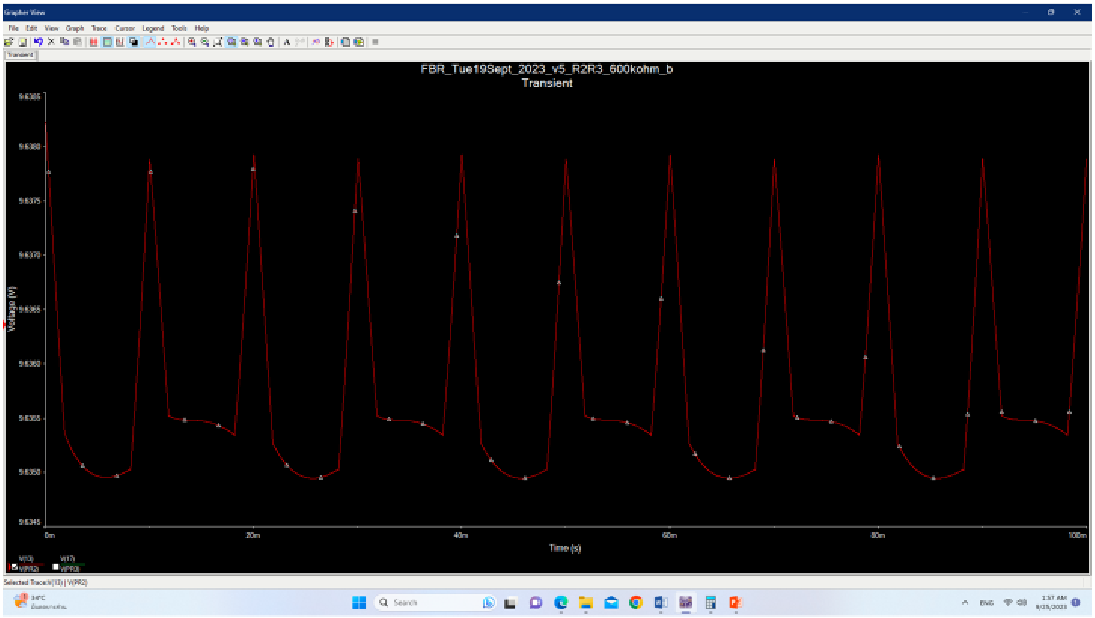


Figure 13. Illustrates the output waveform of the difference amplifier (AD600JN) when it's connected directly between the function generator and the Novel Full Bridge Regulator, without the use of a buffer.

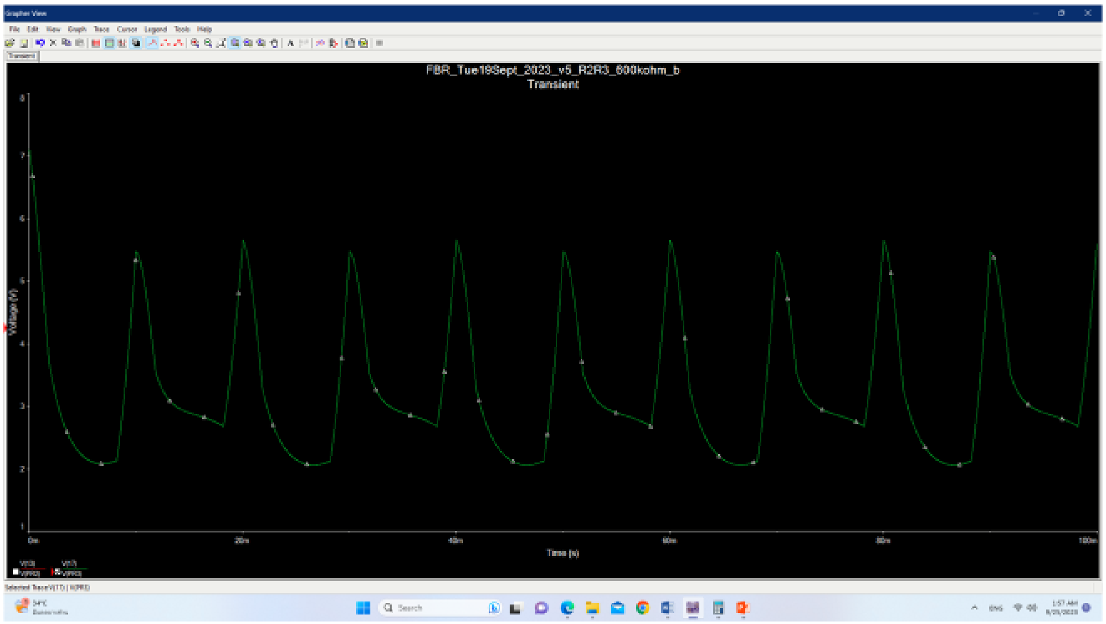


Figure 14 Illustrates the output waveform of the difference amplifier (AD380KH) when it is directly connected between the function generator and the Novel Full Bridge Regulator, without the use of a buffer.

Discussion

This paper explores the modification of the Full Bridge Rectifier, a widely recognized type of rectifier. The modification involves the introduction of a parallel capacitive load alongside a load resistor and the implementation of DC biasing. Subsequently, the differential output voltage is utilized as an input for two op-amps arranged as a difference amplifier. This approach is referred to as 'differential output to single-ended output.' The simulation results for the two parts exhibit some differences, as previously described.

Conclusion

In a future project, one potential focus could be to explore the use of an improved difference amplifier for the conversion of a differential output signal to a single-ended output signal. The goal of such an endeavor would be to achieve experimental results that surpass the recent measurement results.

Notes

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Predicting and Prioritizing Software Bugs with Machine Learning: A Framework Utilizing H2O AutoML

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Abstract: The objective of this article is to discuss the application of machine learning (ML) techniques for predicting and prioritizing software bugs and to propose a framework that utilizes H2O AUTOML for bug detection and categorization. The study utilizes a UNIFIED dataset comprising bugs from an open-source software project. The research involves data collection, feature selection, dataset training, application of the H2O algorithm, and an evaluation process.The results indicate that the "GBM 2 AutoML 20210415 132614" model from the Gradient Boosting Machine family per-forms the best, achieving an accuracy of 73% and a mean per class error of 46%. The proposed framework demonstrates the ability to automatically assign appropriate classes to code bugs, thereby alleviating the time-consuming and resource-limited nature of manual bug prioritization. By leveraging ML techniques, this framework offers a more efficient approach to software testing and bug management.

Keywords: Bug prioritization, Bug detection, H2O AutoML, Open-source software, Feature selection, Software testing.

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Introduction

The field of software engineering has seen a surge of interest in software bug prediction, which involves building prediction models to identify and locate future bugs based on past mistakes. Detecting and eliminating bugs in software systems is a crucial aspect of software engineering, and predicting bugs beforehand can improve soft-ware quality and reduce costs [2][9].

To achieve these goals, modern approaches to artificial intelligence (AI) and machine learning (ML) have been developed. However, improving the efficiency of ML engineers remains a central challenge. Automated ML (AutoML) has emerged as a solution to reduce the time and effort spent on tedious tasks in ML pipelines, such as data processing, feature design, model selection, Hyperparameter optimization, and result analysis.

One example of AutoML is H2O AutoML, a machine learning model included in the H2O framework that is easy to use and capable of producing high-quality models for deployment in enterprise environments. H2O AutoML supports supervised training of regression, binary classification, and multi-class classification models on plain datasets. Additionally, H2O models offer fast scoring abilities, with some models able to generate predictions in sub-millisecond scoring times. H2O AutoML also offers APIs in several languages (R, Python, Java, Scala), making it accessible to a diverse group of information scientists and experts.

Literature Review

This article focuses on related works and studies related to machine learning (ML) and the techniques were applied to software bugs classification. This section introduces recent studies and literature that are related to bugs' classification.

Abozeed et al. (2019) demonstrates that studies have shown that fixing errors in software becomes more expensive as the project progresses. Therefore, identifying faulty classes as soon as they are committed to the Version Control System could significantly reduce the cost. Software repository mining is an emerging research field that explores innovative techniques and models to analyze software repository data and extract useful information that can aid in bug prediction. Deep Learning has been proven to achieve remarkable results in many fields, and the paper aims to study the impact of feature selection on bug prediction models and test if Deep Learning techniques could improve the results. The study found that applying feature selection using a simple filter approach did not improve the performance measures, but Deep Learning models performed better than the set of base classifiers for small and balanced datasets.

Tóth (2019) discusses two main topics, the development of new bug datasets for bug prediction and a philosophy for estimating practicality in heritage frame-works written in RPG programming language. The authors gathered existing public bug datasets from various sources and developed a new dataset with unique bug data. They proposed a method for unifying open bug datasets to share common descriptors. They compared the metric suites of different datasets and demonstrated the capabilities of assembled bug prediction models using the newly created GitHub Bug Dataset and the Unified Bug Dataset. They suggest that researchers should first try to use existing bug datasets and only create a new customized dataset if necessary.

Perera (2020) in his work aims to improve the bug detection capability of search-based software testing (SBST) techniques by incorporating defect prediction information. The approach involves allocating time budget to classes based on their likelihood of being defective and guiding the search algorithm towards defective areas in a class. The empirical evaluation on 434 real reported bugs in the Defects4J dataset shows that this approach is significantly more efficient than the state-of-the-art SBST under resource-constrained environment. The preliminary results of the second research objective also show a positive impact on finding more bugs by guiding the search algorithm using the likelihoods of methods being defective. The outcome of RQ1.4 has been accepted at the International Conference on Automated Software Engineering (ASE).

Other researchers (Ferenc et al., 2020) explains how bug datasets are used to create and validate bug prediction models. The authors aimed to gather existing public source code metric-based bug datasets and combine them into a unified dataset. They analyzed the source code of 5 datasets and produced a single dataset at the class and file level. They found differences in metric definitions and values across the datasets and used a decision tree algorithm to demonstrate the dataset's bug prediction capabilities. They com-pared the original and extended metric suites' bug prediction capabilities and merged all files and classes into one large dataset. The authors investigated the cross-project capabilities of the bug prediction models and datasets and made the unified dataset publicly available to facilitate reproducible research in bug prediction.

Ferenc et al. (2020) propose a method to improve the process of finding bugs in software products by combining static source code metrics and deep learning techniques. The authors adapted deep neural networks to bug prediction and applied them to a large bug dataset of Java classes, comparing their results to traditional algorithms. Their experiments showed that deep learning with static metrics can improve prediction accuracies, with their best model achieving an F-measure of 53.59%. They also demonstrated that these values could improve further with more data points. The authors have open-sourced their experimental Python framework to help other researchers replicate their findings.

Kaen et al. (2020) discuss the growing use of artificial intelligence, specifically machine learning and deep learning, in various fields such as robotics, healthcare, and soft-ware engineering. The focus is on software bug prediction using machine learning, and the authors propose using the Chi-Square feature selection method to identify important features for building machine learning models. They test their approach using three classification algorithms (Support Vector Machine, Naïve Bayes, and Linear Discriminant Analysis) and a new metric of code smell intensity. The results show that their approach outperforms the baseline in terms of average accuracy among nine datasets, with improvements of up to 5.12%, 4.15%, and 1% on the Naïve Bayes, Support Vector Machine, and Linear Discriminant Analysis classifiers, respectively.

Khan and others (2020) discusses the use of software bug prediction (SBP) models to improve software quality assurance processes by predicting buggy components. Ma-chine learning classifiers are used in these models, but requiring optimization of hyper-parameters to ensure better performance. The authors propose a software bug prediction model that uses seven machine learning classifiers in conjunction with the Artificial Immune Network (AIN) to improve bug prediction accuracy through hyper-parameter optimization. They conducted the experiment on a bug prediction dataset, and the results showed that using AIN to optimize the hyper-parameters of machine learning classifiers performed better than using classifiers with their default hyper-parameters. The seven classifiers used were support vector machine Radial base function (SVM-RBF), K-nearest neighbor (KNN) with Minkowski metric and Euclidean metric, Naive Bayes (NB), Decision Tree (DT), Linear discriminate analysis (LDA), Random forest (RF), and adaptive boosting (AdaBoost).

Pandey et al. (2020) discuss a software fault prediction system that aims to detect faulty modules using feature selection and machine learning methods. The proposed framework, named BPDET, uses ensemble learning and deep representation techniques to address the class imbalance problem in software bug prediction models. The study uses NASA datasets to evaluate the efficiency of the proposed approach in terms of performance metrics such as MCC, AUC, PRC, F-measure, and time. The results show that BPDET outperforms existing bug prediction methods and is stable across multiple cross-validation experiments.

Brumfield’s (2020) thesis aims to improve software bug prediction using deep learning techniques and miniature examples. The goal is to identify potentially faulty code during the development process, allowing designers to focus on testing and troubleshooting only the affected parts. The study uses static analysis and AI methods to construct models based on the relationships between measurements and programming errors in software pro-jects.

Bilgin and others (2020) presents a study focuses on predicting software vulnerabilities using machine learning techniques to ensure trustworthy software systems. The researchers developed a source code representation method and used machine learning to distinguish between vulnerable and non-vulnerable code fragments. They used a public dataset containing labeled real source code parts and showed the effectiveness of their proposed method in vulnerability prediction compared to state-of-the-art methods.

Felix (2020) focuses on predicting the number of defects in software at the method level, which has received little attention in research. The authors propose using variables of defect density, defect velocity, and defect introduction time to construct regression models that can predict the estimated number of defects in a new version of the soft-ware. The authors conduct an experiment on open-source Java projects and report correlation coefficients of 60% for defect density, -4% for defect introduction time, and 93% for defect velocity. The results suggest that defect velocity is strongly correlated with the number of defects at the method level. The study also motivates investigating the performance of classifiers before and after meth-od-level data preprocessing and the level of entropy in the datasets.

Also, others (Wójcicki & Dabrowski, 2018) propose a study that aims to verify whether the approach used in previous fault prediction studies can be applied to Python. The authors conducted a preliminary study using machine learning techniques to predict faults in Python programs and obtained experimental evidence that similar fault prediction methods for C/C++ and Java can be applied successfully to Python. The results showed a recall up to 0.64 with false positive rate 0.23, indicating that more research in this area is worth conducting, including the use of more sophisticated machine learning techniques, additional Python-specific features, and extended datasets.

Lee et al. (2011) propose the use of micro interaction metrics (MIMs) to capture developers' direct interactions, such as file editing and selection events, and evaluates their performance in defect prediction. The study shows that MIMs significantly improve defect classification and regression accuracy, indicating the potential of using developers’ behavioral interaction patterns to enhance soft-ware quality.

Ramay et al. (2019) propose a deep neural network-based approach for the automatic prediction of the severity of bug reports, which is important for prioritizing bug fixing efforts. The approach includes natural language processing techniques for text preprocessing, computation of emotion scores for each bug report, creation of a vector for each preprocessed bug report, and use of a deep neural network-based classifier for severity prediction. The proposed approach is evaluated on historical bug report data and outperforms state-of-the-art approaches, improving the f-measure by 7.9%.

Fan and others (2019) proposed a framework called DP-ARNN that uses attention-based recurrent neural net-works for software defect prediction. The approach uses abstract syntax trees (ASTs) of programs, extracting them as vectors, which are then encoded using dictionary map-ping and word embedding. The attention mechanism is employed to generate significant features for accurate defect prediction. The method is evaluated on seven open-source Java projects within Apache and outperforms the state-of-the-art methods in terms of F1-measure and area under the curve (AUC). The proposed approach improves the F1-measure by 14% and AUC by 7% on average.

Mani and others (2019) proposed an approach for automatic bug triaging, using an attention-based deep bidirectional recurrent neural network (DBRNN-A) model to learn syntactic and semantic features from long word sequences in bug reports. The proposed approach uses unfixed bug reports, which were completely ignored in previous studies, to provide a large amount of data to learn the feature learning model. The results show that the proposed approach outperforms the traditional bag-of-words (BOW) feature models and machine learning approaches. Additionally, a public benchmark dataset of bug reports from three open source bug tracking systems is provided.

Bani-Salameh et al. (2021) describes a study on predicting the priority level of bug reports in software maintenance, which is important but time-consuming task. The study proposes a deep learning RNN-LSTM neural net-work model that considers multiple factors to predict the priority level of bug reports, and compared its performance with KNN and SVM algorithms. The study found that the proposed RNN-LSTM model significantly outperformed the other two models in terms of accuracy, F-measure, and AUC, achieving an accuracy of 90% and an F-measure improvement of 15.2% compared to KNN. The study concludes that LSTM is the most accurate and effective algorithm for predicting the priority level of bug reports.

Proposed Approach

This study utilizes a dataset that consists of bugs from various open-source software projects. The objective is to apply H2O AUTOML (Candel et al., 2016) for the detection and categorization of code bugs. The categorization process involves: data collection, assigning bug's priority (labeling), feature selection, dataset training, applying the H2O algorithm, get the best model, and finally evaluate the model (Figure 1).

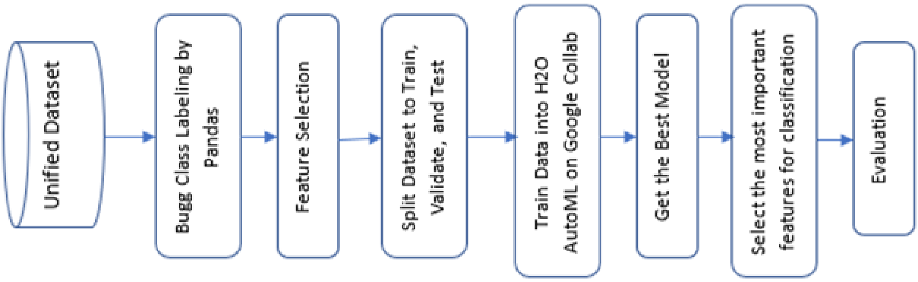

Figure 1. Proposed Framework Flow.

Data Collection

The dataset was obtained from the Department of Software Engineering at the University of Szeged on December 20, 2019, and it includes java classes with their associated metrics and code bugs. It was extracted from five public bug datasets, namely PROMIS, Eclipse Bug, Bug Prediction, Bug catchers Bug, and GitHub Bug.

The corresponding source code for each system in the datasets has been downloaded. They performed source code analysis using OpenStaticAnalyzer-1.0-Metrics to extract a common set of source code metrics. The outcomes of this process were then merged into a single dataset consisting 47,618 elements with 72 feature. Therefore, this dataset is a valuable source of data for bug prediction models.

- ***Labeling bugs' categories:*** The bug categories were labeled using the pd.cut function from the PANDAS library. The dataset was divided into four classes (No, Low, Medium, Haigh) based on the severity of the bugs, which enabled the classification task.
- ***Feature selection:*** As mentioned earlier, the dataset contains of a large set of features, and processing them with the proposed model can be difficult. Therefore, a subset of features was selected as an input for the model. The unnecessary columns such as: 'ID', 'Type', 'Name', 'LongName', 'Parent', 'Component', 'Path', 'Line', 'Col-umn', 'EndLine', 'EndColumn', were dropped. This process was performed automatically by H2O AUTOML.

Evaluation Metrics

The performance and efficiency of classification algorithms can be evaluated using various metrics such as: MSE, RMSE, Log Loss, and Mean per Class Error. Following is a brief description of the used metrics.

1) ***MES***: The MSE metric measures the root mean square of error or deviation. MSE squares the distance from the point to the regression line (these distances are called "errors") to eliminate the negative sign. The lower the MSE, the best model performance (see Equation 1).

$$\frac{1}{n}\sum_{i=1}^{n}(x_i - y_i)^2 \qquad (1)$$

2) ***RMSE (Root Mean Squared Error)***: the RMSE metric evaluates how properly a version can are expecting a continuous value. The RMSE devices are like the anticipated target, that's beneficial for information if the dimension of the mistake is of challenge or not. The smaller the RMSE, the higher the model's performance.
3) ***Logloss***: the log loss rate can be used to evaluate the performance of binomial or polynomial classifiers. Different from the classification effect of the "Area Under Curve" test model on binary targets, the log loss estimates the closeness between the predicted value of the model and the actual target value.

H2O AutoML Algorithms

H2O AutoML was used, which is a machine-learning algorithm for tabular data, which is part of the H2O ma-chine-learning platform. H2O is easy to use and extensible and has a very active and participating user base in the open-source machine learning community. H2O AutoML can deal with lost or classified data, including a comprehensive modeling strategy for powerful functional combination components and the ability to easily deploy and use H2O models in enterprise production environments. Use Python to implement H2O AUTOML in a unified data set.

- ***Input Variables***: Considering many factors (indicators), input variables were selected to predict category. Operators are columns reserved after features se-lection in the data set, except for the "bug" category.
- ***Output variables***: In this paper, Bug class is the out-put variable used in the ML algorithms to be predict-ed.

Experiment and Results

The modified unified data set was divided into three parts (train, validation, test), the train part was used to train the models, and the verification part was used to set the hyperparameters and choose the best model for the problem, and the test part was used to verify Model performance in non-visual data.

Figure 2 shows the distribution of classes in the dataset during the data exploring process, which showed imbalanced classes, a problem in which the distribution of examples be-tween known classes is biased or skewed. The distribution range can range from slight offset to severe imbalance, with one example in the minority class for hundreds, thousands in the majority class or classes.

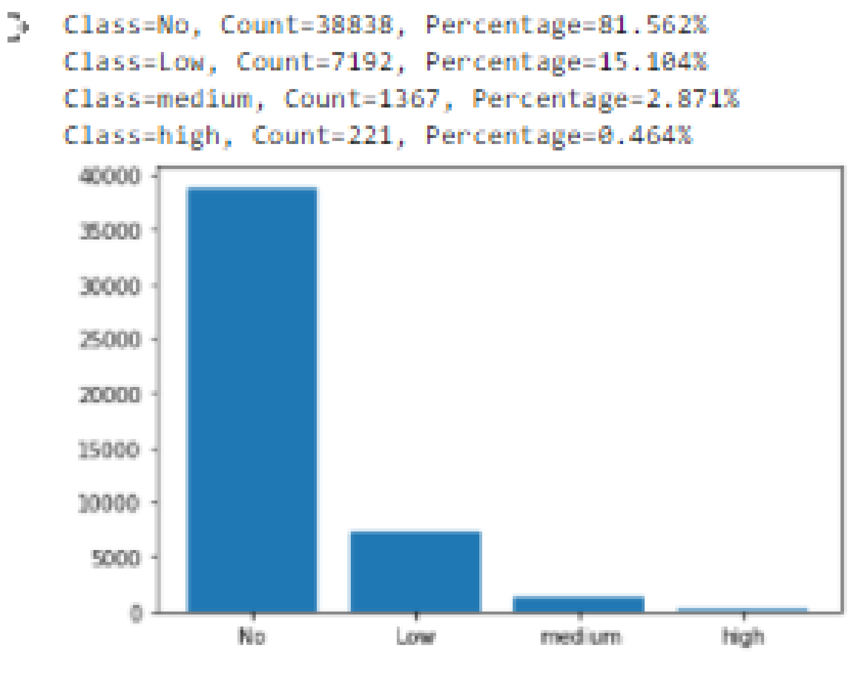

Figure 2. The distribution of the classes during the data exploring process.

Therefore, the train part of data had been sampled using “SMOTE" (Synthetic Minority Oversampling Technology), an oversampling technology that uses the k algorithm to generate synthetic data for the nearest neighbors. SMOTE first selects random data from the minority class and then determines the k nearest neighbors of the data. Then the data placed between the random data and the randomly selected nearest neighbor

k. the process Repeated until the minority category has the same proportion as the majority category (Chawla et al., 2002).

After that, the dataset had been trained into google Colab by the H2O Autml library. The H2O AutoML interface is designed to contain as few parameters as possible. Customers only need to refer to their data set, define a response column, and optionally specify a time limit or the total number of trained models. Some of parameter that could be changed such as Max models, Nfolds, Max run-time secs, Balance classes, Stopping metric, Stopping rounds, Stopping tolerance, and Keep cross validation models (Candel et al., 2016). Then, the model had been trained into the oversampled dataset, and the problem determined automatically by H20 as a multiclass.

After completing the training process, the result showed that 19 models belong to 6 families had been built during training (XGBoost, GLM, DRF, GBM, DeepLearning, DRF), a classification table is created every time AutoML is started. According to the nature of the problem, use standard metrics (the second column in the classification table) to classify the model. AUC is a metric used for binary classification problems, and the average error of each category is used for classification problems involving multiple categories. The standard ranking indicator for regression problems is variance. The user can choose to change the default ranking index of the ranking table. The result shows that the best 10 models for our dataset as presented in Table 2.

In addition, the result showed that the best model that solves the problem is “GBM 2 AutoML 20210415 132614", from the Gradient Boosting Machine family which is a forward learning ensemble method that sequentially builds regression trees on all the features of the dataset in a fully distributed way each tree is built in parallel. This family is used for both Regression and Classification problems. The H2o suggests adapting the model settings as in Table 3 to give the best result in the unified dataset.

Table 1. Best 10 models’ fitted dataset.

Model_Id	MPCR	LogLo	RMSE	MSE	Algo.
GBM_1_AutoML_20210524_001830	0.4574	0.9416	0.5992	0.3590	GBM
GBM_2_AutoML_20210524_001830	0.4743	0.9214	0.5914	0.3498	GBM
XGBoost_3_AutoML_20210524_001830	0.4747	0.7273	0.5075	0.2575	XGBo
GBM_3_AutoML_20210524_001830	0.4777	0.9811	0.6165	0.3801	GBM
GBM_4_AutoML_20210524_001830	0.4794	1.0040	0.6268	0.3929	GBM
GBM_grid__1_AutoML_20210524_00183	0.4869	0.8688	0.5664	0.3208	GBM
GBM_grid__1_AutoML_20210524_00183	0.5137	0.5732	0.4369	0.1909	GBM
GBM_5_AutoML_20210524_001830	0.5258	0.9920	0.6227	0.3877	GBM
XGBoost_1_AutoML_20210524_001830	0.5283	0.7760	0.5292	0.2800	XGBo
GBM_grid__1_AutoML_20210524_00183	0.5455	1.2190	0.7029	0.4941	GBM

Table 2. Models’ parameter summary.

id	parameter	value
1	number_of_trees	7
2	number_of_internal_trees	28

3	model_size_in_bytes	23704.0
4	min_depth	6
5	max_depth	6
6	mean_depth	6
7	min_leaves	54
8	max_leaves	64
9	mean_leaves	62.857143

The METRICS of the best model into train, validate, and test parts of unified dataset are mentioned in Table 3.

Table 3. The metrics of the best model.

Metric	train_data	cross_validation	trest_data
MSE	0.37648429685384704	0.3775879368430466	0.35906867464119113
RMSE	0.6135831621335832	0.614481844193176	0.5992233929355488
LogLoss	0.9703039488095602	0.9732992146307755	0.9416925324811019
MPCE	0.29158092018227255	0.2918014111421432	0.4574829531658866

Table 4 shows a summary of the cross-validation metrics for the best model.

Table 4. A summary of the cross-validation metrics.

Cross-Validation Metrics Summary:

		mean	sd	cv_1_valid	cv_2_valid
0	accuracy	0.7300272	0.0053789173	0.7262237	0.7338307
1	auc	NaN	0.0	NaN	NaN
2	aucpr	NaN	0.0	NaN	NaN
3	err	0.2699728	0.0053789173	0.27377626	0.26616934
4	err_count	14693.0	292.74222	14900.0	14486.0
5	logloss	1.0175679	6.08243E-4	1.0179979	1.0171378
6	max_per_class_error	0.42002004	0.013946684	0.41015828	0.42988184
7	mean_per_class_accuracy	0.7300389	0.0054462566	0.72618777	0.73388994
8	mean_per_class_error	0.26996115	0.0054462566	0.27381223	0.26611006
9	mse	0.39997348	1.5427692E-4	0.40008256	0.39986438
10	pr_auc	NaN	0.0	NaN	NaN
11	r2	0.68002087	1.5002872E-4	0.6799148	0.68012697
12	rmse	0.63243455	1.21970654E-4	0.6325208	0.6323483

Moreover, the result showed that the most 20 importance features that effect classification for the best model were as mentioned in Table 5. The statistical significance of each variable in the data in terms of its effect on the model was represented by variable importance. The variables were listed in descending order of importance (see Figure 3). The percentage values represent the proportion of importance across all variables, scaled to 100%. The algorithm determines how to compute the importance of each variable.

Table 5. The most 20 important features.

CLASS\METRIC	WMC	CBO	RFC	MCABE	LCOM
InGameController	132	84	593	6.838	0.426
InGameController	120	83	573	5.235	0.032
CHANGE	-12	-1	-20	-1.603	-0.394
SimpleCombatModel	14	29	120	9.923	0.869
SimpleCombatModel	12	25	94	7.273	0.867
CHANGE	-2	-4	-26	-2.65	-0.002
Monarch	33	18	123	3.586	0.8
Monarch	32	18	119	3.39	0.797
CHANGE	-1	0	-4	-0.196	-0.003
ColonyPlan	37	43	229	9.375	0.869
ColonyPlan	36	43	226	9.452	0.867
CHANGE	-1	0	-3	0.077	-0.002
SimpleMapGenerator	22	64	255	9.25	0.688
SimpleMapGenerator	17	49	196	8.933	0.677
CHANGE	-5	-15	-59	-0.317	-0.011
TerrainGenerator	25	23	183	11.625	0.769
TerrainGenerator	20	22	166	10.317	0.767
CHANGE	-5	-1	-17	-1.308	-0.002

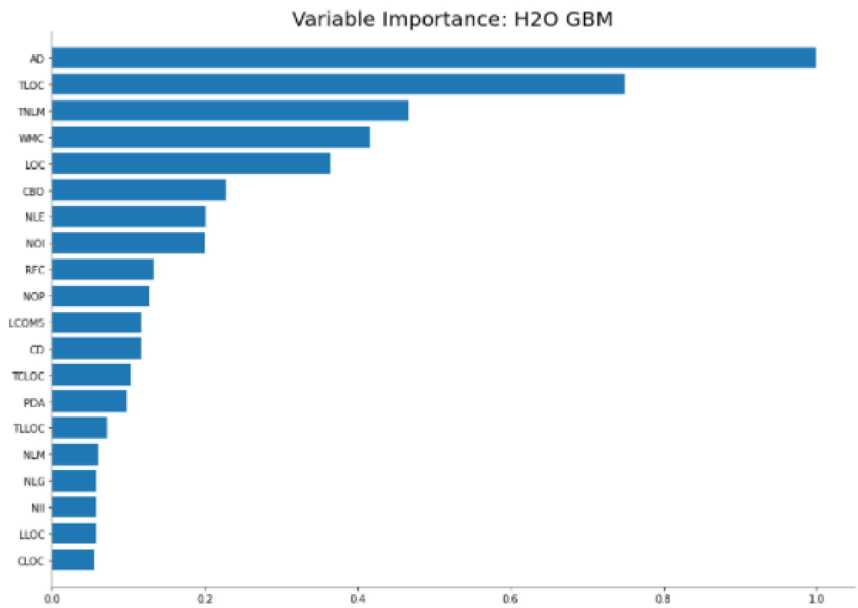

Figure 3. Variable importance.

Conclusion and Future Works

All in all, this research provides a framework that can automatically assign appropriate classes to code bugs, thereby avoiding time-consuming and resource-limited software testing. The proposed structure involves using the library H2O AUTOML to determine the best model that matches the bugs unified dataset .the results showed that the best model is “GBM 2 AutoML 20210415 132614" from the Gradient Boosting Machine family with an accuracy of 73% and mean per class error of 46%. In addition, Features that most affect bug classification have been identified.

The ability to use H2O AutoML to classify bugs in Unified dataset has been demonstrated, H2O exceeds expectations in terms of ease of use and scalability, active customer base, and open-source machine learning community.

In future work, we plan to perform the following operations: perform the same experiment on new datasets, metrics, and other types of bugs. Use different types of AutoML libraries such as AutoKeras and Autogloun to train new models and compare the results between them. Development of a new tool based on the best model that fits the data set for automatic bug classification and correction.

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Enhancing Diabetes Classification with Deep Neural Networks

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Abstract: Diabetes is a major public health concern affecting millions of individuals worldwide. Early and accurate diagnosis is crucial for effective management and prevention of complications. In recent years, deep neural networks (DNNs) have shown great promise in improving diabetes classification accuracy due to their ability to capture complex patterns in the data. However, several challenges must be addressed for optimal performance of DNNs, including data preprocessing, data imbalance, and hyperparameter tuning. In this research article, a comprehensive approach to enhancing diabetes classification using DNNs is proposed. First, data preprocess using feature scaling, dimensionality reduction, and missing value imputation techniques to improve the quality of the input data. Next, the issue of data imbalance is addressed using oversampling and undersampling techniques to balance the classes. Finally, hyperparameter tuning was performed using a combination of grid search and random search to identify the optimal set of hyperparameters for each DNN model. The performance of proposed approach was evaluated on a publicly available dataset of 768 patients and compare the performance of our DNN-based models with traditional machine learning algorithms. The obtained results showed that the proposed approach significantly improves diabetes classification accuracy compared to traditional machine learning algorithms. Specifically, an accuracy 90%, precision of 85%, F1 score of 82%, recall of 83%, and area under the ROC curve (AUC) of 94% were achieved. The findings suggest that addressing data preprocessing, data imbalance, and hyperparameter tuning are essential for optimal performance of DNNs in diabetes classification. The proposed approach can potentially lead to earlier and more accurate diagnosis of diabetes, enabling more effective treatment and management of the disease.

Keywords: Diabetes; Classification; Deep Learning; Pima Dataset; Data Imbalance

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Introduction

Diabetes is a chronic metabolic disorder that affects millions of people worldwide. Early detection and classification of diabetes are crucial for effective management and prevention of complications. In recent years, machine learning techniques, especially deep neural networks (DNNs), have gained significant attention for diabetes classification due to their ability to automatically learn complex patterns from large datasets. However, DNNs require careful preprocessing of the data and hyperparameter tuning to achieve optimal performance, especially when dealing with imbalanced datasets (Hasib et al., 2022; Ding et al., 2022; Xu et al., 2020).

Data preprocessing is an essential step in preparing the input data for DNN models. Several studies have shown that feature scaling and dimensionality reduction techniques such as PCA can enhance the performance of DNN models (Thaiyalnayaki 2021; Naz & Ahuja, 2020). Addition-ally, imputing missing values using mean imputation or other methods can improve the accuracy of DNN models (Kamalraj et al., 2022).

Imbalanced datasets are a common issue in medical diagnosis tasks, where the positive class (presence of diabetes) is often underrepresented. Several techniques have been proposed to address data imbalance, including oversampling and under-sampling methods. SMOTE, ADASYN, and Tomek links are among the most popular methods for oversampling and undersampling in medical diagnosis tasks (Hasib et al., 2022; Ding et al., 2022; Xu et al., 2020).

Hyperparameter Tuning: Hyperparameters are settings that need to be tuned to optimize the performance of DNN models. Grid search and random search are commonly used techniques for hyperparameter tuning in DNN models (Liao et al., 2022). Several hyperparameters, including the number of layers, number of neurons, learning rate, and dropout rate, have been found to significantly affect the performance of DNN models in diabetes classification (Thaiyalnayaki 2021; Kamalraj et al., 2020).

In recent years, numerous studies have explored the use of DNNs for diabetes classification, with promising results. However, few studies have addressed the challenges of data preprocessing (Chawla et al., 2022), data imbalance, and hyperparameter tuning in a comprehensive manner. Therefore, this research article aims to propose a comprehensive approach to enhancing diabetes classification using DNNs, considering data preprocessing, data imbalance, and hyperparameter tuning. The results of this study have the potential to advance the field of diabetes classification and improve public health outcomes.

Prior to this study, we conducted a series of investigations to ascertain the state of the art in multiple related areas (Junaid et al., 2022a; 2022b; 2020c). These studies contributed significantly in establishing the foundation for this research. Other similar studies that assisted the modeling of a centralized repository are (Imam et al., 2020; Kumar et al., 2020; Imam et al., 2018). A predictive algorithm that based on a novel hybrid multifilter wrapper feature selection method (Balogun et al., 2022). was also implemented to continuously predict potential software defects on the system (please see Figure 1). Using these studies as a guide, a repository that can accommodate all datasets was implemented in accordance with the guidelines proposed by Imam et al. (2018).

Materials and Methods

This section outlines the details of the proposed approach; the proposed approach combines data preprocessing, data imbalance, and hyperparameter tuning techniques to enhance the performance of DNN models for diabetes classification.

Dataset Description

This experiment utilizes the popular Pima Indians Diabetes datasets. The Pima Indians Diabetes dataset was presented by the National Institute of Diabetes and Digestive and Kidney diseases [9]. This dataset comprises of features such as Glucose, Pregnancies, skin thickness, blood pressure, BMI, Insulin, Age, Diabetes Pedigree Function and Outcome (1 = Diabetic and 0 = Non -Diabetic). Table 1 provide the features description while Table 2 presents the sample.

Table 1. Description of Pima Indians Diabetes Datasets Features

Feature Name	**Feature Description**	**Feature type**
Pregnancies	Number of pregnancies of a woman	Numeric
Glucose (mg/dl)	Plasma glucose concentration for 2 hours in oral glucose tolerance test	Numeric
Blood pressure (mmHg)	Diastolic blood pressure	Numeric
Skin thickness (mm)	Triceps skinfold thickness	Numeric
Insulin (mu U/ml)	2-hour serum insulin	Numeric
BMI (kg/m2)	Body mass index (weight in kg/(height in m)2)	Continuous
Diabetes pedigree function	Diabetes pedigree function	Continuous
Age	Age in years	Numeric
Outcome	Target variable (0 or 1) 0 for negative, 1 for positive	Binary

Table 2. Sample Pima Indians Diabetes Datasets

Pregnancies	Glucose	Blood Pressure	Skin thickness	Insulin	BMI	Diabetes Pedigree	Age
6	148	72	35	0	336000	0.6270	50

1	85	66	29	0	266000	0.3510	31
8	183	64	0	0	233000	0.6720	32
1	89	66	23	94	281000	0.1670	21
0	137	40	35	168	43100	2.2880	33
5	116	74	0	0	256000	0.2010	30
3	78	50	32	88	31	0.2480	26
10	115	0	0	0	35300	0.1340	29

Data Preprocessing

Various data preprocessing techniques were applied to enhance the quality of the input data. Although the Prima dataset as shown in Table 2 is standard and popular, it is still a raw dataset and needs processing before using for the experiments. The dataset has a number of instances with zero (0) as value. For instance, insulin and blood pressure are with 0 values and in reality this is not possible as a living human being cannot reach zero insulin or blood pressure level. Consequently, this research considered these zero (0) instances points as outliers and were cleaned before utilizing the dataset. For better results, all the outlier instances point with the suspected outlier points are re-moved as part of data processing. Similarly, for improved readability, the outcome is converted into categorical variables with 1 as Diabetic and 0 as Non - Diabetic. Additionally, we imputed the missing values using the mean imputation method.

The study addressed the issue of data imbalance, where the classes are not equally represented, by using both oversampling and undersampling techniques. Specifically, the study used the Synthetic Minority Oversampling Technique (SMOTE) [8] to balance the data.

Proposed Deep Neural Network (DNN)

The proposed DNN was implement using five different architectures (A1-A5), where by each architecture is design with different number of hidden layers and number of neurons, to classify the presence or absence of diabetes. To optimize the performance of the DNN models, hyperparameter tuning was performed using a combination of grid search and random search. Various hyperparameters were tuned, including the number of layers, the number of neurons, the learning rate, and the dropout rate. The hidden layers and the number of neurons of each architecture is shown in Table 3.

Table 3. Number of Hidden Layers and Neurons in Each DNN Architecture

Architectures (A)	Hidden layers (H)	Number of neurons
A1	H1	20
A2	H1	20

	H2	45
A3	H1	55
	H2	20
	H3	20
A4	H1	55
	H2	20
	H3	45
	H4	20
A5	H1	20
	H2	45
	H3	20
	H4	45
	H5	20

Designing of Web Application

A user friendly web application was built to implement the proposed model. Figure 1 depicts the user interface for the developed system.

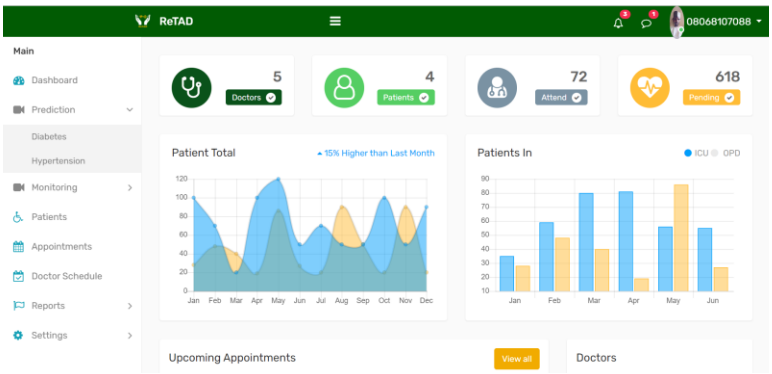

Figure 1. Web Application Interface for Real-time Analysis (retadcare.com)

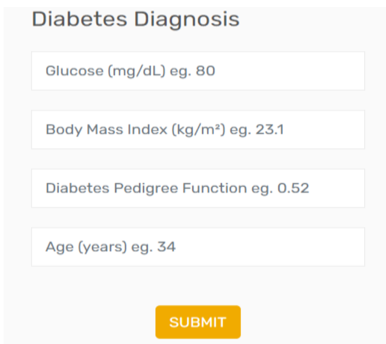

Figure 1. Diabetes diagnosis Interface

Hypertext Markup Language (HTML), Javascript, and Bootstrap Framework were used to develop the front end of the application. Python web framework called Flask was used to deploy the proposed deep neural network (DNN). The deployed network was sufficiently trained using the datasets as described in Table 2. In order to have real-time diagnostic assessments, an interface (as shown in Figure 2) is provided to capture additional values that aid the analysis and prediction. The web application provides an interface for users to enter the readings taken from patient and the proposed DNN makes the prediction and output the result, which are recorded and used for predictions overtime.

Performance Metrics

We evaluated the performance of the DNN models using metrics such as classification accuracy, sensitivity, specificity, and F1-score. We used 5-fold cross-validation to validate the results and ensure that the models were not overfitting. The following measures are used to assess the classification outcomes: accuracy, precision, F1 score, recall, area under the ROC curve (AUC), and Matthews's correlation coefficient (MCC). The formulas for these metrics are shown in Equations (1) through (7). The letters TP, TN, FP, and FN in these equations stand for true positives, false positives, true negatives, and false negatives, respectively. The 5-fold cross-validation was used to validate the results and ensure that the models were not overfitting.

In Equation (1), accuracy is defined as the proportion of accurately predicted data samples to all input samples.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \quad (1)$$

High accuracy is associated with a low false positive rate. Precision is defined in Equation (2) as the ratio between accurately predicted positive samples and the total expected positive samples.

$$\Pr ecision = \frac{TP}{TP + FP} \quad (2)$$

Recall is the proportion of accurately predicted positive samples to all samples in the actual class. See Equation (3).

$$\operatorname{Re} call = \frac{TP}{TP + FN} \quad (3)$$

The Harmonic Mean between recall and precision is referred to as the F1 Score in Equation (4). Therefore, both false positives and false negatives are considered while calculating this score.

$$F1Score = 2*\frac{Precision*Recall}{Precision+Recall} \quad (4)$$

Performance measures for classification issues at various threshold levels include the Receiver Operating Characteristic (ROC) curve and AUC. These metrics can be used to determine how well the model can differentiate between classes. In particular, ROC is a probability curve that displays how well a classification model performs across the board. The TP and FP parameters are shown by this curve. The true positive rate, as stated in Equation (5), is the proportion of positive data points that are actually regarded as positive compared to all positive data points.

$$TPR = \frac{TP}{TP+FN} \quad (5)$$

False Positive Rate, as stated in Equation (6), is the ratio of negative data points that are wrongly interpreted as positive to all negative data points.

$$FPR = \frac{FP}{FP+TN} \quad (6)$$

Both of the aforementioned values fall between [0, 1]. The AUC is moreover the outcome under the curve of the plot of the False Positive Rate vs. True Positive Rate (ROC curves). MCC is a performance metric for model quality classification. Eq. (7) defines the mathematical measure.

$$MCC = \frac{TP*TN+FP*FN}{\sqrt{(TP+FP)(TP+FN)(TN+FN)(TN+FP)}} \quad (7)$$

Implementation Details

The data preprocessing, data imbalance, and DNN models were implemented using Python 3.8. We used Scikit-learn, TensorFlow, and Keras libraries for data pre-processing, oversampling, undersampling, and model building. All experiments were on an AMD Ryzen 7 4800H with Radeon Graphics processor with 24GB of RAM.

Results

In this section, the result obtained from the experiments are presented. It's important to note that these results are generated after the implementing all the libraries as explained in Section 2.5. Therefore, the results do not directly represent the values presented on the web application in Section 2.4. The results are divided into two sections, namely; performance of the different DNN architectures, and 2) comparison with other methods from the literature.

Performance of the different DNN architectures

The result obtained using each of the five architectures are presented in Table 4-8 and summarized in Table 9.

Table 4. Results Obtained using Architecture 1 (A1)

	Accuracy	**Precision**	**Recall**	**F1-score**	**Area Under Curve AUC)**
	0.88	0.84	0.78	0.81	0.94
	0.94	0.94	0.85	0.89	0.98
	0.88	0.84	0.78	0.81	0.94
	0.88	0.88	0.72	0.79	0.9
	0.93	0.92	0.85	0.88	0.97
Average	0.9	0.88	0.8	0.84	0.95
STD	0.027	0.041	0.049	0.041	0.028

Table 5. Results Obtained using Architecture 2 (A2)

	Accuracy	**Precision**	**Recall**	**F1-score**	**Area Under Curve AUC)**
	0.89	0.82	0.82	0.82	0.94
	0.91	0.91	0.8	0.85	0.96
	0.85	0.74	0.8	0.77	0.92
	0.87	0.82	0.72	0.77	0.91
	0.92	0.85	0.9	0.88	0.98
Average	0.89	0.83	0.81	0.82	0.94
STD	0.026	0.055	0.057	0.044	0.026

Table 6. Results Obtained using Architecture 3 (A3)

	Accuracy	**Precision**	**Recall**	**F1-score**	**Area Under Curve AUC)**
	0.89	0.84	0.8	0.82	0.94
	0.93	0.92	0.85	0.88	0.97
	0.89	0.82	0.82	0.82	0.93
	0.89	0.88	0.74	0.81	0.91
	0.9	0.81	0.87	0.84	0.97
Average	0.9	0.85	0.82	0.83	0.94
STD	0.015	0.041	0.045	0.025	0.023

Table 7. Results Obtained using Architecture 4 (A4)

	Accuracy	**Precision**	**Recall**	**F1-score**	**Area Under Curve(AUC)**
	0.89	0.81	0.85	0.83	0.94
	0.92	0.92	0.82	0.87	0.96
	0.88	0.79	0.85	0.82	0.92
	0.86	0.84	0.67	0.74	0.9
	0.92	0.87	0.87	0.87	0.98
Average	0.89	0.85	0.81	0.83	0.94
STD	0.023	0.046	0.073	0.048	0.028

Table 8. Results Obtained using Architecture 5 (A5)

	Accuracy	**Precision**	**Recall**	**F1-score**	**Area Under Curve (AUC)**
	0.88	0.79	0.82	0.8	0.94
	0.93	0.92	0.85	0.88	0.97
	0.88	0.79	0.85	0.82	0.92
	0.86	0.84	0.67	0.74	0.89
	0.92	0.87	0.87	0.87	0.98
Average	0.89	0.84	0.81	0.82	0.94
CM	0.027	0.05	0.073	0.051	0.033

Table 9. Average Accuracy, Precision, Recall, F1-Score and AUC of the Five Architectures

Architecture	**Accuracy**		**Precision**		**Recall**		**F1-score**		**Area Under Curve**	
	Average	**STD**	**Average**	**STD**	**Average**	**STD**	**Average**	**STD**	**Average**	**STD**
A1	0.9	0.027	0.88	0.041	0.8	0.049	0.84	0.041	0.95	0.028
A2	0.89	0.026	0.83	0.055	0.81	0.057	0.82	0.044	0.94	0.026
A3	**0.9**	**0.015**	**0.85**	**0.041**	**0.82**	**0.045**	**0.83**	**0.025**	**0.94**	**0.023**
A4	0.89	0.023	0.85	0.046	0.81	0.073	0.83	0.048	0.94	0.028
A5	0.89	0.027	0.84	0.05	0.81	0.073	0.82	0.051	0.94	0.033

Result from Table 9 shows the average accuracy, precision, recall, and AUC of the five architectures used for effective prediction of diabetes using deep learning approach. The results indicate that the five different architectures performed averagely the same in terms of the different metrics used.

Comparison with other methods from the literature

Table 10 shows the comparison of the proposed framework with the existing methods in the literature in terms of the average accuracy. By referring to Table 10, it can be observed that the proposed work has scored up to 90% accuracy as compared to the state of the art. In 2017, a method was proposed by Li et al. which scored up to 80.21% accuracy using General Regression Neural Network (GRNN). However, this method was improved in the same year using Multi Objective Fuzzy Classifier and was able to obtain the accuracy of 83.04%. A slightly improved method with an average score of 83.83% was introduced in 2018 by Zou et al. using Re-Rx with J48graft combined with sampling selection. This improvement was considered significant before the arrival of Decision Tree Based Ensemble Classifiers in 2019 by Gaurav & Vijay. This method was able to score up to 89.70% accuracy, which is a remarkable improvement. The following section discussed these differences in details and their causes.

Table 10. Comparison of the Proposed Approach with other Methods from the Literature

Approach	Accuracy (%)	Algorithms
(Zou, et al., 2018)	83.83	Re-Rx with J48graft combined with sampling selection
(Edla & Ramalingaswamy, 2017)	83.04	Multi Objective Fuzzy Classifier
(Li, Yan, & Geng, 2017)	80.21	GRNN
(Gaurav & Vijay, 2019)	89.70	Decision Tree Based Ensemble Classifiers
Proposed work	**90.00**	DNN architecture

Discussion

The results of the study demonstrate that careful data preprocessing, handling of data imbalance, and hyperparameter tuning can significantly improve the performance of deep neural network (DNN) models for diabetes classification.

Firstly, the results show that feature scaling, principal component analysis (PCA), and imputation of missing values using mean imputation can enhance the performance of DNN models. Feature scaling standardizes the input variables to have a mean of zero and a standard deviation of one, which helps to improve the convergence of DNN models. PCA reduces the dimensionality of the input data and removes redundant features, which can improve the generalization ability of DNN models. Imputation of missing values can help to reduce bias and improve the accuracy of DNN models.

Secondly, the results demonstrate that handling of data imbalance is crucial for improving the performance of DNN models in diabetes classification tasks. SMOTE technique was used to balance the class distribution. The SMOTE improved the sensitivity and specificity of DNN models.

Finally, the results show that hyperparameter tuning is essential for optimizing the performance of DNN models in diabetes classification tasks. We used grid search to tune the hyperparameters of the DNN models, including the number of layers, number of neurons, learning rate, and dropout rate. The results show that the optimal hyperparameters varied depending on the dataset and that hyperparameter tuning significantly improved the performance of DNN models.

Conclusion

This study demonstrates that a combination of careful data preprocessing, handling of data imbalance, and hyperparameter tuning can significantly enhance the performance of DNN models for diabetes classification tasks. The proposed approach can help to improve the accuracy and reliability of diabetes diagnosis, which can ultimately lead to better management and prevention of diabetes-related complications. However, further studies are needed to validate the proposed approach on larger and more diverse datasets and to compare its performance with other machine learning techniques.

Recommendations

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Using Data and Analytics to Find Fraud: A Case Study

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Abstract: The demand for accountants with data and analytics skills is increasing. Employers seek accounting graduates who can effectively analyze and interpret financial data to make informed business decisions. By integrating data and analytics into the curriculum, students become more competitive in the job market and have a higher chance of securing positions. First-year college students are constantly using technology. Social media apps like Instagram, TikTok, and YouTube dominate their lives. However, they need to gain expertise in programs like Microsoft Excel, Tableau, and PowerBI. Using a case study that discusses fraud in a Financial or Forensic Accounting course introduces students to accounting concepts while guiding them through analytical steps to assist in their decision-making. After performing their analysis, students must create visualizations they incorporate into a written communication to their client. This practical application allows students to apply their knowledge to a real-world fact pattern, creating a deeper understanding of analytics in accounting and enhancing their critical thinking and problem-solving abilities.

Keywords: excel, fraud triangle, data visualization, data analytics, critical thinking

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Case

In this case, your objective is to gain insight into a business environment while identifying internal control issues and potential instances of fraud. You will leverage analytical software (choice of your instructor but could include Microsoft Excel only, Microsoft Excel and Tableau, or Microsoft Excel and Microsoft PowerBI) to examine data, explore the issues, and ultimately draw conclusions supported by your analytical findings. Finally, you will communicate your determinations concisely, while incorporating visualizations of your data analysis into your report.

Case Facts

You are a Certified Public Accountant specializing in forensic accounting. Pete Baker, the Chief Operating Officer of Baker’s Sawmill and Custom Carpentry, has asked your accounting firm to investigate the company’s accounting data for fraud. Baker’s Sawmill and Custom Carpentry, Inc. is a small, family-owned and operated business in Robbinsville, Massachusetts (open to customers from 9 am to 5 pm Tuesday-Friday and Saturday from 9 am to 12 pm). For over a century, the company has been selling lumber, cabinets, and furniture from its lumber yard and showroom while also offering custom carpentry services to local contractors and individuals.

Gibbs Baker, the CEO and sole shareholder, employs his sons Pete and Mike full-time. Pete, the COO, works with Gibbs in the lumber yard, and Mike works in the showroom as an office manager. The company also employs Gibb's sister, Cassie, as a part-time accountant and several college students who help in the showroom during the week. Mike is the only employee at the business location on Saturdays since Gibbs and Pete complete installation and onsite carpentry work at client sites every Saturday. Sue makes deposits for Cassie on Saturdays since Cassie plays in her local pickleball club on the weekends.

The business is situated on a 10-acre property and comprised of two separate buildings. One building, located directly off the street, houses the office, showroom, and sales functions. The lumber yard and custom carpentry buildings are situated down a long driveway about a 2–3-minute walk from the showroom. The lumber yard has a separate entrance accessible only to employees. Additionally, there is a 4-bedroom house adjacent to the showroom where Mike and his family reside. Gibbs, the owner of the land and buildings, charges Mike minimal rent for use of the home.

Table 1. Employee Information

Gibbs Baker	CEO and Sole Shareholder, Sawyer, and Carpenter **Job Description:** Produced all the lumber products and performed all of the custom carpentry with his son, Pete. **Family Structure:** Father to Pete (and his wife Carol) and Mike (and his wife Sue), Brother to Cassie **Residence:** Fairview, Massachusetts (a 10-minute drive from the business location)
Pete Baker	COO, Sawyer, and Carpenter **Job Description:** Produced all the lumber products and performed the custom carpentry with his father, Gibbs. Worked off-site, at times, for special custom jobs. **Family Structure:** Son to Gibbs, Brother to Mike, Nephew to Cassie, Husband to Carol **Residence:** Fairview, Massachusetts (a 10-minute drive from the business location)
Mike Baker	Office Manager **Job Description:** Point person for customer orders, equipment purchases, and supplies purchases,

	collected all of the mail (including customer payments), created the budgets and entered journal entries, mailed invoices. Answered all the phone calls and emails. **Family Structure:** Son to Gibbs, Brother to Pete, Nephew to Cassie, Husband to Sue **Residence:** Robbinsville, Massachusetts (in a house located on the business property)
Cassie Dupont	**Part-Time Accountant** **Job Description:** Makes deposits, files monthly and quarterly tax returns, etc. **Family Structure:** Sister to Gibbs, Aunt to Pete and Mike **Residence:** Robbinsville, Massachusetts (a 2-minute drive from the business location)
Sue Baker	No Official Position **Job Description:** Sporadically helps Mike in the office. Makes deposits on Saturdays. **Family Structure:** Wife to Mike **Residence:** Robbinsville, Massachusetts (in a house located on the business property)
Hourly Customer Service Employees	**Joe Raskin**: resides at the local college campus and worked for the company last year. **Bobby Owl:** resides in an apartment off campus, no prior work experience. **Liam Conway:** resides at the local college campus and worked for the company last year.

Internal Control and Fraud Concerns

Over the past year, Pete has become increasingly concerned that someone is stealing from his father's company. Despite his worries, Pete's father is extremely trusting and refuses to believe that any of his employees would ever steal from him. Pete has hired your firm to investigate the matter and meets with you to share his concerns. According to financial statements and tax returns, sales have dropped. However, production has been busier than ever, and prices have increased due to demand.

Pete was first suspicious when his brother, Mike, took off a Saturday in April to go on vacation for his 20th wedding anniversary. Sales were substantially higher than on any other Saturday. When Pete arrived at the showroom parking lot, customers were waiting at the door. Customers informed Pete that Mike consistently opens the showroom for early morning sales every Saturday, even though they're not officially open until 9 am. Mike seldom takes a break or a day off. In addition to his customer service responsibilities, he hires and manages all hourly employees, approves payroll, collects the mail, pays bills, and performs basic bookkeeping.

Because Mike and the other hourly workers enter and exit through the employee entrance at the showroom, Gibbs and Pete don't typically interact with them as they enter and exit through the lumber yard. The showroom workers are solely responsible for customer service and handling cash transactions. To gain access to the register located in the office, employees must swipe their badge, similar to accessing a hotel room. The office has a small window where employees can assist clients.

Pete also shares that he is concerned about another employee, Robert "Bobby" Owl, whom he has never met. Payroll records indicate Bobby Owl works 40 hours per week (hint: see hours of operation). Pete called and texted Bobby Owl numerous times in April to ask if he could work on Saturday, 4/23 (remember: Mike cannot work on 4/23). Bobby's voicemail was full, and he never returned Pete's calls or texts.

Lastly, Pete shares that Liam Conway called out sick on Wednesday, 4/13. Pete is aware that they do not have sophisticated internal controls as small family business. He has also researched the fraud triangle and understands that there is ample opportunity for fraud due to the cash nature of the business. Pete has offered to provide the firm with exports from the company's accounting information system for the month of April to aid in your investigation.

Using Microsoft Excel to Analyze Data and Create Visualizations

After reading through the case facts and internal control and fraud concerns, develop a list of questions and concerns. What are your theories based on the facts provided? What information should you request from the client to start your investigation? Draft a client letter to request information from the company.

You are provided with several exports of accounting data from April 2022 in Microsoft Excel format, including Badge Sign-ins, Deposits, Register Voids, and Sales Receipts. You are also provided with a current Employee List as of April 2022. First, you must review the Microsoft Excel files for basic formatting issues. Data is not always exported in a way that can be easily analyzed. Therefore, you will need to clean the data first.

Clean the Data

The data in the Microsoft Excel file will need to be cleaned to manipulate it in a Pivot Table. In the Employee List, you will need to format the titles properly. The objective is to use proper headings, proper formatting, and text to columns. In Sales Receipts, Register Voids (available after Conditional Formatting is complete), and Deposits, you will add a column and use the day of the week formula to help you quickly identify the transactions that occurred on Saturdays (the day the client was suspicious of). In Deposits, you will need to change the titles so there are no duplicate headings.

Analyze the Data Using Microsoft Excel and Create Visualizations: Part A - Conditional Formatting

Since you are concerned about missing cash, you will need to investigate the cash receipts for any missing transaction numbers using Conditional Formatting in Microsoft Excel. After following the steps, missing transactions can be identified by a highlighted cell. The transaction number immediately after the highlighted cell is missing. Transactions may need to be voided for many reasons, such as a typo or an error in the products scanned, so it is important to avoid jumping to conclusions (see Figure 1). If there are any missing transactions, draft a professional email to your client requesting further information. (Instructors will provide students access to the Voided Transactions Microsoft Excel file once this step is complete.)

CASHIER	TRANSACTION_NUMBER
MB	1246
JR	1247
JR	1248
JR	1249
MB	1250
MB	1251
JR	1253
MB	1254
MB	1255
MB	1256
MB	1257
MB	1258
MB	1260
MB	1262
MB	1263

Figure 1. Visualization of Conditional Formatting: Voided Transactions

Analyze the Data Using Microsoft Excel and Create Visualizations: Part B - Pivot Tables

You will create a pivot table using the cleaned Sales Receipt Microsoft Excel file to analyze the cash receipts by day. By adding the day of the week column during the cleaning process, you can easily group daily cash receipts in a pivot table. Next, create a 2-D column chart visualization from the pivot table to help you identify any suspicious activity related to cash receipts (see Figure 2). What does this chart tell you about the sales? Does the information in the chart support any of your theories?

Next, you will create a pivot table using the cleaned Sales Receipt Microsoft Excel file. Here, you can identify the cash receipts by cashier. Consider part-time and full-time status when analyzing the data. Next, create a 2-D column chart visualization from the pivot table to help you identify any suspicious activity related to cash receipts by Cashier (see Figure 3). After analyzing the chart, what does it tell you about the cashiers? Do you have further questions after performing this analysis?

CASH SALES BY DAY	CASH RECEIPTS
Tuesday	**$ 74,843.09**
4/5/22	$ 22,096.86
4/12/22	$ 17,979.05
4/19/22	$ 16,153.88
4/26/22	$ 18,613.30
Wednesday	**$ 79,671.00**
4/6/22	$ 24,496.14
4/13/22	$ 14,452.97
4/20/22	$ 20,995.08
4/27/22	$ 19,726.81
Thursday	**$ 91,087.85**
4/7/22	$ 28,781.67
4/14/22	$ 16,646.92
4/21/22	$ 26,010.25
4/28/22	$ 19,649.01
Friday	**$ 90,012.02**
4/1/22	$ 15,679.74
4/8/22	$ 17,738.77
4/15/22	$ 18,598.66
4/22/22	$ 20,773.13
4/29/22	$ 17,221.72
Saturday	**$ 51,176.14**
4/2/22	$ 391.90
4/9/22	$ 1,222.88
4/16/22	$ 1,227.58
4/23/22	$ 47,135.70
4/30/22	$ 1,198.08
Grand Total	**$ 386,790.10**

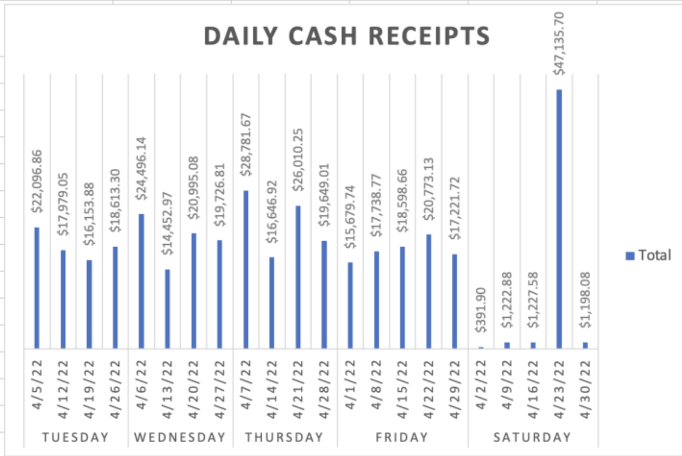

Figure 2. Using a Pivot Table to Create a Visualization of Daily Cash Receipts

CASHIER	CASH RECEIPTS
JR	$ 161,000.97
LC	$ 136,317.07
MB	$ 75,311.22
PB	$ 11,515.62
RO	$ 2,645.22
Grand Total	**$ 386,790.10**

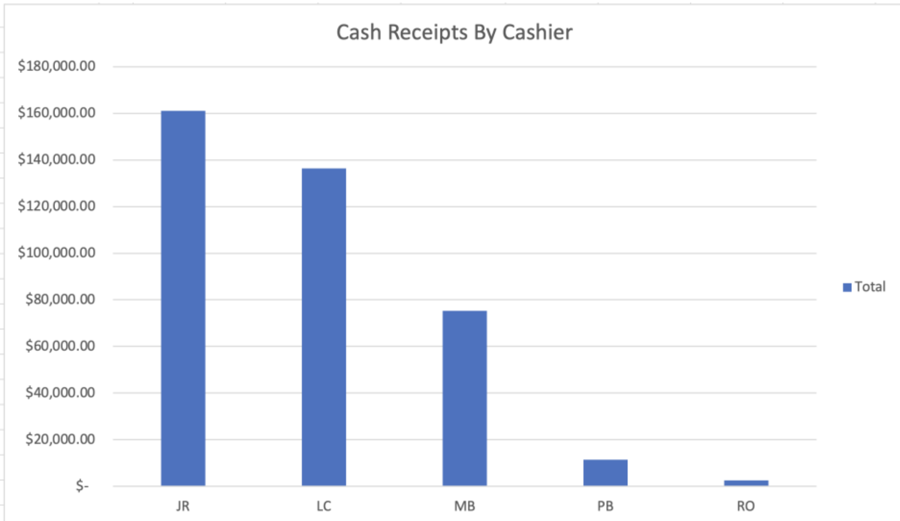

Figure 3. Using a Pivot Table to Create a Visualization of Cash Receipts by Cashier

Using the Badge Sign-Ins Microsoft Excel file, create a pivot table to help you test whether all cashiers used their badges to access the office. Since all employees must use their badge to access the cash register, you will analyze the badge sign-ins and the sales by cashier information completed above (see Figure 4). After analyzing the chart, what does it tell you about the cashiers? Did all the cashiers access the office to cash out customers? What questions do you have after performing this analysis?

Cashier Badge Swipes	Location SHOWROOM	Grand Total
JR	10	10
LC	8	8
MB	48	48
Grand Total	**66**	**66**

CASHIER	CASH RECEIPTS
JR	$ 161,000.97
LC	$ 136,317.07
MB	$ 75,311.22
PB	$ 11,515.62
RO	$ 2,645.22
Grand Total	**$ 386,790.10**

Figure 4. Comparing Pivot Tables to Identify Ghost Employees

Using the cleaned Sales Receipts Microsoft Excel file, create a pivot table to summarize the cash receipts into daily totals. The data must be summarized before it is compared to the deposit data. Create a 2-D column chart to help you analyze the data (see Figure 5). What does this chart tell you about the cashiers? What questions do you have after performing this analysis?

DEPOSITOR BY DATE	CASH RECEIPTS	CASH DEPOSITS
CD	**$ 351,074.97**	**$ 351,074.97**
4/1/22	$ 15,679.74	$ 15,679.74
4/5/22	$ 22,096.86	$ 22,096.86
4/6/22	$ 24,496.14	$ 24,496.14
4/7/22	$ 28,781.67	$ 28,781.67
4/8/22	$ 17,738.77	$ 17,738.77
4/12/22	$ 17,979.05	$ 17,979.05
4/14/22	$ 16,646.92	$ 16,646.92
4/15/22	$ 18,598.66	$ 18,598.66
4/19/22	$ 16,153.88	$ 16,153.88
4/20/22	$ 20,995.08	$ 20,995.08
4/21/22	$ 26,010.25	$ 26,010.25
4/22/22	$ 20,773.13	$ 20,773.13
4/23/22	$ 47,135.70	$ 47,135.70
4/26/22	$ 18,613.30	$ 18,613.30
4/27/22	$ 19,726.81	$ 19,726.81
4/28/22	$ 19,649.01	$ 19,649.01
SB	**$ 35,715.13**	**$ 27,215.13**
4/2/22	$ 391.90	$ 391.90
4/9/22	$ 1,222.88	$ 222.88
4/13/22	$ 14,452.97	$ 10,452.97
4/16/22	$ 1,227.58	$ 227.58
4/29/22	$ 17,221.72	$ 15,221.72
4/30/22	$ 1,198.08	$ 698.08
Grand Total	**$ 386,790.10**	**$ 378,290.10**

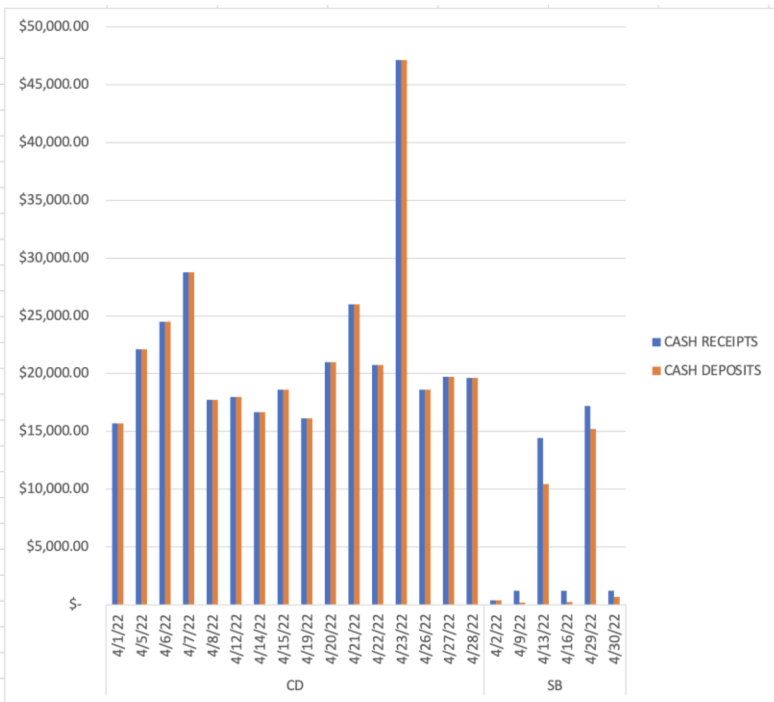

Figure 5. Comparing Cash Receipts with Cash Deposits

Although the chart can help the user visualize the difference between cash receipts and cash deposits, it is also important to include a calculated field, helping the user quickly identify the dollar amount of the difference. Using your Pivot Table from Figure 5, you will create a calculated field to calculate any differences between cash receipts and cash deposits (see Figure 6). What conclusions can you draw from this analysis?

CASH RECEIPTS AND DEPOSIT ANALYSIS	CASH RECEIPTS	CASH DEPOSIT	DEPOSIT AND CASH RECEIPTS DIFFERENCE
CD	**$ 351,074.97**	**$ 351,074.97**	**$ -**
4/1/22	$ 15,679.74	$ 15,679.74	$ -
4/5/22	$ 22,096.86	$ 22,096.86	$ -
4/6/22	$ 24,496.14	$ 24,496.14	$ -
4/7/22	$ 28,781.67	$ 28,781.67	$ -
4/8/22	$ 17,738.77	$ 17,738.77	$ -
4/12/22	$ 17,979.05	$ 17,979.05	$ -
4/14/22	$ 16,646.92	$ 16,646.92	$ -
4/15/22	$ 18,598.66	$ 18,598.66	$ -
4/19/22	$ 16,153.88	$ 16,153.88	$ -
4/20/22	$ 20,995.08	$ 20,995.08	$ -
4/21/22	$ 26,010.25	$ 26,010.25	$ -
4/22/22	$ 20,773.13	$ 20,773.13	$ -
4/23/22	$ 47,135.70	$ 47,135.70	$ -
4/26/22	$ 18,613.30	$ 18,613.30	$ -
4/27/22	$ 19,726.81	$ 19,726.81	$ -
4/28/22	$ 19,649.01	$ 19,649.01	$ -
SB	**$ 35,715.13**	**$ 27,215.13**	**$ 8,500.00**
4/2/22	$ 391.90	$ 391.90	$ -
4/9/22	$ 1,222.88	$ 222.88	$ 1,000.00
4/13/22	$ 14,452.97	$ 10,452.97	$ 4,000.00
4/16/22	$ 1,227.58	$ 227.58	$ 1,000.00
4/29/22	$ 17,221.72	$ 15,221.72	$ 2,000.00
4/30/22	$ 1,198.08	$ 698.08	$ 500.00
Grand Total	**$ 386,790.10**	**$ 378,290.10**	**$ 8,500.00**

Figure 6. A Calculated Field in a Pivot Table

Deliverables

Upon the conclusion of the case, you should provide the following items to your client:

1. Engagement Letter
   a. An engagement letter is a legal document between you and your client. It should include a letterhead, date, address of the client, salutation, subject line, multiple sections detailing the engagement (see b. below), official closing, and a signature.
   b. The multiple sections within the body of the engagement letter should be similar to the following: the parties, scope of the engagement, your responsibilities, limitations, conflicts, timing, fees, documentation, litigation assistance (if applicable), termination, disputes, disclaimer, and any additional terms you feel are necessary.
   c. The engagement letter should be single-spaced within paragraphs, double spaced between paragraphs. Paragraphs should be left justified with 1-inch margins at the top, bottom, left, and right of every page. No title page should be included.
2. Client Letter
   a. The client letter should be a clear, concise request for information. It should include a letterhead, date, address of the client, salutation, subject line, a summary with an explanation (if applicable), official closing, and a signature.
   b. Within the summary paragraph, if multiple documents are requested, they should be listed using bullet points or numbers.

3. Professional Email
    a. Email has become the standard form of communication within the accounting industry. Students must learn how to draft an email that is organized, direct, and professional.
    b. The email should include opening remarks, a body paragraph requesting additional information, a closing paragraph, and a sign off. Students should include the topic of the email in the subject line.
4. Business Brief (including data visualizations).
    a. The brief should be one-page, single-spaced within paragraphs, and double-spaced between paragraphs. Paragraphs should be left justified with 1-inch margins at the top, bottom, left, and right of every page. No title page should be included.
    b. The business brief should include an opening paragraph, an analysis section detailing the story of the fraud, and a conclusion. The analysis section does not explain how you performed the analysis but provides an interpretation of your internal control and fraud findings with recommendations (if applicable).
    c. Include your data visualizations as appendices to your brief.
5. PowerPoint Presentation
    a. The PowerPoint slides should include a title page, facts, concerns, assumptions, findings, and then a conclusion slide. Include the visualizations in the slides.
    b. Slides should be attention-grabbing, but still professional.
    c. In addition, record your presentation to your client using Zoom, Panopto, or YouTube.

Discussions

The case was developed in response to the lack of current and comprehensive Forensic Accounting textbooks focusing in data analytics and data visualization. In addition, accounting students are now required to graduate with advanced data analytical skills to successfully prepare for the 2024 CPA exam, and these skills are required under the new CPA Evolution Model for business education (see https://www.evolutionofcpa.org).

This is an introductory case that is primarily for students who are new to using Microsoft Excel and Pivot Tables. This case encourages critical thinking skills by requiring students to analyze quantitative and qualitative data to identify internal control and fraud concepts. The case challenges students to apply data analytics techniques to test information and present their findings using data visualization.

Teaching Notes

Teaching Notes and a Student Version of the Case, including the Action Items, Step-by-Step Instructions, and the Microsoft Excel files are available upon request. In addition, a Student Sample complete with an Engagement Letter, Client Letter (Request for Information), and Business Brief (including visualizations) can also be provided upon request. Please do not make the Student Sample available to students or post them on websites.

Acknowledgments

Thank you to Debra Petrizzo, DBA for providing the business brief guidelines and reviewing the case. Thank you to Logan Scarlotta for reviewing and completing the case study in its entirety, with detailed feedback, before it was introduced to my courses.

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Thermal Management of the Hybrid Electric Wheel Loader

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Abstract: Electrification of vehicles used in construction sides, industrial fields, and similar areas is rapidly developing, and their numbers are increasing in a similar and parallel way to the automotive industry. The motors/generators, inverters, battery packages, DC/DC converters, and other electrical components need to be cooled down. In this study, the thermal management of a hybrid electric construction machine is described. The cooling requirement has been determined for each component of the system. The flow diagram of the cooling system has been designed and the working system has been created. Through the developing technology, this and similar thermal management systems are controlled by software. A system control algorithm has been created to be used in the development of the software. It is quite significant that the cooling system architecture is designed correctly for the sufficient and efficient operation of such systems. Generally, for this kind of system, multi pumps and radiators are used to cool down the components. In this study, one pump and one radiator are used, which brings several technical advantages and lowers system costs.

Keywords: Electrification, Hybrid-Electric, Thermal Management, Wheel Loader, Electric Vehicle, Electric Construction Machinery.

Citation: Karahan, M. (2023). Thermal Management of The Hybrid Electric Wheel Loader. In A. A. Khan, E. Cakir, & M. Unal (Eds.), *Proceedings of ICSEST 2023-- International Conference on Studies in Engineering, Science, and Technology* (pp. 118-126), Antalya, Turkiye. ISTES Organization.

Overall Layout of the Hybrid Electric Wheel Loader

In this study, thermal management of a serial hybrid wheel loader has been developed. In serial hybrid topologies, there is no direct mechanical connection from the engine to consumers. See the Figure 1. The power generator driven by the diesel motor provides energy to the system. The supercapacitors store kind of energy and make the engine work at more efficient ranges possible by providing the stored energy. The hydraulic system and power train are driven by separate motors to increase the system's overall efficiency. The brake system is capable of energy recuperation from the traction motors. The regenerative energy is stored in the supercapacitors as well.

Thermal System Architecture

In electric vehicles, thermal systems consist of radiators, pumps, expansion tanks, hoses, etc. One of the most significant points for thermal management is creating a sufficient and efficient cooling system architecture. One of the innovative ways of this study is pumping and cooling down the coolant of all the electric components by a single pump and radiator, which has several advantages;

-Reducing the overall costs of the thermal system,

-Reducing the package size and complexity,

-Proving higher and better cooling capacity and performance for each element,

-Avoiding controlling multi-circulation pumps and fan drive.

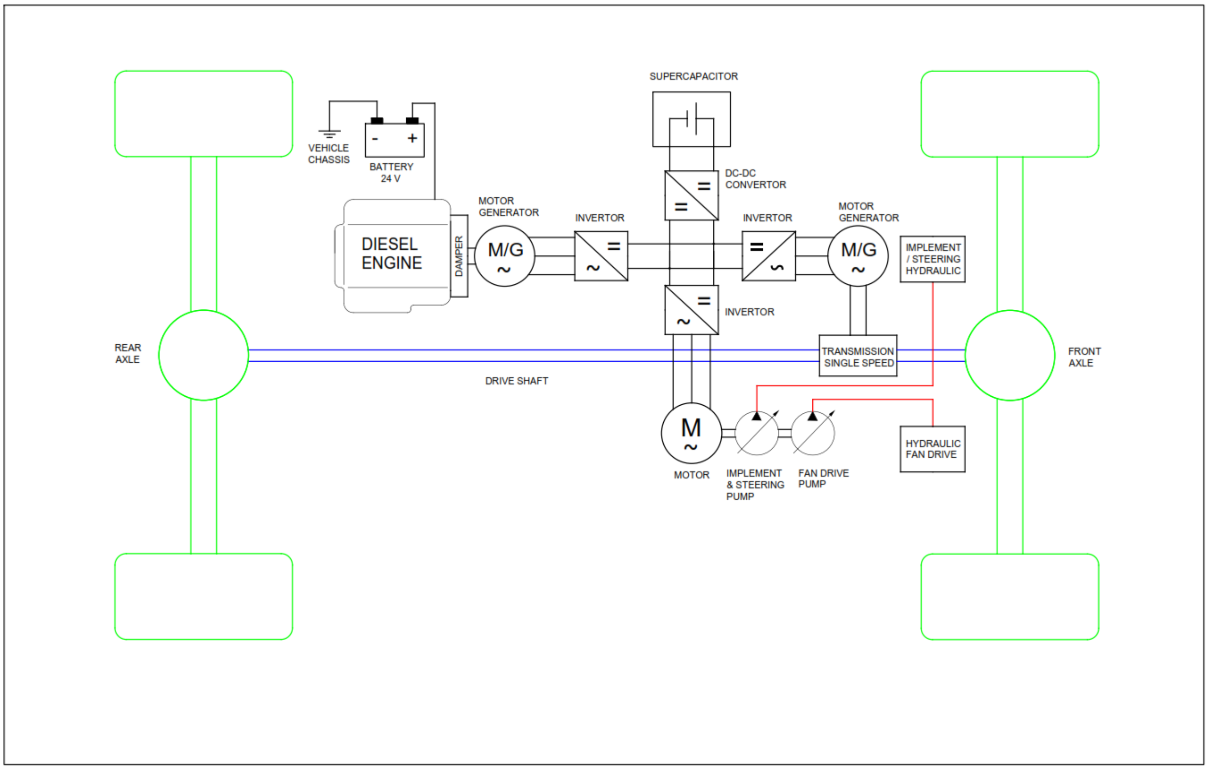

Figure 1. The overall layout of the Hybrid Electric Wheel Loader

As shown in Figure 2, the single pump provides the coolant circulation, the flow regulator block arranges the flow rate of each cooling line, and temperature sensors detect the temperature of each element and return line. The expansion tank provides an extra volume when the coolant gets hotter and expands. The single radiator cools down the coolant. The arrangement of the components in the cooling system is quite significant to gain better performance. Flow and heat rejection rates are considered as the elements are arranged. The elements with similar flow rates are aligned in the same cooling line. The components with relatively high heat rejection rates are avoided in the same line to prevent the second element from overheating.

Determining the Cooling Requirements

In order to obtain maximum performance of electric components, they need to be cooled down to efficient working temperatures. When the components overheat, they limit themselves to less power, which means low performance and productivity of the vehicle.

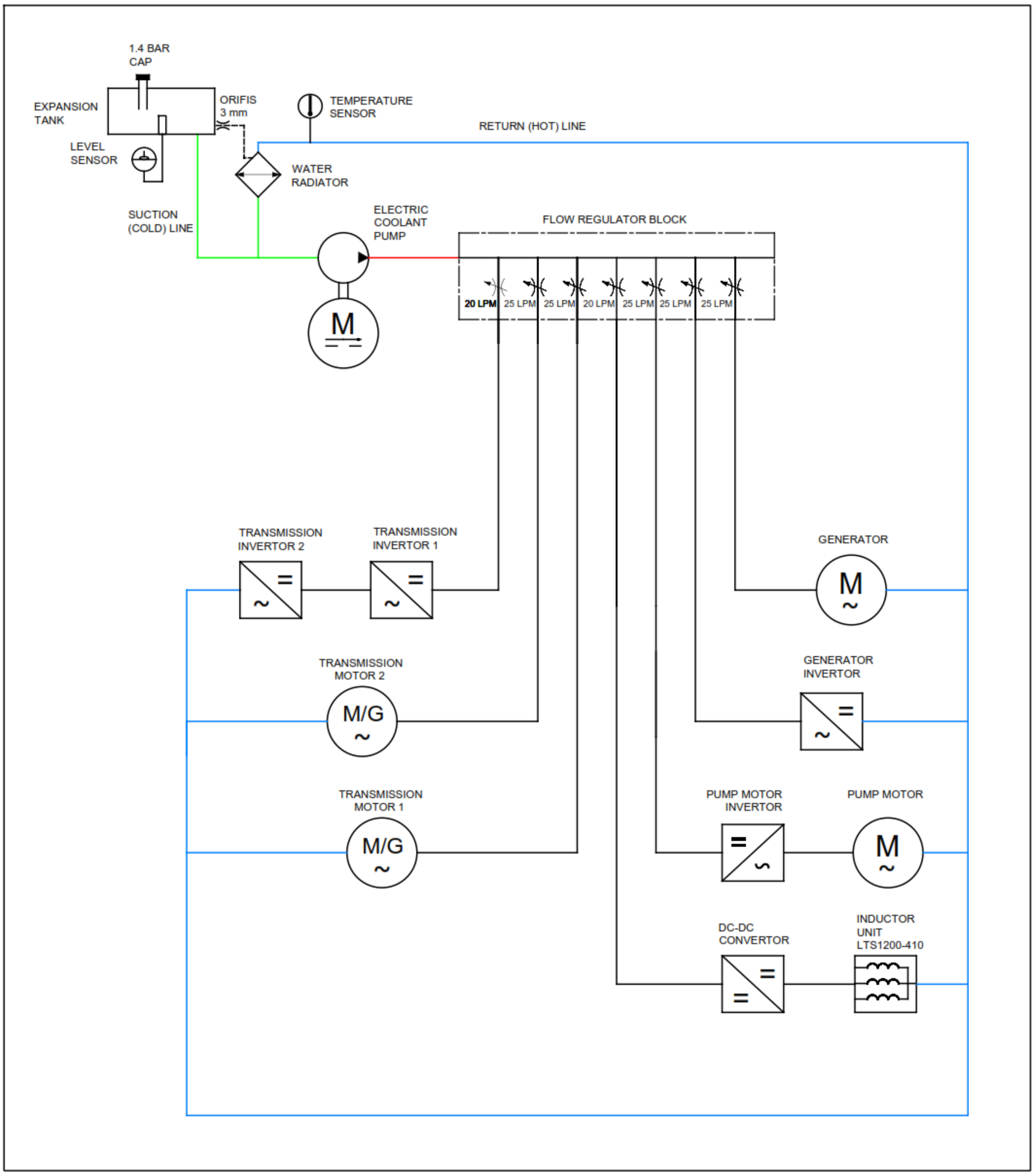

Figure 2. Thermal System Architecture of the Hybrid Electric Wheel Loader

There are two main parameters regarding the requirements. The first is heat rejection, and the second is the pressure drop of each component and cooling line at the required flow rate.

When determining the heat rejection of the components, the main concentration is the efficiency of each component. In this study, permanent magnet electric motors are used as the generator, hydraulic pump, and traction motors, which have approximately 96% efficiency. The other 4% is the loss and is assumed to be converted to heat energy. For the inverters and DC-DC converters, the efficiency is around 98%. Regarding the efficiency assumption, one of the essential points is working speed by torque. In the efficiency map of the motors in Figure 3, it is seen that the motors have around 96% efficiency in the definite area. It is significant to ensure that motors or generators work in the efficient area of the application. Heat rejection is calculated with Equation 2. Total heat rejection is calculated with Equation 1. Radiator heat transfer is calculated with Equations 3. and 4. Equation 5 shows the radiator cooling power in kW.

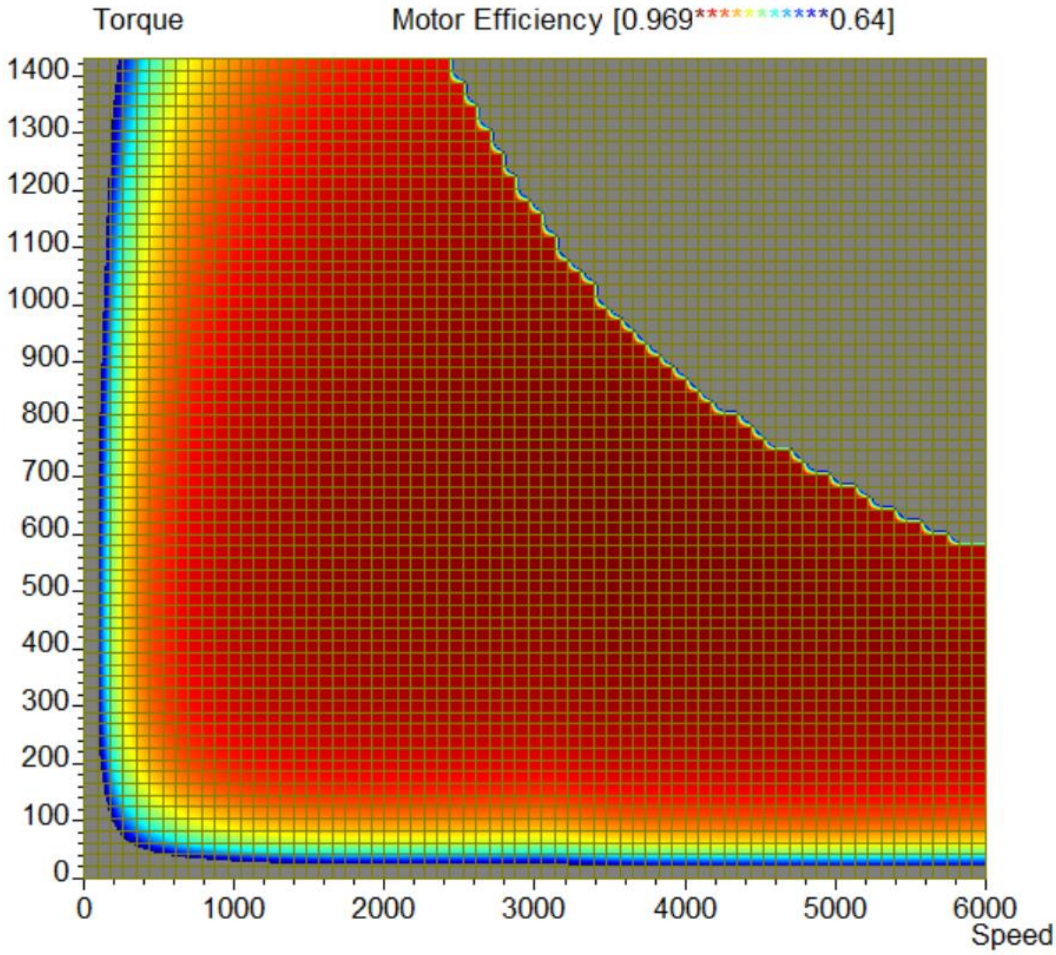

Figure 3. Efficiency Map of the Electric Motors

$$P_T = P_{H1} + P_{H2} + P_{H3} + P_{H4} + P_{H5} + \cdots + P_{Hn} \quad (1)$$

$$P_H = P_{maks} * (1 - \eta) \quad (2)$$

$$Q_R = m * c * \Delta T \quad (3)$$

$$Q_R = q_R * \rho * 1000 * 60 * c * \Delta T \quad (4)$$

$$P_R = Q_R / t \quad (5)$$

P_T	: Total heat rejection [kW]
$P_{max.}$	: Maximum working power [kW]
η	: Efficiency of each component
P_H	: Heat rejection [kW]
Q_R	: Radiator cooling [kJ]
m	: Flow mass [kg]
q_R	: Radiator flow rate [l/min]
c	: Specific heat capacity [kJ / kg* K]
ρ	: Coolant density [kg/ m^3]
ΔT	: Radiator inlet/outlet temperature difference [K]
P_R	: Radiator cooling power [kW]
t	: Time

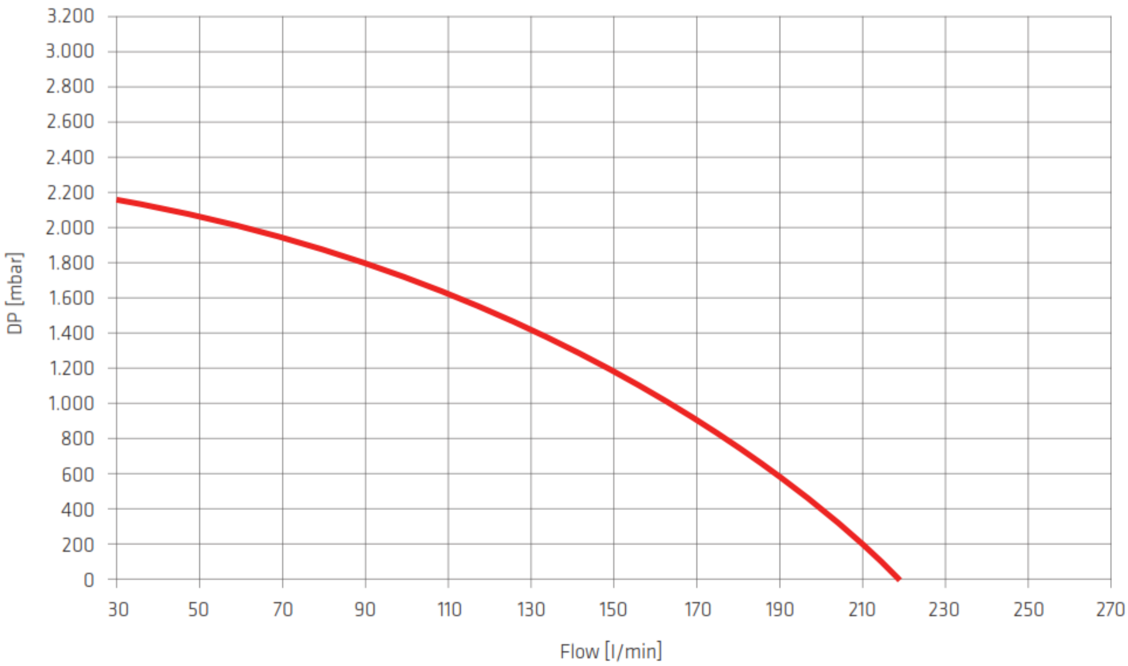

Figure 4. Circulation Pump Performance Curve (Flow Rate by Pressure Drop)

The second is pressure drop, essential when the coolant flow rate and the circulation pump are specified. The pump must overcome all pressure drops in each line to circulate the coolant properly. Each cooling line of the flow regulator must be adjusted to the permissible flow rate range of the relevant components.

$$\Delta P_T = \Delta P_L + \Delta P_{FR} + \Delta P_C + \Delta P_R \quad (6)$$

$$\Delta P_p > \Delta P_T \quad (7)$$

ΔP_T : Total pressure drop of each line

ΔP_L : Pressure drop of the line elements, such as hoses, fittings, connectors, etc., at the rated flow

ΔP_{FR} : Pressure drop of the relevant section of the flow regulator at the rated flow

ΔP_R : Pressure drop of the radiator

ΔP_P : Pump pressure drop

The total pressure drop must be less than the pressure drop that the pump withstands (Equation 7). Otherwise, the pump cannot provide the required flow rate, which means it drops. For example, in this system, the total flow rate is 165 lt/min. At this flow rate, the total pressure must be less than 1000 mbar to carry out the coolant circulation without the drop. See Figure 4. The pressure drop curve of the inverter is shown in Figure 5.

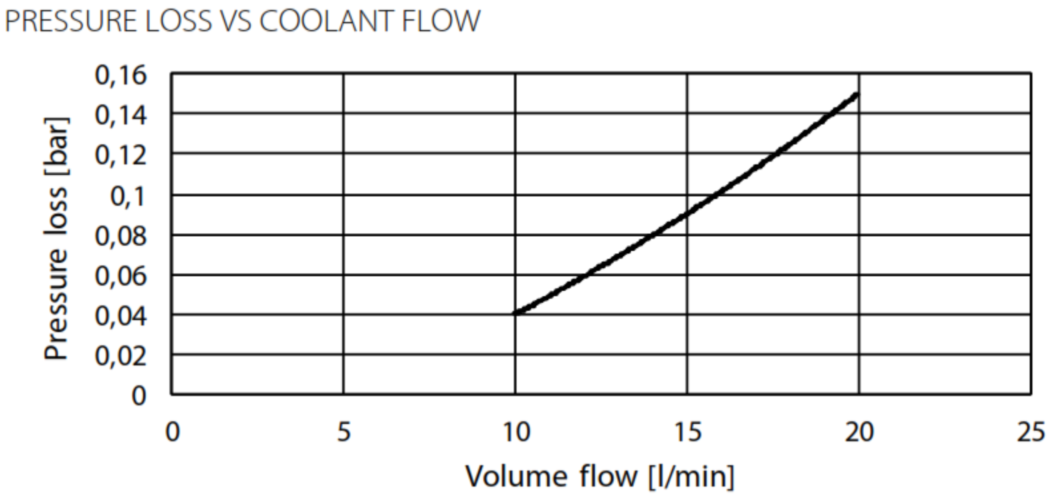

Figure 5. Pressure Drop Curve of the Inverter

Control Algorithm

There are two main variables to arrange the cooling capacity. The first is the flow rate of the coolant, which is dependent on the circulation pump, and the second is the cold air flow rate, which is dependent on the fan speed. In this system, each electric component has its own temperature sensor. Besides, there is a main temperature sensor on the return (hot) line of the cooling system to detect the radiator inlet temperature.

There is an electronic controller named machine control unit (MCU) in the vehicle. MCU has its own software according to the working algorithms. MCU takes the instantaneous temperature from each electric component and the return line. It determines the maximum temperature of the components. Over 45° C, MCU adjusts the circulation pump speed according to Figure 6. Over 50° C, MCU adjusts the fan speed according to Figure 7. The fan drive system consists of a hydrostatic pump/motor couple. The control algorithm is based on the temperature feedback, shown in Figure 8.

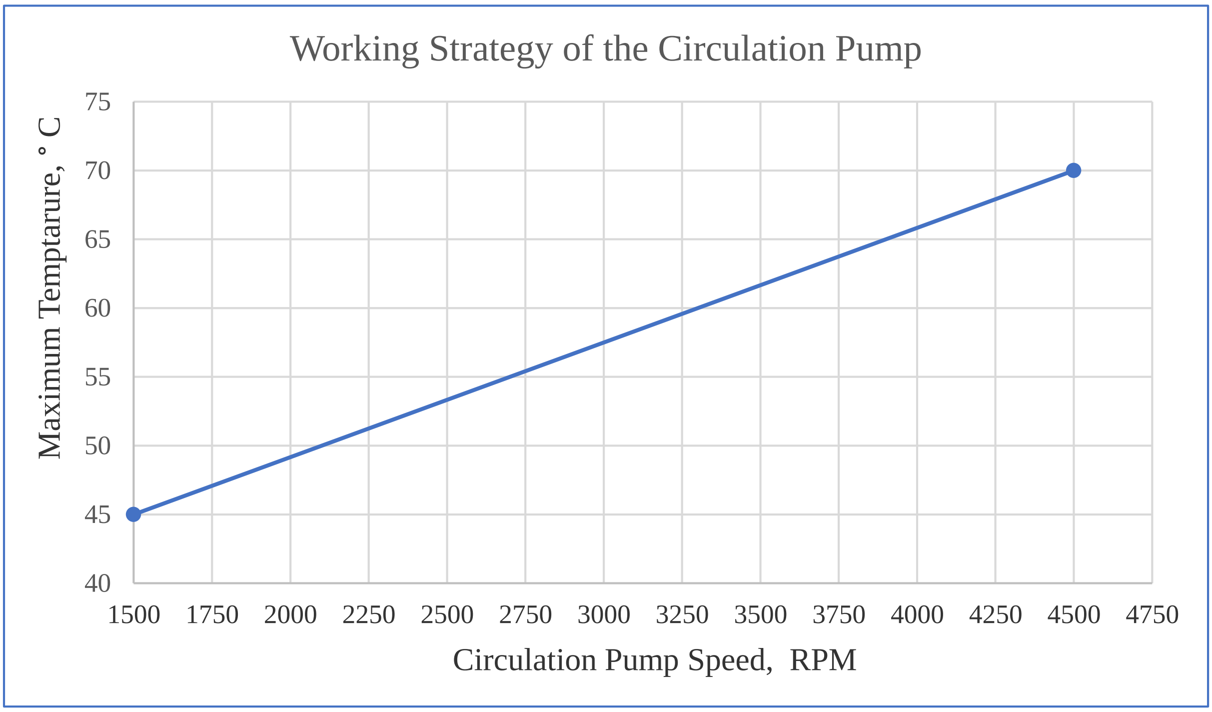

Figure 6. Working Strategy of the Circulation Pump

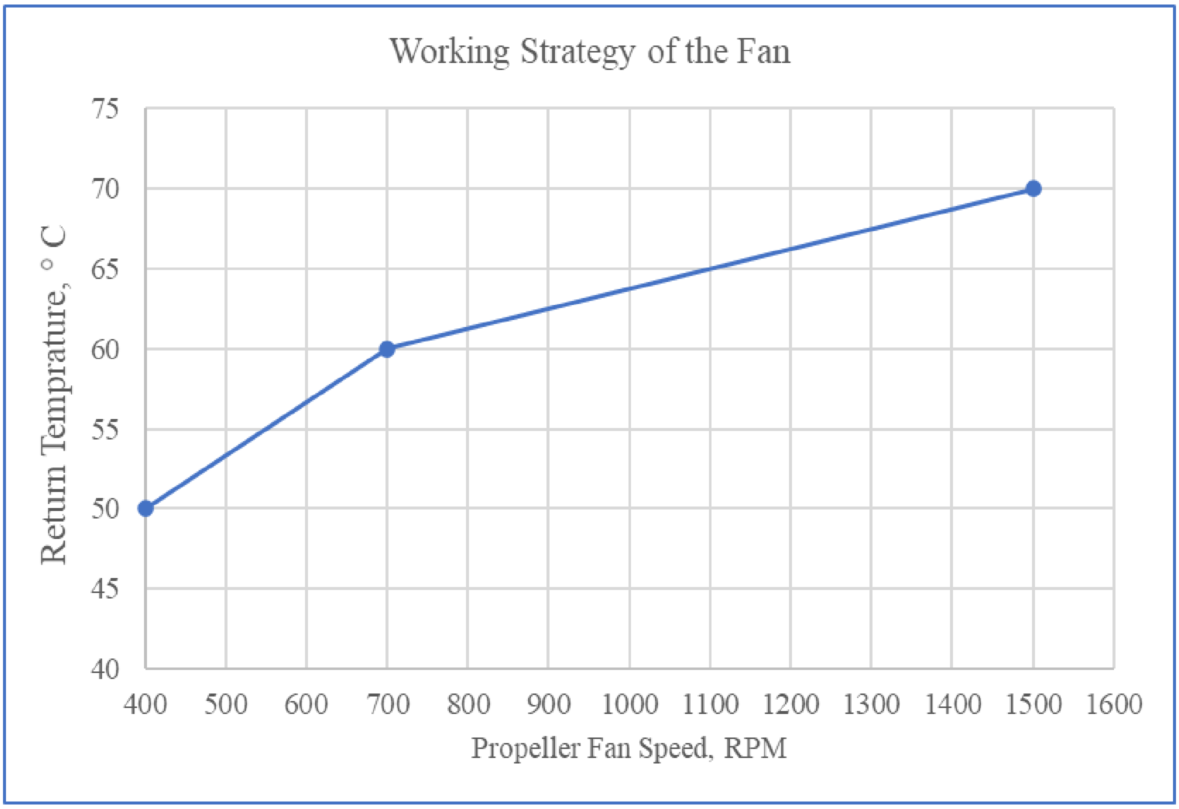

Figure 7. Working Strategy of the Circulation Pump

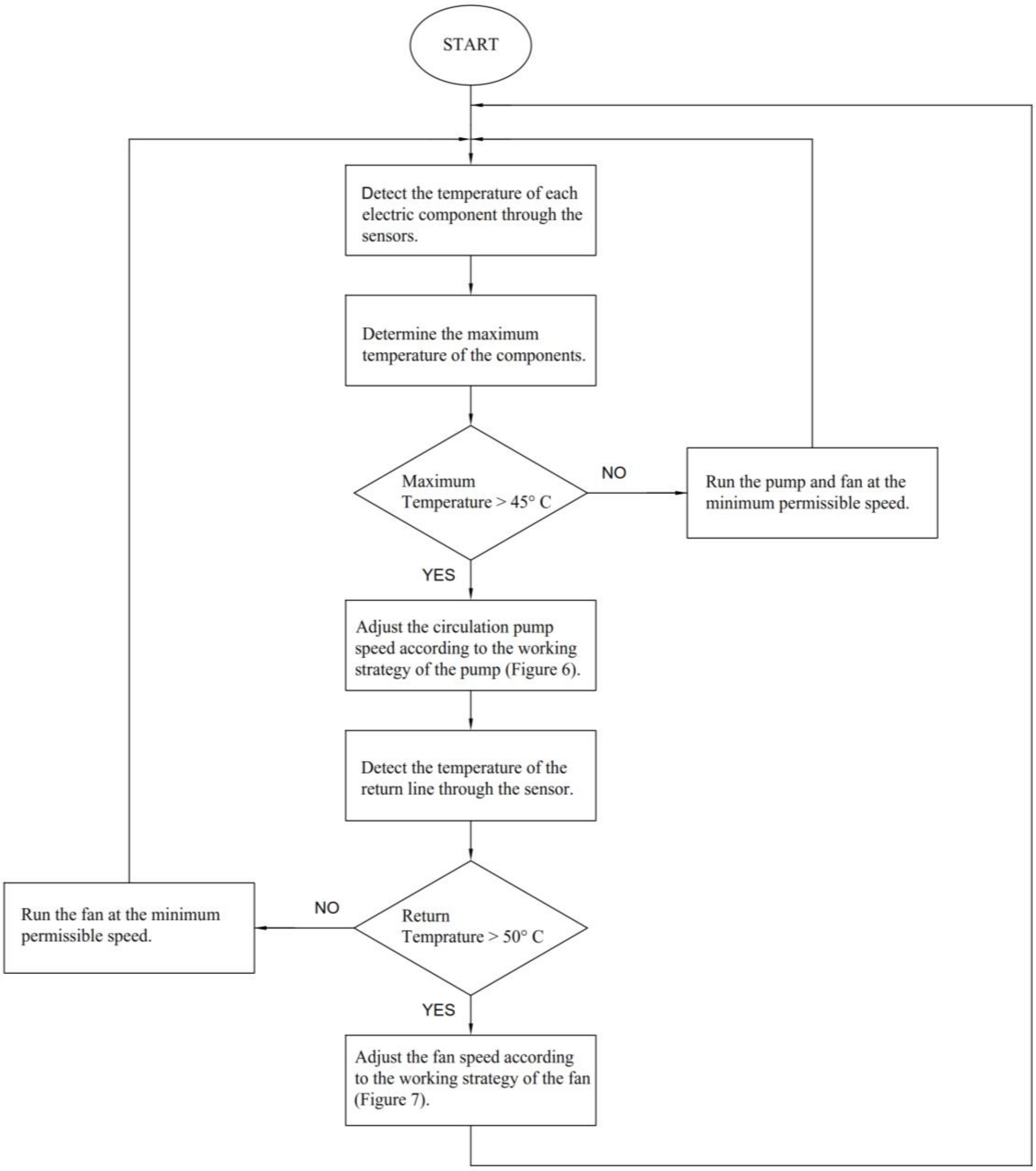

Figure 8. Thermal System Control Algorithm

Conclusions

The environmental concerns and constantly rising oil prices will attract the automotive and construction equipment industries. Thus, the number of hybrid and fully electric vehicles will increase.

This paper has presented an overview of the thermal management system of the hybrid electric wheel loader. The general architecture of the vehicle has been introduced. The architecture and overall schematic of the thermal system have been described. The innovative way of this system, using a single pump and radiator to circulate and cool down the coolant, has been introduced, and its advantages have been mentioned. The cooling requirement of each component has been described. The calculation method of the cooling capacity of the radiator is mentioned. The algorithm of the thermal system has been introduced. The working strategy of the circulation pump and fan has been explained.

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Enhancing Antenna Education for Junior-Level Undergraduate Students: A Case Study of an Effective Teaching Approach

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Abstract: Teaching electromagnetics and antennas to senior-level undergraduate students is acknowledged to be challenging due to the complexity of the theory and intensive mathematics. As a result, such topics became increasingly less popular in recent times. Moreover, presenting antennas to second-year undergraduate students poses an even greater challenge for similar reasons. To address this issue, a distinctive teaching approach needs to be adopted that involves minimum theory and more computer simulations as well as experimental work to capture students' attention and ensure their engagement. With the advancement in computer simulation tools, there are many options that fit the required purpose and, in this case, CST Microwave Studio, students' edition, was utilized to design a patch antenna with a matching network. In addition, a low-cost portable network analyzer was employed to measure the return losses and far-field patterns. This was delivered as a 2nd-year design project exercise over a period of seven weeks with two lab sessions per week, each last for three hours. The first three sessions were preceded by a one-hour lecture each that introduced the project's aim, basic antenna parameters, and Smith chart. Furthermore, a separate tutorial was delivered on the effective use of CST. At the end of the project, students gained a clearer understanding of antennas and matching techniques that are usually taught at more advanced teaching levels. Besides, they developed important transferable skills in terms of antennas simulations, measurements as well as team working.

Keywords: Teaching, Electromagnetics, Antenna, CST and Undergraduate Education

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Introduction

Teaching antennas at higher education presents a formidable challenge, primarily due to the abstract nature of antenna concepts and the heavy reliance on complex mathematics. This disconnects between classroom theory and real-world antenna engineering dilemmas has led to dwindling student interest, making antenna-related courses a less popular choice among both junior and senior-level students. Recognizing this issue, educators and researchers have been striving to revitalize students' enthusiasm for electromagnetics and antennas through innovative teaching approaches. Over the past few decades, several studies have emerged with the aim of proposing engaging and effective teaching methodologies.

One such approach, discussed in [1], revolves around the integration of multimedia elements into electromagnetics and antenna instruction. In the same study, a virtual antenna laboratory was introduced, aiming to bridge the gap between theoretical learning and practical application. Meanwhile, [2] advocates the use of powerful mathematical software like Mathematica and MATLAB to teach electromagnetics, providing students with hands-on experience and making the subject matter more accessible. Additionally, [3] suggests the utilization of CAD tools as a means to assess the comprehension of undergraduate students in this field, promoting a more interactive and application-oriented learning experience. These innovative strategies aim to make the study of electromagnetics and antennas not only more comprehensible but also more captivating for students.

In response to these challenges, an unconventional teaching approach has been adopted, one that is based on introducing antenna to students earlier in their undergraduate study. The proposed approach is based on minimizing theoretical content and instead places a strong emphasis on utilizing computer simulations and hands-on experimentation. This method not only captivates students' interest but also ensures their active involvement in the subject matter. To implement this approach effectively, CST Microwave Studio student edition served as a tool for designing a regular patch antenna with a matching network.

Additionally, a cost-efficient portable network analyzer was put to use for measuring return losses and far-field patterns. Besides, Sigmaplot has been employed for professional presentations of the results and to acquire the important skill of comparing measured and simulated results on the same graph. This innovative teaching approach has the potential to rekindle students' enthusiasm for electromagnetics and antennas while simultaneously equipping them with invaluable skills that will prove beneficial in their academic and professional pursuits. The students were assessed by submitting individual reports and delivering oral presentations highlighting their design and findings.

Leveraging Commerical Software for Antenna Design Amidst COVID-19 Pandemic

Amid the COVID-19 pandemic, when physical access to laboratories became impossible due to restrictions, utilizing commercial software became a pivotal solution. To facilitate this remote learning approach, students were provided with the option to download the free CST student version onto their personal computers. Concurrently, lectures were conducted in an online format. It should be noted that other tools such as HFSS or FEKO could have been equally useful.

To ensure effective collaboration and engagement, students were organized into groups using the Blackboard

Ultra, where each student could access their respective group. The design process was thoroughly explained to all participants during these virtual sessions. Subsequently, students were encouraged to commence their antenna designs independently, with continuous support and assistance available to address any challenges or queries during the design process. However, very limited experimental work was carried out due to the safety restrictions that were in place.

Methodology

The methodology has been carefully structured into four clearly defined sections: theoretical lectures, simulations and measurements, as well as data analysis and evaluation. Each of these components plays a pivotal role in facilitating the teaching process.

Theoretical Lectures

This initial phase consists of three pivotal lectures, each with a specific focus, scheduled for one hour per week.

Lecture 1: Antenna Fundamentals

In the inaugural lecture, students are introduced to the designated antenna for their study. This session delves into the antenna's type, elucidates the foundational equations governing its construction, and explores essential parameters like gain, polarization, efficiency, and radiation pattern.

Lecture 2: Impedance Matching & Smith Chart

In this lecture, important concepts were introduced such as wave reflection, voltage standing wave ratio, matching stubs, and Smith chart. Acquiring such concepts is essential for the successful completion of the exercise.

Lecture 3: CST Software Introduction

The third lecture is dedicated to acquainting students with the CST software, a potent tool within the field of electromagnetics. This software specializes in simulating and optimizing electromagnetic components, including antennas, microwave circuits, RF components, and other high-frequency devices. Within this session, students embark on designing a simplified antenna using the software. They then conduct a comparative analysis, pitting the simulated design against the theoretical concepts introduced earlier. The third lecture marks the pivotal shift toward the practical dimension of the course. Here, students are guided to initiate the design of different simple types of antennas like dipole or patch antenna, drawing upon the theoretical knowledge and software skills acquired in the previous sessions. This transition heralds the advent of the second stage in the learning journey

Design and Measurements

In this phase, the entire process is divided into eight distinct sessions combining simulations and measurements, as depicted in Figure 1. In the initial lab session, students begin their target design by creating a circular patch antenna using CST based on specific design parameters. Following this, the second session commences with initial measurements of the pre-fabricated antenna, ensuring the alignment of simulation and measurement. To enhance the antenna gain, the third session focuses on incorporating a director into the design, guided by director sizes and height. Progressing to the fourth session, students proceed to measure the antenna with the director in position. The fifth and sixth sessions are dedicated to improving impedance matching through the addition of stubs along the transmission lines, employing both the CST simulation and Smith Chart. Ultimately, the seventh and eighth sessions signify the culmination of the antenna measurement process, encompassing both the director and stubs. By this point, students gained the skills needed to operate measuring equipment effectively, paving the way for a transition into the ensuing phase of results.

Data Analysis

By exporting data from both CST and laboratory measurements, students utilize SigmaPlot, a scientific graphing and data analysis software. SigmaPlot is extensively employed by researchers, scientists, and engineers for visualizing and interpreting data, enabling students to present their data in a comprehensible, well-organized, and readily comparable format.

Evaluation

Students receive assessments based on three distinct factors: their report, presentation, and their attendance and engagement. Specifically, 76% of the evaluation is attributed to the individual report, 19% to the group presentation, and the remaining 5% to attendance and engagement.

Proposed Antenna Design

The developed antenna model is presented in Figure 2. The antenna prototype is illustrated in Figure 3 and was fabricated on a grounded FR-4 substrate with a relative permittivity of 4.5. To comprehensively analyze the antenna's performance, various parameters including input impedance, radiation pattern, and gain were thoroughly investigated. Additionally, understanding the Smith chart holds significant importance for RF engineers, aiding in impedance matching. Figure 4 demonstrates a practical application of the Smith chart in designing a single stub-matching network. The objective is to precisely determine the stub's length and position along the microstrip line. As part of this process, the stubs were meticulously handcrafted using double-sided adhesive copper tape and then carefully integrated into the antenna structure.

For measurements of the antenna’s characteristics, advanced equipment such as the vector network analyzer and EMScan RFXpert were employed as illustrated in Figure 5. These tools were instrumental in quantifying parameters like isolation, reflection coefficient, and far-field radiation patterns. To provide a clear understanding of the performance comparison between simulation and measurement, Sigmaplot has been used, as depicted in Figure 5, where students were encouraged to quantify any discrepancies between measurements and simulations.

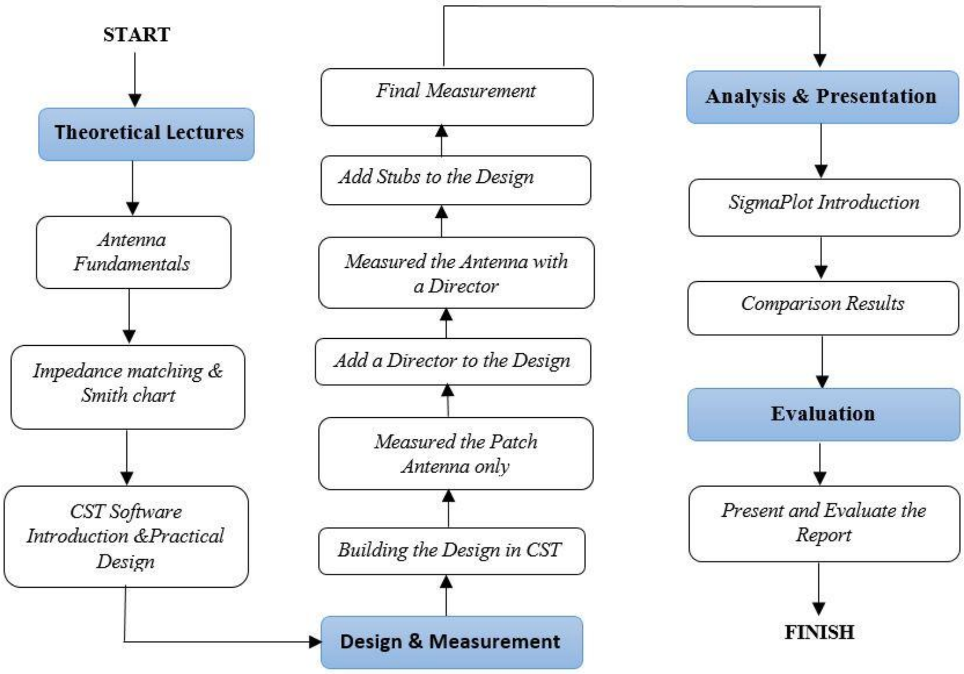

Figure 1. The instructional approach's methodology.

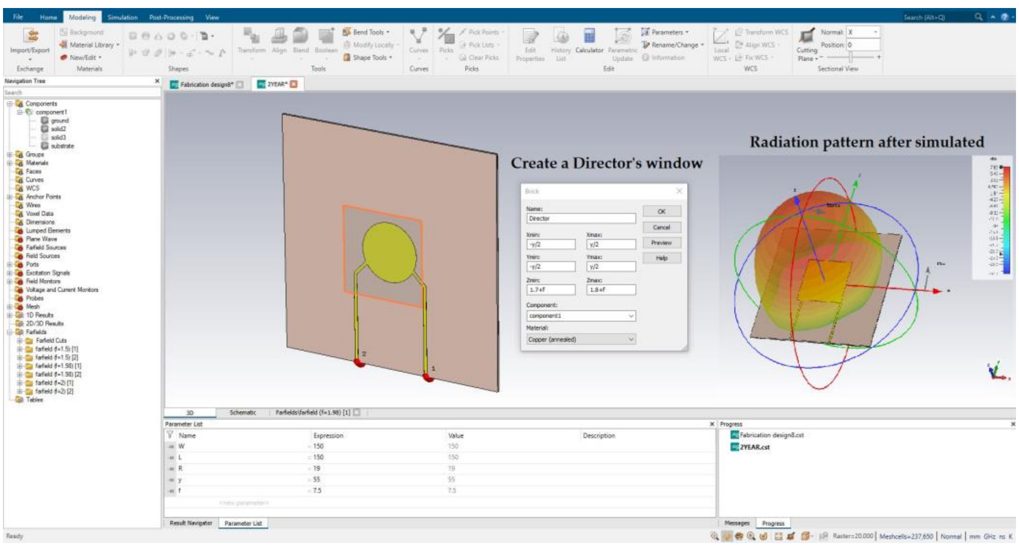

Figure 2. Modelling of patch antenna using CST

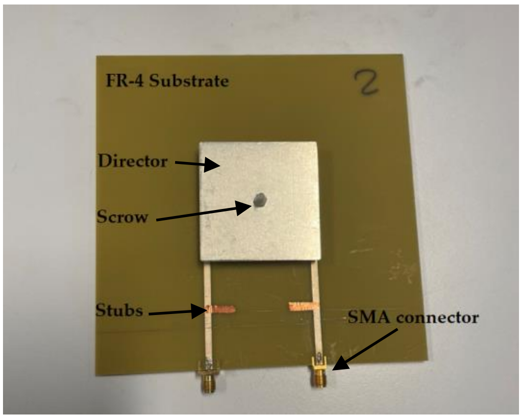

Figure 3. Patch antenna with director

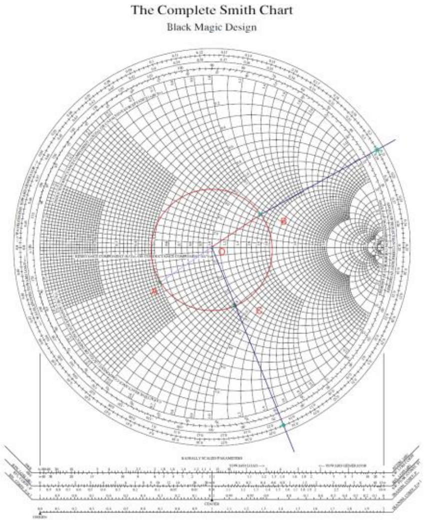

Figure 4. Smith chart processing


Figure 5. Measuring equipment in the laboratory.

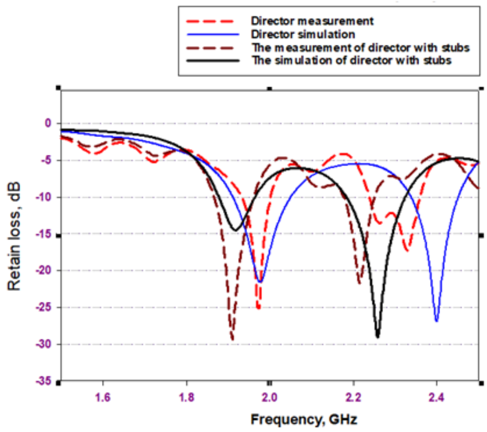

Figure 6. Data analysis and comparison.

Conclusion

This innovative teaching strategy was implemented by introducing antennas to 2nd year students in a high-level manner that is based on simulations and measurements. Such an approach represents a gentle and appealing introduction to a topic that is known for its complexity and taught later as a senior level module. Such an approach was successful in presenting antennas as an interesting topic and every year a number of students who enrolled in this design exercise choose a 3rd year project that is focused on antenna design. The second-year design project spanned seven weeks, comprising two three-hour laboratory sessions per week. The initial three sessions were preceded by one-hour lecture each, which introduced students to the project's objectives, fundamental antenna parameters, impedance matching and Smith chart. Furthermore, a dedicated tutorial was provided to instruct students on effectively utilizing the CST software.

A circular patch antenna has been chosen to meet a given specification. Results obtained by the computer simulations have been compared with measured results. The first stage of the exercise provided students with an understanding of how the geometric configuration of a patch antenna affects its electromagnetic properties. The second and third stages have included design and testing of a dual-polarized patch antenna. The input impedance and isolation, S_{21}, of the antenna were measured using a Vector Network Analyzer (VNA). Radiation patterns have been verified through measurements.

By the culmination of the project, students not only attained a deeper comprehension of antennas and matching techniques, typically reserved for more advanced levels of instruction, but also cultivated invaluable transferable skills in antenna simulations, measurements, and teamwork. This approach not only addressed the challenge of teaching complex electromagnetic concepts to junior students but also equipped them with practical skills and knowledge that will serve them well in their future endeavors.

Recommendations

Based on the successful implementation of this distinctive teaching approach for electromagnetics and antennas, several recommendations can be made:

- Implement Active Learning Techniques: Encourage educators to incorporate more active learning techniques, such as computer simulations and hands-on experiments, into the teaching of complex subjects. This not only enhances student engagement but also aids in conveying abstract concepts effectively.
- Utilize Modern Simulation Tools: Emphasize the importance of utilizing free modern simulation tools like CST Microwave Studio, students' edition, to simplify complex tasks. Ensure that students are trained in using these tools effectively, as they are readily available and offer practical insights into real-world applications.
- Integrate Practical Projects: Encourage the integration of practical projects into the curriculum, as such projects provide students with real-world applications for the theories they learn and offer opportunities to develop problem-solving skills.
- Offer Introductory Lectures: Ideally before hands-on laboratory sessions. These lectures should aim to clarify project objectives, introduce fundamental concepts, and provide students with a roadmap for their practical work.
- Promote Teamwork: Emphasize the importance of teamwork as a key aspect of engineering and scientific work. Collaborative projects, such as antenna design exercises, not only improve students' technical skills but also foster teamwork and communication abilities.

By implementing these recommendations, educational institutions can enhance the teaching of complex subjects like electromagnetics and antennas, making them more accessible and engaging for students while preparing them with practical skills for their future careers.

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Use of Adequate Technology to Attain Engineering Graduate Attributes

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Abstract: Digital literacy has become a necessity in this digital age; thus, the world is determined to prepare its citizens. In the recent past, world history has accelerated while handling the challenges of the pandemic. Consequently, the world population lived a decade in a few years, with several new initiatives commencing on an immediate basis. Nations and institutions invested heavily in technology to continue the delivery of programs with minimal impact. Due to these constraints, educators were compelled to think about the potential of technology to maintain and or enhance the learning of their students. Application of technology and appropriate processes with recognition of their limitations along with the use of analytical tools are essentially required to accomplish engineering learning outcomes that stand on the foundation of digital literacy. On the other hand, the use of technology in the classroom and attaining engineering competencies has multiple outcomes. Some educators consider that advanced technological gadgets are a source of disturbance in classroom delivery while others consider their utilization as interest-generating tools in learning activities. The paper discusses various adequate technologies that can be used for the enhancement of learning and engineering competencies achievement are thus, not viewed as an impingement. Also, it covers the impact of Artificial Intelligence as an easy way out for resolving different student tasks. Educators are still contemplating how to make pedagogical gains from AI to have a positive influence on teaching and learning. It concludes that imagination supports critical thinking skills and problem-solving ability therefore, undue inclination towards the use of AI will end up in losing an individual's capacity or reducing the confidence in being able to use the imagination. This will end up eluding critical thinking skills and loss of problem-solving ability among future generations.

Keywords: Digital literacy, Artificial Intelligence, Engineering Competencies, Critical Thinking, Problem-solving.

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Introduction

In the contemporary digital era, digital literacy has transformed from a mere skill into an absolute necessity, prompting nations across the globe to diligently prepare their citizens for the complexities of this digital age. Recent world events, particularly the unprecedented challenges posed by the global pandemic, have propelled humanity through an accelerated timeline of history (Zakaria, 2020). Within the span of just a few years, the world has experienced an upheaval equivalent to a decade's worth of progress, necessitating immediate, transformative actions. In response, nations and institutions have made substantial investments in technology to ensure the continued delivery of programs and services with minimal disruption (Charania et al., 2021; Storey & Zhang, 2021).

The educational landscape has been profoundly impacted by this transformation. Educators have been thrust into a rapidly evolving environment, prompting them to explore the potential of technology to uphold and, optimally, enhance the learning experiences of their students. This accelerated digital shift has elevated the importance of digital literacy and emphasized the urgency of equipping students with this essential competency (Charania et al., 2021; Siyabi et al., 2020). Effectively leveraging technology to achieve educational outcomes now stands as a cornerstone of modern pedagogy. It requires not only the integration of technology but also an in-depth understanding of its limitations.

The use of analytical tools and innovative educational processes has become indispensable in engineering the next generation of learners who stand firmly on the foundation of digital literacy. However, the intersection of technology and education produces diverse outcomes. Some educators, while recognizing the potential of advanced technological tools, perceive them as sources of distraction within the classroom environment (Bates & Poole, 2003; Lewis et al., 2013; Venkatesh et al., 2014). Others, however, regard these tools as catalysts for engagement and interest in various learning activities. This contrast forms the backdrop for a dynamic and ongoing discourse within educational circles (Rashdi, 2017).

This paper undertakes a comprehensive exploration of the various technologies at our disposal for enhancing the learning journey and facilitating the attainment of engineering competencies. Rather than viewing these technologies as disruptive elements, this discussion places them in a positive light, recognizing their potential as enablers of educational progress. Moreover, the paper delves into the burgeoning realm of Artificial Intelligence (AI) and its profound impact on education. AI has emerged as a versatile tool with the capacity to simplify and enhance a myriad of student tasks. Educators, in response, are grappling with the challenge of harnessing AI's pedagogical potential to create meaningful impacts on the teaching and learning processes (Singh & Hiran, 2022).

The narrative culminates in an important reflection on the role of imagination in nurturing critical thinking skills and problem-solving abilities. While AI presents enticing possibilities, the paper underscores the value of preserving an individual's imaginative capacity. An over reliance on AI, at the expense of nurturing creativity, could potentially erode confidence in imaginative thinking (Celik et al., 2022; Fahimirad & Kotamjani, 2018; Popenici & Kerr, 2017). Ultimately, this may compromise critical thinking skills and diminish problem-solving abilities among future generations.

In a world where digital literacy is non-negotiable, this exploration navigates the intricate intersection of technology and education, highlighting the pivotal role that innovation and digital literacy play in shaping the future of learning (Bawden, 2008; Eshet, 2004; Martin & Grudziecki, 2006).

The Enduring Impact of Technology in Engineering Education:

In today's digital era, technology has become an indispensable tool, seamlessly integrated into nearly every aspect of our lives. The realm of education is no exception, as technology has emerged as a transformative force, redefining the way we teach and learn. In the field of engineering education, technology plays a pivotal role in shaping the educational landscape, fostering the development of essential skills and qualities in graduating engineers.

Competency Models and Graduate Attributes

The engineering profession demands a diverse range of competencies, encompassing both technical expertise and broader professional skills. Competency models, widely embraced by educators, employers, and industry leaders, provide a framework for defining these essential attributes (Khan, 2018; Khan et al., 2021). These models typically categorize competencies into three main areas: core, discipline-specific, and job-specific proficiencies as shown in Figure 1.

Core competencies, such as effective communication, problem-solving, and leadership skills, are fundamental for success in any engineering endeavor. Discipline-specific competencies, such as knowledge of engineering principles, design methodologies, and analytical techniques, are tailored to the specific engineering discipline. Job-specific competencies, such as familiarity with industry standards, software applications, and project management methodologies, are tailored to the demands of the engineering job role (Leslie, 2016).

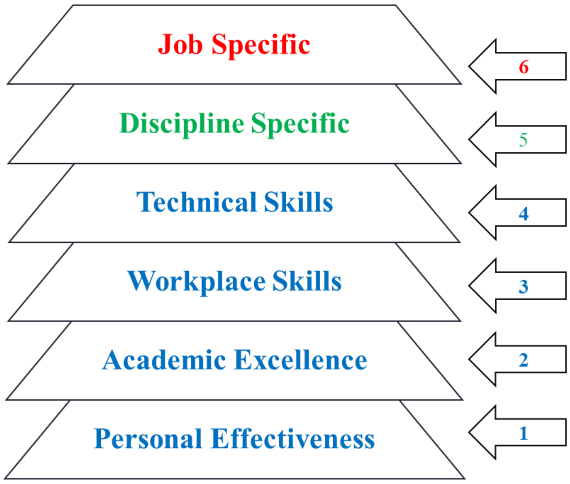

Figure 1. Engineering Competencies

Technology as a Catalyst for Competency Development

Technology stands at the forefront of the revolution in engineering education, serving as a powerful catalyst in the development of these graduate attributes (Hussain et al., 2022). From simulation software and 3D printing to virtual reality and online collaboration platforms, technology offers a diverse array of tools and resources that can be harnessed to enhance student learning and skill development. Some of the significant engineering graduate attributes are being discussed in the subsequent paragraphs.

Technical Competence

Engineering students can leverage technology to enhance their technical competence through realistic simulations and access to cutting-edge software. Simulation software developed over the time provides students with hands-on experience with engineering concepts and principles, allowing them to apply their theoretical knowledge to practical problems. Additionally, access to cutting-edge software tools, such as CAD and finite element analysis software, enables students to develop proficiency in industry-standard tools that are essential for engineering practice.

Problem-solving Skills

Technology can be employed to refine problem-solving skills through technology-driven projects and real-world simulations (Xiao et al., 2019). Technology-driven projects provide students with opportunities to tackle complex engineering challenges using technology tools, fostering their ability to identify, analyze, and solve problems effectively. Real-world simulations allow students to apply their problem-solving skills to realistic scenarios, enhancing their ability to adapt their approaches to different contexts.

Communication Skills

Online platforms and collaborative tools can facilitate the development of communication skills by fostering teamwork and discussion. Online platforms provide a virtual space for students from diverse backgrounds to collaborate on projects, enhancing their ability to communicate effectively in a team environment. Collaborative tools, such as online whiteboards and chat forums, enable real-time communication and discussion, promoting the exchange of ideas and the development of effective communication strategies (Bakos Jr, 1997). The use of such technologies has risen manifold, addressing the challenges of pandemic environment.

Leadership Skills

Leadership and teamwork are one of the essential engineering graduate attributes that needs to be developed among the engineering graduates during their period of study at the higher education institution (Flanagan & Jacobsen, 2003). Technology encourages the development of leadership skills through virtual team projects, where students must lead and coordinate efforts remotely, mirroring real-world professional scenarios. Virtual team projects provide students with opportunities to take on leadership roles, develop their ability to motivate and inspire others, and effectively manage team dynamics in a distributed setting.

Ethics and Professionalism:

Technology is developing exponentially therefore its social implications are also on the rise. Human values and attitudes are used to help ensure that the systems we rely on can be maintained, and continue to provide beneficial, useful gains to meet our needs. Ethical considerations in and through technology involve the application of moral reasoning to address the practical issues arising from technology development. Technology plays a pivotal role in ethics education by enabling discussions on ethical dilemmas and professional conduct (Brey, 2017). Online forums and discussion boards provide a platform for students to engage in discussions on ethical issues, helping them to develop their own ethical frameworks and understand the importance of professional conduct in engineering practice.

Challenges and the Path Forward

Despite its transformative power, the integration of technology into engineering education is not without its challenges. Limited access to technology and the need for proper training remain significant hurdles. Ensuring equitable access to technology resources and providing adequate training to educators and students are essential steps in realizing the full potential of technology in engineering education. Achieving the right balance between technology-driven learning and valuable personal interactions remains an ongoing endeavor in the ever-evolving landscape of engineering education. Technology should complement, not replace, traditional face-to-face instruction and interactions. Technology-enhanced learning environments should foster critical thinking, creativity, and collaboration, while also providing opportunities for personal interactions and mentorship as shown in Figure 2.

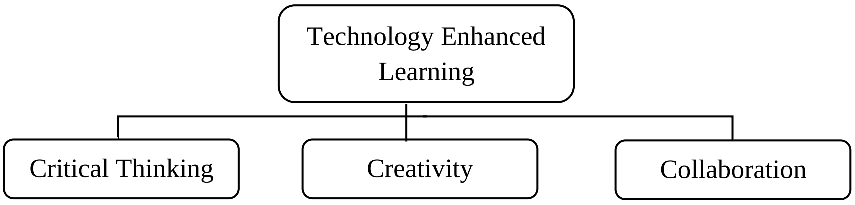

Figure 2. Engineering Competencies

In summary, engineering education has undergone a transformative change with the advent of technology, presenting a wide array of tools and resources to enhance student learning and skill acquisition. Nonetheless, the incorporation of technology requires thoughtful consideration to overcome challenges such as restricted access, the necessity of adequate training, and maintaining a balance between innovative technological tools and human interaction. By striking a balance between technology-driven learning and traditional face-to-face instruction, engineering education can harness the power of technology to nurture the next generation of competent, adaptable, and socially responsible engineers.

Case Study: MCT's Virtual Math Center

In an effort to enhance student learning and improve outcomes in Engineering Mathematics, Military Technological College (MTC) implemented a virtual Math Center, providing students with access to an online platform featuring interactive lessons, real-world applications, and personalized support. The introduction of the virtual Math Center resulted in a significant improvement in student engagement, academic performance, and overall satisfaction.

Engineering Mathematics is a critical foundation for success in various engineering disciplines (Goold, 2012). However, many students struggle with the abstract concepts and complex problem-solving involved in these courses. Traditional teaching methods, often relying on lectures and textbook exercises, may not adequately cater to the diverse learning styles and needs of all students.

Intervention

To address these challenges, MTC developed a virtual Math Center, an online platform designed to provide students with a more engaging and personalized learning experience in Engineering Mathematics. The virtual Math Center offers a variety of features, including:

- Interactive lessons: Students can access self-paced, interactive lessons that explain mathematical concepts in a clear and concise manner.
- Real-world applications: The virtual Math Center provides students with opportunities to apply mathematical concepts to real-world engineering problems, helping them to understand the relevance

of mathematics to their chosen field.

- Personalized support: Students can receive individualized support from tutors and instructors through online chat, video conferencing, and email.

Evaluation

To assess the impact of the virtual Math Center, MTC conducted a comprehensive evaluation, comparing student outcomes before and after its implementation. The evaluation focused on the following metrics, and the statistical analysis is tabulated in Table 1:

- Average Math course GPA: The average Math course GPA increased from 2.7 to 3.2 after the introduction of the virtual Math Center.
- Percentage of students passing Math courses: The percentage of students passing Math courses increased from 60% to 80% after the introduction of the virtual Math Center.
- Student satisfaction with Math courses: Student satisfaction with Math courses increased from 65% to 85% after the introduction of the virtual Math Center.
- Time spent on Math homework: The average time spent on Math homework decreased from 5 hours per week to 3 hours per week after the introduction of the virtual Math Center.
- Student confidence in Math skills: Student confidence in their mathematics skills increased from 70% to 90% after the introduction of the virtual Math Center.

Table 1: Statistical Analysis

Metric	Before Virtual Math Center	After Virtual Math Center
Average Math course GPA	2.7	3.2
Percentage of students passing Math courses	60%	80%
Student satisfaction with Math courses	65%	85%
Time spent on Math homework	5 hours/week	3 hours/week
Student confidence in Math skills	70%	90%

Discussion

The evaluation results demonstrate that the virtual Math Center has had a positive impact on student learning and outcomes in Engineering Mathematics. Students who attended the virtual Math Center reported improved understanding of mathematical concepts, increased confidence in their mathematics skills, and a greater appreciation for the relevance of mathematics to their engineering studies.

Conclusion

Technology in education has drastically changed traditional teaching methodologies and pedagogical techniques, offering a dynamic and interactive learning environment. The assimilation of digital tools, online resources, and interactive platforms has enriched both the accessibility and effectiveness of education. Students now have access to a wealth of information at their fingertips, supporting personalized learning experiences. Moreover, technology facilitates collaborative and engaging activities, encouraging critical thinking, and advancing problem-solving skills. However, it is essential to carefully navigate potential challenges such as ensuring equitable access, promoting digital literacy, and maintaining an equilibrium with traditional teaching methods to harness the full potential of innovative technology in education.

The MTC virtual Math Center serves as a successful example of how technology can be leveraged to enhance student engagement, improve academic performance, and boost overall satisfaction in Engineering Mathematics courses. The virtual Math Center offers a personalized and engaging learning experience that cater to the diverse learning styles and needs of students. The implementation of the virtual Math Center has significantly improved student outcomes in Engineering Mathematics, providing a valuable resource for future engineering professionals.

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Classification of African Artifacts Using Machine Learning

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Abstract: For the organization and understanding of the continent's diverse heritage, the classification of African artifacts is of the utmost importance. The goal of this study is to use Machine Learning to create a classification system for the three main categories of African artifacts: clay, metal, and wood. The suggested system will help these artifacts be categorized, examined, authenticated, and conserved effectively. A total of 880 collected datasets were obtained from Google images keywords specific to distinguish between Clay, Metal, and Wood. The four CNN models were used, and each model's performance was assessed to evaluate how effectively it classified the three different categories of artifacts. LeNet distinguished between items made of clay, wood, and metal with the best degree of accuracy (74%). Inception and Pretrained_Inception demonstrated their ability to classify artifacts with intermediate accuracy scores of about 61% and 65%, respectively. ResNet50, however, only managed to differentiate the artifact types with an accuracy of 58%, demonstrating its limits.

Keywords: Artificial Intelligence, Machine Learning, African Artifacts, Convolutional Neural Networks.

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Introduction

Properly understanding and classifying the materials used in creating African artifacts is crucial (Read, 2016) when utilizing technologies like robots to handle and transport these valuable and delicate objects (Engelhardt et al., 1992; Li et al., 2019). Accurate classification plays a significant role in minimizing challenges faced by museum curators, art historians, and anthropologists. It ensures the appropriate display of artifacts with the necessary contextual information and aids in the identification of counterfeit and forged items (Muscarella, 1988). The classification of African artifacts provides researchers and historians with an opportunity to delve deeper into the cultural significance and historical context of these objects (Kasfir, 1992), facilitating a more comprehensive understanding of African heritage. Despite the fact that humans can categorize images based on their overall properties, such as colors or shapes, classic feature extraction methods, such as color and shape, generally have significant drawbacks. For instance, color-based extractors do not have spatial information from the image. The goal of the image classification method is to systematically assign semantic meanings to an image's visual components (Masoud et al., 2017). Additional factors including work demands, setting, and individual differences can also have an impact on our attentional processes (Estes, 1972; Yantis & Jonides, 1984). Therefore, there is a need to classify an image or an artifact without any interaction factors in the human mind and use it as a biologically plausible artificial neural network in machine learning (Ciregan et al., 2012).

Human Limitations on Artifacts Images Categorization

It is crucial to recognize the limitations that humans may face when classifying images. It is crucial to thoroughly contemplate the potential negative consequences that could arise from implementing these restrictions. When humans automatically detect the intriguing parts of an image scene and easily dismiss the uninteresting parts, this is known as the phenomenon of image saliency (Wolfe, 1994). Our attention is often drawn to stimuli that stand out from the environment due to their brightness, color, contrast, or motion. These stimuli are known as salient stimuli and play a crucial role in guiding our attention and eye movements. As we prioritize processing these salient inputs, visual salience becomes a significant factor in how we direct our attention. It is crucial to consider that various factors can influence our ability to concentrate on distinct components of an image.

- Subjectivity: When it comes to categorizing images, humans can have subjective biases and interpretations. This is because different people may perceive and classify images in various ways, depending on their personal experiences, cultural backgrounds, and biases.
- Limited Capacity: Processing and categorizing large amounts of visual data can be difficult for humans, as our capacity for doing so is limited. It can be challenging to accurately and efficiently categorize a large number of images within a short period of time.
- Inconsistency: It's common for humans to face difficulties when trying to make consistent categorization decisions, even when dealing with a single image. These decisions can differ greatly between individuals or even by the same person at different moments, which can result in inconsistent classification outcomes.
- Biases and Errors: Humans can be influenced by various biases and make errors when categorizing images. These biases can include cultural biases, cognitive biases, or even biases introduced by the training data used to learn the categorization task
- Limited Generalization: It can be challenging for humans to categorize new or unfamiliar images accurately. They may rely heavily on their prior knowledge and experience, which can limit their ability to generalize their categorization skills.

It's worth noting that even though humans have limitations, they also have exceptional cognitive abilities like contextual understanding and common sense reasoning that can assist with image categorization tasks. Moreover, humans can adjust and learn from their errors, enhancing their categorization proficiency as time goes on (Fleuret et al., 2011). The use of computer vision has been crucial in accurately classifying images and minimizing the occurrence of human errors in job execution (Dias & Torkamani, 2019; Elngar et al., 2021).

African Artifacts

African artifacts are a variety of items produced by the numerous cultures that make up the African continent. Among these relics are objects with cultural, historical, artistic, and spiritual importance, such as sculptures, masks, pottery, jewelry, textiles, tools, and more (Vansina, 2014). There are several types of African artifacts that involve the interaction of people, geographical locations, and cultures (Pelrine, 1995). In this study, the major concern in the African artifacts are Clay, Wood, and Metal, which play a huge role in cultural diversity in the African heritage (Burt, 2006).

The cultural heritage of African art is known for its rich and diverse artistic expression. From the intricate carvings on wooden masks to the metalwork on elaborate jewelry, African artifacts not only boast aesthetic appeal but also serve as a window into the diverse cultural traditions and beliefs of the continent (Adekunle, 2007; Dornan, 1925; Mbiti, 2015; "More on 'African Art and Authenticity' - Comment/Reply," 1992). In this context, machine-learning classification plays a crucial role by providing a systematic and efficient approach to categorizing and analyzing these artifacts (Emmitt et al., 2022; Wang et al., 2021). By employing machine-learning techniques, we can uncover hidden patterns, identify stylistic variations, and gain a deeper understanding of the cultural significance and historical context embedded within African art.

Researchers must study the classification of African artifacts for crucial reasons. African art is diverse and encompasses a broad range of forms and practices, much like Western art. Although some serve as entertainment, others hold political or ideological significance. Many are used in rituals, while some possess intrinsic aesthetic value. To fully comprehend African art, it is essential to explore and understand local aesthetic values rather than imposing externally derived categories (Hess, 2020, October 23). It is of utmost importance to study the classification of African artifacts for the preservation of cultural heritage. The diverse purposes of African art, including conveying royalty, sacrality, inner virtues, aesthetic interests, and genealogy, played a crucial role in their respective communities. Through a thorough analysis of the classification of these artifacts, we can develop a better understanding of the cultural heritage of various African communities and make concerted efforts to safeguard it for future generations (Amselle, 2004; Ross, 1995). For over 50 years, the authenticity of African artifacts has been a concern for academics, museum curators, collectors, and gallery dealers. However, early studies were limited to categorizing these artifacts based on their style, which failed to represent the wide range of materials and forms used in African art and their significance to African people. In order to be considered authentic, an artifact must have been made in Africa, in a recognized ethnic style, by African artists for African patrons (Steiner, 1994). While this approach has been helpful, it also has its limitations. A closer examination of how African artifacts are classified can help us better understand what constitutes authenticity in African visual culture and prevent any misrepresentation or misattribution of African art. To appreciating the diversity of African art (Sinamai, 2020), African art is incredibly diverse, with a variety of materials and shapes used in its creation. Wood is a common material, resulting in many wood sculptures being part of African art. Jewelry is also a popular art form, and it can be used to indicate status, group affiliation, or simply for aesthetic purposes. By examining the classification of African artifacts, we can gain a better appreciation for the breadth of African art and understand the many different forms and techniques used throughout the continent.

Regarding style variations, regularities of form and tradition do occur, making it possible to assign specific African artifacts to specific locations, regions, or eras. This form of style identification is made feasible by four different variables. The first is geography, in that, given all other factors being equal, individuals tend to manufacture or do things differently depending on where they live. The second is technology, as different styles in particular fields depend on the material used (Oladumiye, 2013). The third quality is individuality, which refers to the ability of an expert to recognize the creations of specific artists; the inability to do so typically results from unfamiliarity. The fourth is an establishment, in that the production of artistic works occurs under the influence of the social and cultural institutions characteristic of any given location (Hess, 2020, October 23).

This study aims to apply Artificial Intelligence (AI) and machine learning techniques to achieve high-accuracy classification of three prevalent African artifacts: Clay, Metal, and Wood. The research focuses on utilizing these cutting-edge technologies to correctly classify and differentiate between distinct artifact types, producing enhanced classification outcomes (Demir et al., 2021). Machine learning involves the development of computer algorithms that mimic human intelligence, enabling computers to learn and make intelligent decisions based on data (El Naqa & Murphy, 2015). Despite this, variations in training outcomes may arise when employing different machine learning models. Hence, this study presents a comparative analysis of four distinct machine-learning models to identify and classify three specific African artifacts. It aims to find out how well these models perform in correctly classifying the various artifact categories by comparing and analyzing their performance.

Convolutional Neural Networks – CNN

When using Convolutional Neural Networks (CNN) for image classification, it is crucial to prioritize efficiency due to their widespread and extensive use (Li et al., 2021; O'Shea & Nash, 2015). CNN image classifications takes an input image, process it and classify it under certain categories (LeCun & Bengio, 1995). When processing an input image, it's crucial to understand that it's essentially an array of pixels. The size of this array is defined by the image's resolution, which is represented as h x w x d (where h stands for height, w for width, and d for dimension). To clarify, a 4 x 4 x 3 resolution image would be a matrix of RGB values, while a 4 x 4 x 1 resolution image would be a matrix of grayscale values. It's important to keep this in mind for accurate image processing (Albawi et al., 2017). CNNs possess several crucial features. Initially, Convolutional Layers function to extract features from input images by applying filters to detect specific features like edges or corners. Subsequently, Pooling Layers work to reduce the size of feature maps produced by Convolutional Layers, thereby preventing overfitting and reducing computational complexity. Moreover, Fully Connected Layers classify input images based on the features extracted by the previous layers. Additionally, Transfer Learning can be employed to leverage pre-trained models for new tasks. Finally, CNNs are more efficient than traditional neural networks for image processing tasks because they are specifically designed to process pixel data and exploit the spatial correlation present in natural images.

Other Studies

The classification of artifacts using machine learning has garnered substantial interest in the past few years. As technology continues to advance and AI becomes more prevalent, there have been various studies, research, and projects related to this topic. One such study used deep neural networks to differentiate between worked stone artifacts and natural clasts (Emmitt et al., 2022). For the study, photographs and artifact classification were used for both the training and testing sets. Another research project is utilizing CNN-based modeling approaches to process and classify images using machine learning to combat the illegal trade of antiquities. The study employed a dataset of images depicting archaeological artifacts from various regions, such as Africa (Winterbottom et al., 2022). Researchers have successfully utilized deep learning techniques to preserve African dances. The study involved the accurate classification of four traditional African dances, namely Adowa, Swange, Bata, and Sinte dance (Odefunso et al., 2022). A bibliometric analysis has been carried out to examine the trends in Africa over the last three decades. The analysis, powered by machine learning research, has revealed the significant surge in machine learning in Africa and its diverse applications in areas such as image classification. The study has strongly emphasized the utmost importance of addressing poverty, improving education, providing quality healthcare services, and combating sustainability challenges like food security and climate change (Ezugwu et al., 2023).

Historically, African artifacts were often treated as curiosities or natural history specimens, rather than as works of art. However, as attitudes towards non-Western art have evolved, there has been a growing interest in recontextualizing these artifacts as art objects. For example, during the early 1900s, the aesthetics of traditional African sculpture became a powerful influence among European artists who formed an avant-garde in the art world (Murrell, 2008). As the life and technology evolves, there has been developments on the context of classification of African artifacts with wide perspectives. The classification of African art has evolved from a focus on the traditional art of specific regions to a more inclusive approach that considers diverse regions, time periods, and the arts of the African diaspora. The study of African art has also incorporated scientific methods and various analytical approaches. Furthermore, there is a growing recognition of the diversity of African art and the importance of performance in its understanding. One study suggests that archaeologists could use artifacts and landscapes to build general principles of use, discard, and deposition (Ellison et al., 1996).

One ongoing debate concerns the restitution of African artifacts that were taken from their countries of origin during the colonial era (Gbadamosi, 2022). Many African scholars and governments argue that these artifacts should be returned to their rightful owners, while some European museums and governments resist these claims. For this reason, there is a need for technology especially Artificial Intelligence to be used for classification of the African artifacts. Another debate concerns the best approach to understanding the evolution of stone tool technology in Africa. While a highly detailed typology has been developed, some argue that a more historical perspective is needed to fully understand the origins of stone tool technology in Africa (De la Torre, 2011)

Method

Dataset and Data Acquisition

Google Images were used to gather a dataset for this study. Using precise phrases to distinguish African artifacts according to the types of materials they were made of. The three classes of objects were represented by the terms "clay," "metal," and "wood." Based on the distinctive themes, hues, and architecture of different African artifacts, comparisons were made between them. 880 unprocessed photos made up the dataset, which was then separated into three categories for clay, wood, and metal. Each class's dataset was further split into 80% for training and 20% for validation in order to ensure effective training and evaluation. The classification models used to classify the dataset can be thoroughly analyzed and evaluated thanks to this split. Below is an example of African artifact images; (a) metal – Benin bronze metal sculpture, (b) clay – Igbo people's vessel, and (c) wood – the Akuaba hand-carved fertility doll (see Figure 1).

(a) (b) (c)

Figure 1. Benin sculpture (a), Igbo vessel (b), Akuaba fertility doll (c)

In order to standardize the dataset, we selected only the image formats of JPG, JPEG, and PNG. Subsequently, the dataset was segregated based on the materials, colors, and structures of the artifacts, specifically wood, metal, and clay. The initial dataset consisted of 222 raw clay images, which were further divided into two classes: 80% (177 images) for training and 20% (45 images) for validation. Similarly, the dataset contained 288 raw metal images, which were split into two classes: 80% (230 images) for training and 20% (58 images) for validation. Additionally, the dataset encompassed 370 raw wood images, which were divided into two classes: 80% (293 images) for training and 20% (77 images) for validation. For detailed information regarding the classes and the respective numbers of training and validation images, please refer to Table 1 below.

Table 1. Separation of the input dataset

Class	Training (80%)	Validation (20%)
Clay	177	45
Metal	230	58
Wood	293	77

Methods Procedures

Following the dataset preparation, we proceeded to classify (V. N & P, 2022) the three types of African artifacts (Clay, Metal, and Wood) using four different Machine-Learning models: Pretrained_inception, Inception, LeNet, and Resnet-50. The training process involved utilizing a 30-epoch training scheme with a batch size of 32 (Brownlee, 2018). Once the models were trained, we evaluated and compared their performance in classifying the artifacts. See the Figure 2 below.

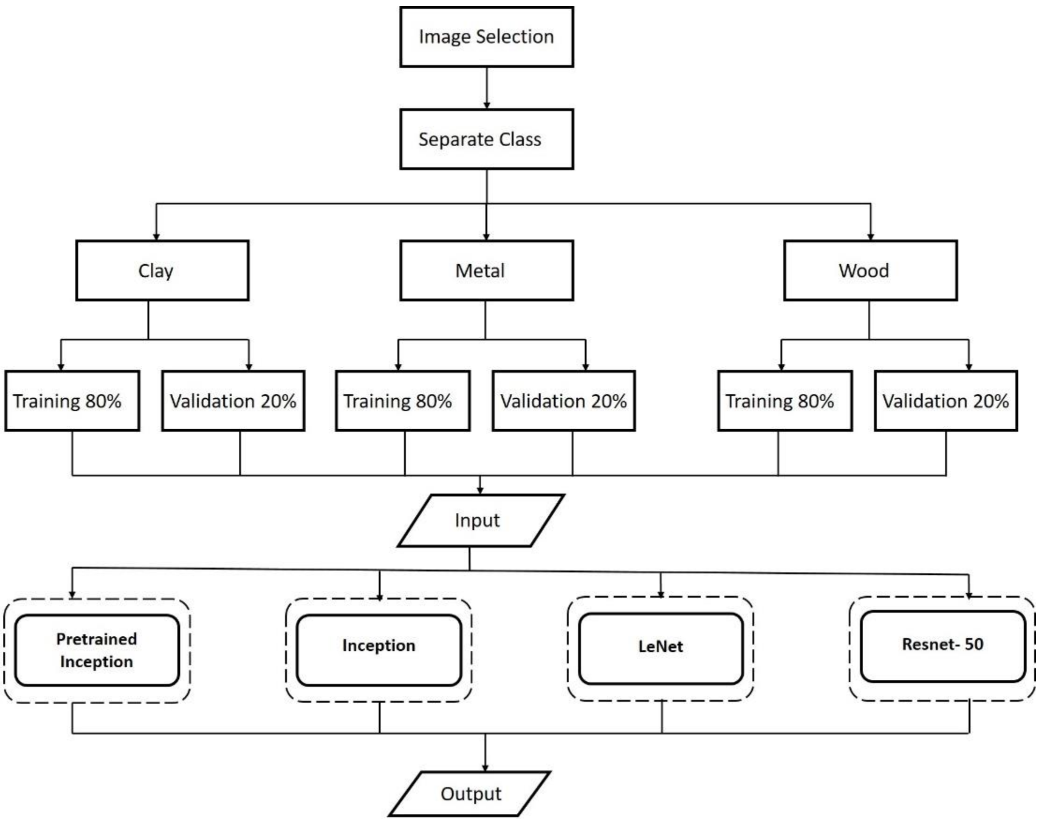


Figure 2. Data processing Flowchart

Machine Learning

Machine learning is a subfield of artificial intelligence, which is broadly defined as the capability of a machine to imitate intelligent human behavior. Artificial intelligence systems are used to perform complex tasks in a way that is similar to how humans solve problems. It is an application of AI that emphasizes the use of data and algorithms to mimic how people solve problems (El Naqa & Murphy, 2015). Machine Learning can be categorized into three major paradigms: supervised learning, unsupervised learning, and reinforcement learning (Qin & Qin, 2020). Machine Learning is the type of algorithm data scientists choose to use depends on what type of data they want to predict (Carbonell et al., 1983). Machine learning has countless practical applications, from chatbots and predictive text to autonomous vehicles and medical diagnosis. Machine learning is an incredibly valuable tool for solving a variety of problems. It can analyze and visualize large amounts of data, uncover important insights, and identify patterns. What's more, computers can learn from this data without explicit programming, and improve their performance based on experience over time.

In this study, four machine-learning models (Song et al., 2017), namely Pre-trained Inception, Inception, LeNet, and ResNet-50, were employed to classify African artifacts into three categories: clay, metal, and wood. The models were trained using images with a target size of 224 x 224 pixels resolution, RGB color mode, horizontal flip augmentation, and a rotation range of 20 degrees. The training process utilized a loss function with cross-entropy error, the Adam optimization algorithm, and various learning parameters such as recall, precision, F-1 score, and accuracy. The performance of each model was compared based on these performance metrics to assess their effectiveness in accurately classifying the artifacts.

Due to the limited number of datasets used, we chose to utilize the Ktrain framework for our experiment. This robust Python library is based on TensorFlow and Keras, making it simple to complete Machine Learning tasks with ease (Maiya, 2022). With the computer hardware platform: Processor Intel(R) Core(TM) i5-9300H CPU @ 2.40GHz Clock Speed 2.40 GHz, RAM 16GB 2666 MHz DDR4, GPU NVIDIA GeForce GTX 1650 Graphic Memory 4GB. The total images of 880, using Epoch 30 and batch size of 32 were experimented.

Pre-trained Inception

The Pre-trained Inception model is a type of convolutional neural network (CNN) that has been pre-trained on a large dataset, such as ImageNet, to ensure it can accurately recognize different objects (Gupta, 2020). The Inception model has a complex design and uses various tactics to improve its speed and accuracy. It has multiple versions, such as Inception V1, V2, V3, V4, and Inception-Resnet, with each one being an improvement from the previous model. The pre-trained Inception CNN models can be a valuable tool in computer vision and image analysis. They can save significant time and resources in developing and training new models, and they can be used for transfer learning and object detection. There are several features of the Pre-trained Inception Model including, Repurposing Learned Knowledge where the learned knowledge, including the layers, features, weights, and biases, can be repurposed for a different problem. This can save significant time and resources in developing and training a new model. Also, many deep-learning libraries host pre-trained models, making them more accessible and convenient for researchers and practitioners (Yalçın, 2020). Another feature is that the Pre-trained CNN models, such as Inceptionv3 (Szegedy et al., 2015), are typically very large, with millions of parameters. This allows them to learn complex features and patterns in the data. In the task of image analysis and object detection, the Pre-trained CNN models, such as Inceptionv3, can be used to classify objects in the world of computer vision (Magaña et al., 2022; Xia et al., 2017). Another important feature of the Pre-trained Inception model is called "Transfer Learning" (Li et al., 2018), whereas Pre-trained CNN models can be used for transfer learning, where the learned knowledge is used as a starting point for a new problem. This can save significant time and resources in developing and training a new model.

For this research, we used an Inception model that has been extensively trained on a large image dataset. The main purpose of this model is to easily categorize images from the current dataset. This technology is very useful for tasks such as sorting African artifacts based on their visual features. It is efficient in feature extraction and image classification. (Habibzadeh et al., 2018; Li et al., 2018).

Inception

The Inception model facilitates in the acquisition and processing of elements at various scales within a picture. The inception module is made up of max pooling layers and parallel convolutional layers with various filter sizes (1x1, 3x3, and 5x5). The model can learn and combine features at various levels of abstraction by executing parallel convolutions, which enables it to concurrently capture fine-grained and high-level features (Alom et al., 2017; Wang et al., 2019). The Inception model can successfully distinguish between clay, metal, and wood objects by making use of its abilities to learn complicated patterns and capture features at multiple scales. The model can recognize distinctive visual traits, such as texture, form, color, and structure, connected to each type of material. This makes it possible to categorize the artifacts correctly into the appropriate groups (Xia et al., 2017).

LeNet

Convolutional, pooling, and fully connected layers are among the layers that make up the LeNet architecture. An image is used as the input to the LeNet model after being subjected to convolutional techniques to extract useful features. In order to detect patterns and features at different spatial scales, the convolutional layers convolve over the input image using learnable filters (LeCun, Jackel, Bottou, Cortes, et al., 1995). This classic convolutional neural network (CNN) architecture, classify unseen African artifacts into three groups using the criteria mentioned above. When an image of an item is fed into the model, it uses its mastered feature extraction and classification skills to determine the artifact's material type. Employing an optimization process, like random gradient descent, to modify its internal parameters in order to reduce the discrepancy between the expected and actual class labels (LeCun, Jackel, Bottou, Brunot, et al., 1995). As a result, the model can pick up distinguishing characteristics unique to items made of clay, metal, and wood.

ResNet-50

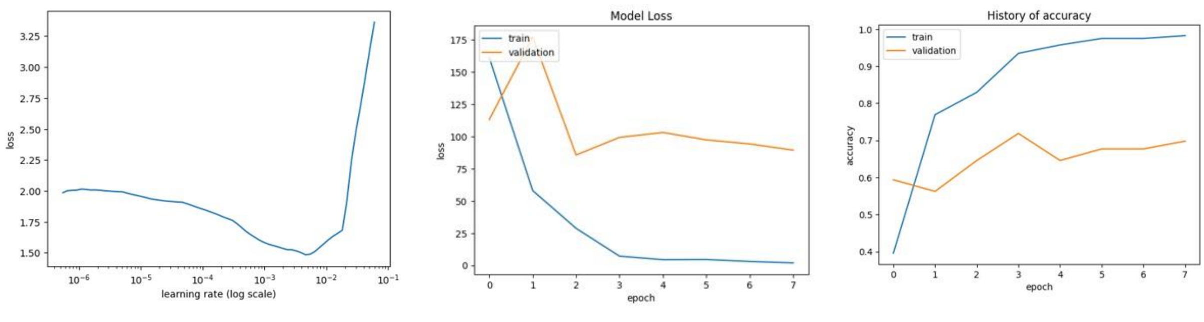
Convolutional neural network (CNN) architecture ResNet-50 is frequently used for image classification applications which is why we use it in the classification of African artifacts. It effectively learns deeper representations by addressing the vanishing gradient problem via skip connections or residual connections. There are 50 layers in ResNet-50, including residual blocks with skip connections (Rezende et al., 2017). By training to extract pertinent features and properly categorize artifacts into groups like Clay, Metal, and Wood by using a dataset of tagged African artifact images. The depth and intricacy of ResNet-50 make it a powerful tool for classifying artifacts since it can catch tiny details and variations in visual attributes (Sarwinda et al., 2021; Wen et al., 2020).

Results

In this study, we utilize Epoch 30 and a batch size of 32 with four K-train models, namely Pre-trained Inception, Inception, LeNet, and ResNet-50, to classify clay, metal, and wood artifacts. The comparative performance metrics of these models are presented in the chart depicted below. The outcomes of the Pre-trained Inception model are illustrated in Figure 3, the Inception model in Figure 4, LeNet in Figure 5, and ResNet-50 in Figure 6.

Pre-trained Inception

The result of the Pre-trained Inception model is shown in Figure 3 below, where (a) is the learning rate, (b) model loss during training and validation, and (c) is the accuracy during the training and validation.

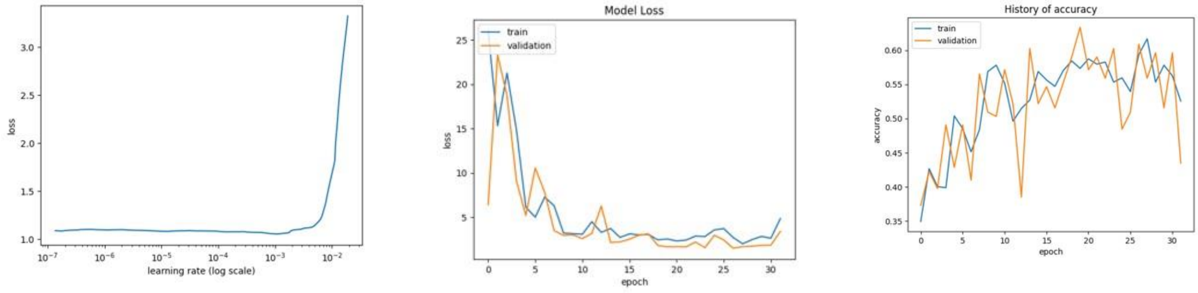


(a) (b) (c)

Figure 3. Result for Pre-trained Inception model

Inception

Result of Inception model as it shows in Figure 4 below, it shows it's learning rate in (a), the model loss during training and validation (b), while (c) is the accuracy during the training and validation.

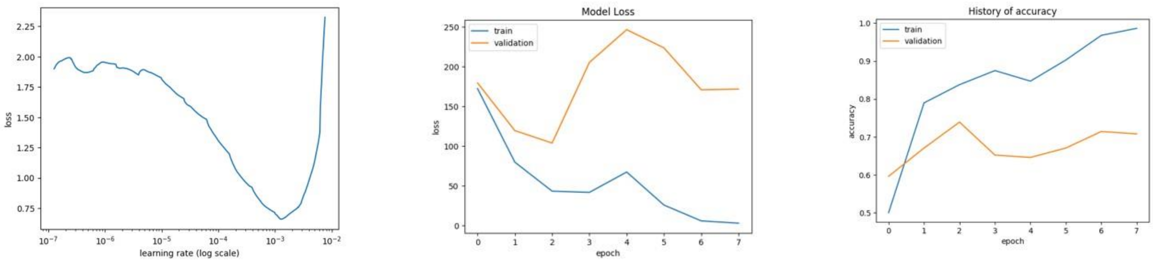


(a) (b) (c)

Figure 4. Result for the Inception model

LeNet

In this model, the results show in the Figure 5 below as follows; (a) The learning rate, (b) model loss during training and validation, as well as (c) is the accuracy during the training and validation.

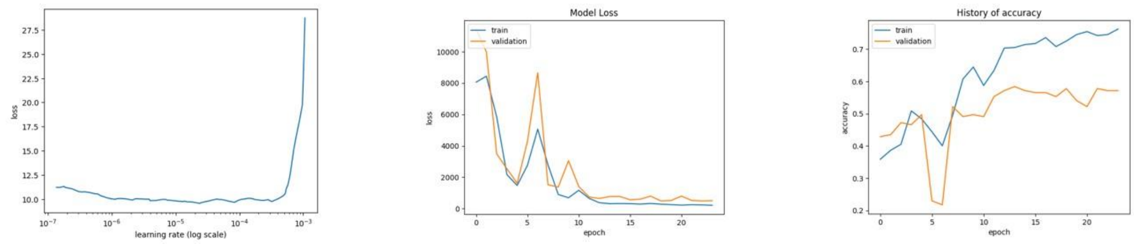


(a) (b) (c)

Figure 5. Result for the LeNet model

ResNet

Below is the results for the ResNet model, which shows, (a) the learning rate, (b) model loss during training and validation, and (c) the accuracy during the training and validation.



(a) (b) (c)

Figure 5. Result for the ResNet model

The four models successfully classify the clay, metal, and wood artifacts from a dataset consisting of 880 samples. All models achieved accuracy rates above 55%. LeNet exhibited the highest accuracy at 74%, followed by Pretrained Inception with a slightly lower accuracy of 65%. Inception attained an accuracy of 61%, while

ResNet-50 demonstrated the lowest accuracy at 58% (Table 2).

Table 2. Metric Performance comparison of the models

Model	Dataset	Model Performance Comparison			
		Precision	**Recall**	**F1-score**	**Accuracy**
Pretrained Inception	Clay	74%	74%	74%	65%
	Metal	70%	68%	69%	
	Wood	46%	48%	47%	
Inception	Clay	55%	49%	52%	61%
	Metal	58%	68%	63%	
	Wood	67%	61%	64%	
LeNet	Clay	70%	74%	72%	74%
	Metal	75%	74%	74%	
	Wood	75%	74%	74%	
ResNet-50	Clay	53%	51%	52%	58%
	Metal	51%	65%	57%	
	Wood	69%	55%	61%	

LeNet demonstrated the highest performance across all metric parameters, achieving a Precision of 75% for both metal and wood classes, a Recall of 74% for clay, metal, and wood classes, and an F1-score of 74% for metal and wood classes. Pretrained Inception exhibited consistent classification performance in the clay class, with Precision, Recall, and F1-score all at 74%, while the wood class had the lowest values, failing below 50% for precision, recall, and F1-score. In contrast, the Pretrained Inception model displayed a lower recall, F1-score values and of 46% for the wood class in Precision.

Discussion

In the framework of classifying clay, metal, and wood in African artifacts, this study significantly advances artificial intelligence. The results show that all four of the study's models, with LeNet having the best accuracy of 74%, have the capacity to categorize artifacts from Africa. LeNet's higher performance can be credited to the way it was specifically created for jobs like handwritten digit identification, which allowed it to read complicated characters carved into metal and wood. The architecture of LeNet comprises convolutional layers, pooling layers, and fully connected layers. The input image undergoes convolutional operations, extracting meaningful features. The convolutional layers employ learnable filters to detect patterns and features at various scales (LeCun et al., 1998).

These findings offer a glimpse into how well various models can classify African artifacts crafted from clay, metal, and wood. It's worth noting that accuracy isn't the sole factor to consider when assessing the performance of a classification model. Precision, recall, and F-1 scores offer supplementary insights into the model's capacity to accurately classify each category (Aquil & Ishak, 2021).

There are a number of reasons why the ResNet-50 model in this study performed less accurately than the other models. First, ResNet-50's deeper and more complex structure might have made training and optimization more difficult, especially with the limited amount of data (He et al., 2016). The complex features and patterns specific to clay, metal, and wood artifacts may have been difficult for the model to reproduce. The ResNet-50 model used in this study had a lower accuracy, which could have been caused by optimization parameters. Additionally, the ResNet-50 model's generalization capabilities may have been restricted by a small or undiversified training dataset. Another potential problem is overfitting, as complicated models like ResNet-50 are more likely to do so and perform badly on untrained instances.

Finally, optimization parameters and hyperparameter settings have an impact on how well deep learning models perform. It is possible that ResNet-50's capacity to converge to an ideal solution might have been restricted if these parameters had not been appropriately calibrated for it. Overall, the ResNet-50 model used in this study may have been less accurate due to a combination of model complexity, dataset constraints, probable overfitting, and unfavorable optimization choices (Dai et al., 2017).

This demonstrates how deep learning model performance can change based on the particular task, dataset, and experimental setup. These elements should be taken into account when choosing an appropriate model, and additional investigation and testing may be required to identify the ideal model for effectively categorizing clay, metal, and wood artifacts in African artifact classification tasks. This finding supports the claim that deeper networks do not always produce superior results in simple image-processing tasks (Chen et al., 2017).

Limitation

As the Data collection for the study was performed using Google images, it had certain challenges, particularly getting a large dataset with the precise shapes of the categorized artifacts. As a result, the dataset included a variety of metal, wood, and clay product shapes, making it difficult to correctly categorize the specific shapes of these three different types of objects.

For an improved classification of African artifacts, it is imperative that researchers prioritize the collection and utilization of datasets that provide detailed shapes of the three distinct types of artifacts. This approach will significantly enhance the classification process and enable the accurate differentiation of the physical characteristics of metal, wood, and clay artifacts. By gathering more precise and representative data, deeper insights into the unique qualities of each artifact type can be gained, and their cultural and historical significance can be understood with greater accuracy.

One significant problem with this study is the severe shortage of image data for African artifacts. It is crucial to have a sufficient amount of labeled data to train Artificial Intelligence and Deep Learning models effectively. Unfortunately, there may be limited data accessible for African artifacts, which makes it challenging to develop highly accurate models (Karamitrou et al., 2022). The limitation posed by the Intra-Class Variation is similar to the one identified in this study (Wei et al., 2015): African artifacts can have distinct differences in their appearance, even if they belong to the same category. This is usually caused by factors such as the specific region, culture, or era they originate from. As a result, it can be difficult for machine learning models to accurately classify African artifacts.

Conclusion

In conclusion, this study has made significant contributions to the field of artificial intelligence in classifying clay, metal, and wood artifacts. The results indicate that all four models used in the study show potential for accurately classifying African artifacts, with the highest accuracy achieved by the LeNet model. This study provides insight into how to classify clay, metal, and wood artifacts using machine-learning algorithms. The outcomes show these models' capability for effectively detecting and differentiating between various material types. This has significant implications for numerous parties involved in the care and preservation of African artifacts.

First, the results of this study offer important insights for people to distinguish between clay, metal, and wood artifacts. Curators, art historians, and anthropologists can better grasp the cultural importance and historical context of an artifact by being aware of the distinctive properties of each material type (Berger, 2016; Woodward, 2007). Their ability to analyze and contextualize these artifacts could be improved by this information, which would further our understanding of African culture and heritage.

Additionally, the field of robotics can benefit from the classification of artifacts using machine-learning models. The design and development of robotic systems that can handle and move these objects with care can be facilitated by the proper identification of material types (Alipour & Harris, 2020). Programming robots to apply specific force and pressure based on the material composition can reduce the danger of damage or improper handling (Gao et al., 2016; Jamali & Sammut, 2011). This can help ensure the preservation of African artifacts for future generations and be very useful to museum curators, conservators, and restoration specialists.

In conclusion, the classification of clay, metal, and wood artifacts using machine learning models offers up possibilities for robotic manipulation (Wang et al., 2020). and movement in addition to providing insights for human comprehension (Harvey, 2017; Knappett, 2011). We can successfully maintain (Gothandaraman & Muthuswamy, 2020) and appreciate the cultural history of African artifacts while assuring their safe handling and protection (Belhi et al., 2023) by fusing the power of machine learning with human experience.

Recommendations

It's important to keep in mind that mistakes can happen when labeling artifact images due to the large dataset. To avoid errors and ensure that CNN structures are interpreted accurately, it's crucial to take your time and use careful techniques when labeling these images (Northcutt et al., 2021).

By utilizing these classification models, researchers can gain a better understanding of the materials used in African artifacts and their classification. This can contribute to the preservation and study of African art, helping to identify and appreciate the cultural heritage represented by these artifacts.

It is worth mentioning that the study focuses on the classification of artifacts based on images of their material composition and does not delve into the broader context and cultural significance of African art. To fully understand African art, it is important to consider local aesthetic values, historical approaches, functional analysis, and the diverse materials and forms used in Africa (Diop, 2021, 2023).

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Abstract : The use of polymer-based chemical additives to improve the chemical and mechanical properties of cement has been increasing rapidly in recent years. Polymer types such as liquid polymer, powder polymer, hydrophilic polymeric structures, latexes are structures that are frequently used as cement additives. Glycol structures from polymer additives are generally used as grinding aids in cement production. In our study, the positive effects of different types of polyethylene glycol diblock copolymers (PEG) on cement as cement grinding facilitators and strength increasers were observed.In CEM I type (90 clinker/5 limestone/ 5 gypsum) cement, 32µ, 45µ and 63µ fineness after laboratory mill grinding of AB1, AB2, AB3 and AB4 coded copolymers compared to Blank (chemical-free), MEG and DEG ground cements, 2 , 7 and 28 days compressive strengths and water requirement changes were observed. AB2 coded copolymer has an advantage of 18.86%, 24.87% and 45.74%, respectively, over blank in 32µ, 45µ and 63µ thicknesses in cement mortar; -9.62%, -12.40% less advantage, 1.92% advantage compared to DEG, respectively; It has -3,64%, -7,41% and -8,51% less advantage over MEG, respectively. There was an increase in water requirement compared to blank, MEG and DEG.The compressive strengths of the AB2 coded copolymer increased by 6.72%, 2.08%, and 4.83%, respectively, compared to the blank in 2, 7 and 28-day results, -11.19%, -7.09%, respectively, according to DEG. It was observed that it decreased by -2,43%, and decreased by -4.51%, -6.21%, -0.95%, respectively, compared to MEG. Although there is no advantage in the compressive strength results of AB1, AB3 and AB4 coded copolymers, it is understood from the results that the compressive strength results of the AB2 coded copolymer are very close to the blank and MEG and DEG additives used in the sector.Mini-slump spreading tests of AB2 coded copolymer were carried out for CEM I cement. It was observed that when various proportions were added to the cement paste, the spreading diameters increased linearly (%0=37.25mm; 0.5%=41.5mm; 1%=45mm; 1.5%=46.25mm; 2%=47mm).

Keywords: Polymeric additive, Cement, Polyethylene glycol, Cement additives

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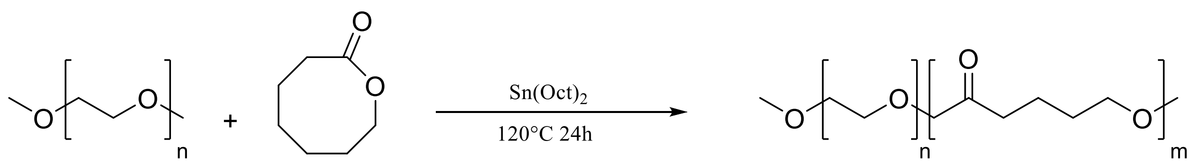
Introduction

Glycols are used in the cement industry as a grinding aid, increasing tensile and compressive strength, providing fluidity, reducing the water need of concrete with a dispersing effect, increasing efficiency and workability, and accelerating hydration. They also show effects that increase the rheology of fresh concrete.



mPEG ε-kaprolakton mPEG-b-PCL

Method

PEG-b-PCL diblock copolymer and PCL-b-PEG-b-PCL BAB type triblock copolymer were obtained. mPEG-b-PCL AB type diblock copolymer was synthesized by ring-opening polymerization on ε-caprolactone at 120°C using mPEG macroinitiator and $Sn(Oct)_2$ catalyst. Fluidity and standard cement tests were carried out with diblock copolymer, which dissolves relatively more than these polymeric structures [1].

Table 1. Synthesized diblock polymers and their average molecular weights

Experimental	Mpeg Mw	Feed Ratio	TİME			GPC	
	Mn/g	(n CL / n mPEG)	h	g	%	Mn	PD
AB1	2000/10	9:1	24	12,8600	84,940	3832	1,0915
AB2	2000/10	9:1	24	11,9840	79,890	3973	1,0520
AB3	2000/10	18:1	24	14,5815	72,908	3679	1,1230
AB4	2000/10	50:1	48	13,2679	88,450	4472	1,0606

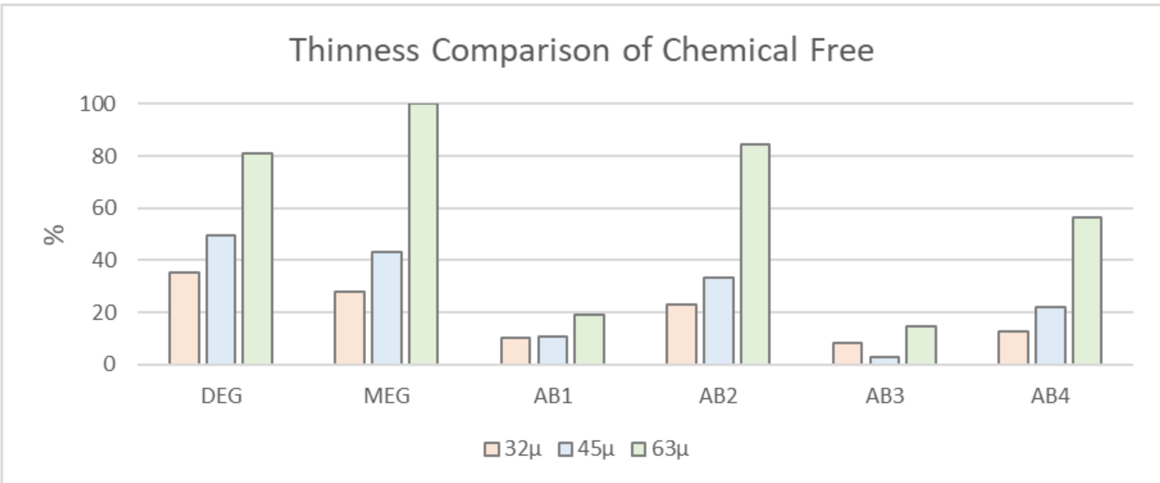
*Mn number average molecular weight, PD polydispersity, CL: ε-caprolactone, PEG: polyethyleneglycol

Results and Discussion

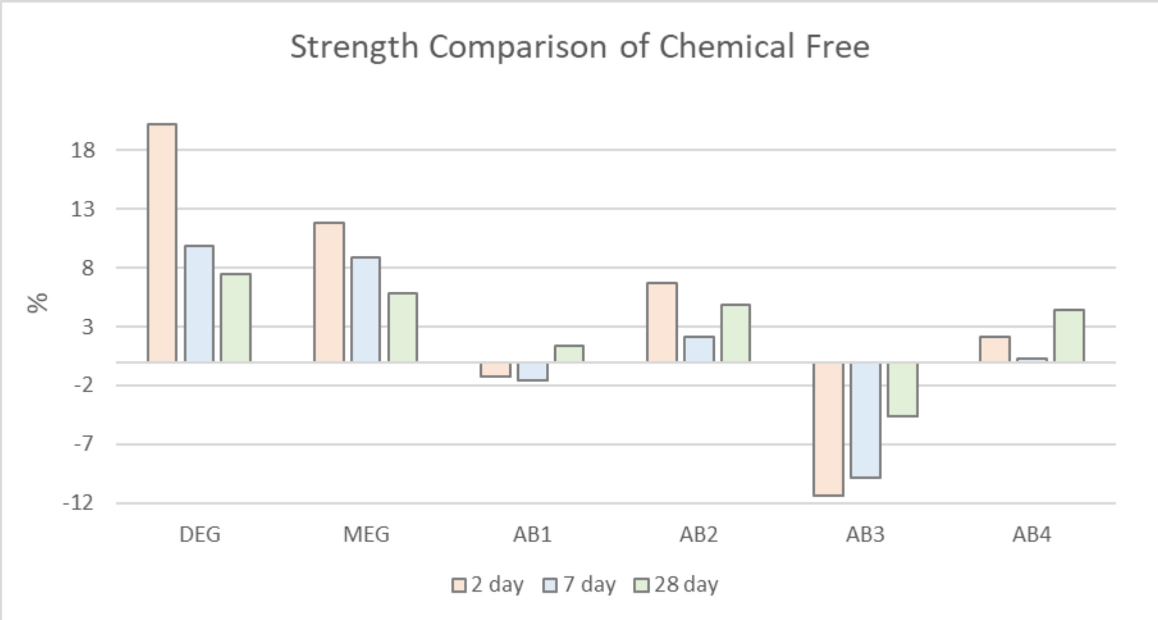
The diblock copolymers obtained were mixed with 90% clinker, 5% gypsum and 5% limestone (CEM I type cement) and ground in the laboratory mill in equal (4500) rounds. Thinness and blaine values tests were done. As a result of the comparison of MEG, DEG and PEG aqueous solutions, which are used in equal dosages, with the blank (chemical-free) cement sample, it was observed that the compressive strength and fineness values of the AB2 test set gave the best results. DEG and MEG additives, which are also used as an aid in grinding the cement, were added to the experimental sets and compared with the synthesized polymer [2].

Sample	Thinnes %			Blaine /100 rev.	Compressive Strengths (MPa)			Setting Times		
	32µ	45µ	63 µ	cm^2/gr	2 day	7 day	28 day	Water Need	Sett start	Sett end
A (chemical free)	28,1	19,3	9,4	4190	23,8	38,5	49,7	23,7	118	213
A+ %50 DEG	20,8	12,9	5,2	4690	28,6	42,3	53,4	25,2	137	189
A+ %50 MEG	22,0	13,5	4,7	4660	26,6	41,9	52,6	25,0	127	186
A+ %100 AB1	25,5	17,4	7,9	4250	23,5	37,9	50,4	24,0	135	214
A+ %100 AB2	22,8	14,5	5,1	4490	25,4	39,3	52,1	25,4	132	197
A+ %100 AB3	26,0	18,8	8,2	4210	21,1	34,7	47,4	23,8	134	213
A+ %100 AB4	24,9	15,8	6,0	4370	24,3	38,6	51,9	23,7	136	217

DEG: diethylene glycol, MEG: monoethylene glycol



Compared to blank cement, after grinding AB1, AB2, AB3 and AB4 coded copolymers in a laboratory scale mill, it was observed that the fineness values of 32µ, 45µ and 63µ showed a reducing effect at different rates and did not negatively change the water requirement. AB2 coded copolymer has an advantage of 18.86% at 32µ fineness, 24.87% at 45µ fineness, and 45.74% advantage at 63µ fineness over the reference concrete in cement mortar; According to the DEG used in the industry, there is a -9.62% less advantage at 32µ fineness, -12.40% less advantage at 45µ fineness, and a 1.92% advantage at 63µ fineness; Compared to the MEG used in the industry, it has a -3.64% advantage in 32µ fineness, -7.41% in 45µ fineness, and -8.51% in 63µ fineness. There was an increase in water requirement compared to concrete, MEG and DEG. Particularly, very close fineness values were obtained compared to MEG, which is used as a cement chemical. Likewise, an increase in blaine was observed, while the chemical-free blaine value was 4190 cm^2/gr, the AB2 blaine value was 4490 cm^2/gr. This shows that AB2 facilitates grinding and therefore increases the mill capacity.



When the compressive strengths of 2, 7 and 28 days are examined, although there is no advantage in the compressive strength results of the AB1, AB3 and AB4 coded copolymers, the compressive strength of the AB2 coded copolymer compared to the blank is 6.72% in the 2-day result, 2.08% in the 7-day result, 2.08% in the 28-day result. it increased by 4.83% in the result, decreased by -11.19% in the 2-day result, -7.09% in the 7-day result, -2.43% in the 28-day result, -4% in the 2-day result according to the MEG, It was observed that it decreased by -6.21% in the result of 51.7 days and by -0.95% in the result of 28 days. A decisive compressive strength increasing effect was not found in AB1, AB3 and AB4, and it was observed that the AB3 coded copolymer decreased the 28-day compressive strength. It is understood from the result that the 2-, 7- and 28-days compressive strength results of the AB2 coded copolymer are very close to the MEG and DEG additives used in the sector.

Mini slump spreading tests of AB2 coded copolymer were carried out for CEM I cement. For the mini slump experiment carried out, a funnel with a height of 57 mm, a base of 38 mm and a diameter of 19 mm was designed, produced and used in a 3D printer. It was observed that the spreading diameters increased linearly when added to the cement paste at various rates (0=37.25mm ; 0.5%=41.5mm ; 1%=45mm ; 1.5%=46.25mm ; 2%=47mm) [3].

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Facile Synthesis of an Ester Acid a-Hydroxyphosphonate: X-RAY, Spectral Characteristics, DFT, Molecular Docking and Biological Studies

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Abstract: Single Diethyl [hydroxy (phenyl) methyl] phosphonate (DHPMP) crystal with chemical formula C11H17O4P, was synthesized via the base-catalyzed Pudovik reaction and Lewis's acid as catalyst. The results of SXRD analyzes indicate that this compound crystallizes into a mono-clinic system with space group P21/n symmetry and Z ¼ 4. The crystal structure parameters are a ¼ 9.293 Å, b ¼ 8.103 Å, c ¼ 17.542 Å, b ¼ 95.329 and V ¼ 1315.2 Å^3, the structure displays one inter-molecular hydrogen bonding. The UV-Visible absorption spectrum shows that the crystal exhibits a good optical transmission in the visible domain, and strong absorption in middle ultraviolet one. Docking studies were performed in MOE software, which records only the top ten positions. This last determine the total energy on the basic of protein ligand interactions. Three types of interaction can be distinguished: van der Waals interaction, hydrogen bonding and electrostatic interaction. In the present study, the intermolecular interactions were analyzed for the DHPMP ester acid with different anti-fungal and anti-bacterial proteins such as Candida albicans (4HOE).

Keywords: a-Hydroxyphosphonate, Pudovik reaction, In silico, MOE.

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Introduction

Organophosphorus compounds containing carbon-phosphorus (C-P) bonds have been attracting significant attention, ever since the first discovery in natural products in 1959 (Hakima et al., 2016; Lingaiah et al., 2012).

At the present time, organophosphorus compounds include many sub-classes such as phosphonates, a-aminophosphonates and a-hydroxyphosphonates. The last subclass compounds are used as precursors for a significant variety of phosphonates derivatives (Louiza et al., 2021; Louiza et al., 2017). The a-hydroxyphosphonates can be synthesized according to several approaches. The most used approach is based on the reaction of aldehyde or ketone with dialkyl phosphite in the presence of acidic or basic catalysts, via the base-catalyzed Pudovik reaction (Nóra et al., 2017).

In this work, Diethyl hydroxy (phenyl) methyl phosphonate (DHPMP) was synthetized and single crystal X-Ray Diffraction (SXRD) and quantum chemical calculation, were used in order to confirm the structure of DHPMP. The spectral study using FT-IR, FT-Raman and UV-visible analyses were also conducted in order to confirm whether a certain correlation exists between molecular structure and vibrational frequencies of DHPMP.

Docking studies were performed in MOE software (Paul et al., 2003), which records only the top ten positions. This last determine the total energy on the basic of protein ligand interactions. Three types of interaction can be distinguished: van der Waals interaction, hydrogen bonding and electrostatic interaction. The intermolecular interactions were analyzed for the DHPMP ester acid with different anti-fungal and anti-bacterial proteins such as Candida albicans (4HOE).

Method

Synthesis

The Diethyl [hydroxy (phenyl) methyl] phosphonate (DHPMP) compound was synthesized by chemical reaction at room temperature of benzaldehyde (1 mmol, purity 99%, Sigma Aldrich), triethyl phosphite (1 mmol, purity 99%, Sigma Aldrich) and $CoCl_2.6H_2O$ (1 mmol, purity 98%, Sigma Aldrich) as a catalyst, under nitrogen reflux. A blue color appeared after 1 h time. The progress of the reaction was followed by thin layer chromatography TLC on silica gel (ethyl acetate/n-hexane 1:4); a single spot was observed after 16 h. For purification, chloroform (10 ml) was added to the reaction mixture and then filtered to separate the catalyst, and then evaporated under vacuum to eliminate chloroform. To be sure that all catalyst present was removed, the obtained product was separated in funnel, adding distilled water (2-100 ml) and dichloromethane (2-50 ml). The organic phase was dried with Na_2SO_4. The reaction scheme is shown in Figure. 1.

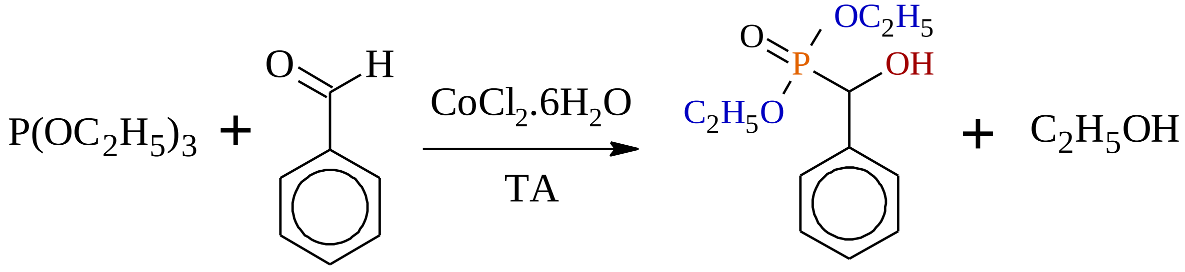


Figure 1. Reaction scheme for synthesis of DHPMP.

Spectroscopic analysis

After solubilizing DHPMP in ethyl acetate, UV-visible spectrum was measured at ambient temperature with the transmission mode, in the range 200-800 nm, utilizing a JASCO V680 spectrometer. Infrared spectra (IR) were recorded using a FT-IR 4200 JASCO spectrometer, in the range 600-4000 cm^{-1}, at room temperature. Nuclear Magnetic Resonance (NMR) spectra were recorded, in DMSOd6, using a Bruker AV III 300 MHz spectrometer.

Crystallographic analysis

Patterns SXRD were performed at room temperature, using Bruker X caliber diffractometer, equipped with MoKa anticathod and a graphite monochromator (l ¼ 0.7107 Å). The refinement was performed by the full-matrix least square method using the Crystal program (Qing et al., 2015).

Molecular docking analysis

For molecular docking, the DHPMP as ligand was optimized by DFT using (B3LYP) method with 6-31G (p, d) basis sets and save as protein data bank (pdb) file. One fungus, Candida albicans (PDB ID: 4HOE), and two bacteria, S. Aureus (+) (PDB ID: 8H1B) and Escherichia coli (-) (PDB ID: 7AB3). The Molecular Operating Environment (MOE) was used for molecular docking (Paul et al., 2003). Crystal structure of proteins was taken for performing molecular docking from RSCB Protein Data Bank (Riadh et al., 2003). The three crystals of proteins were optimized and checked by MOE software package, and all the hetero atoms, water molecules and contaminated inhibitor were removed from raw protein for obtaining fresh protein.

Results

SXRD analysis

Data collected by SXRD indicate that DHPMP crystal crystallizes in mono-clinic system with space group P21/n and Z ¼ 4. The crystal structure parameters are a ¼ 9.293(5) Å, b ¼ 8.103(5) Å, c ¼ 17.542(5) Å, b ¼ 95.329(5). The detailed fractional atomic coordinates and equivalent isotropic displacement parameters were deposited in CCDC with the reference number 1488904. The DHPMP crystalline structure has been given by Li-Tao An et al.

The present work extended furthermore the study by refining and detailing crystalline structure, where results were completed with DFT quantum chemical calculation. The asymmetric unit of DHPMP contains one formal molecule with the chemical formula $C11H17O4P$ (Figure. 2). The presence of C(6)-P(1) and C(6)-OH bonds confirms the formation of a hydroxy-phosphonate compound. The distances between the two carbons C(11)-C(16) and C(10)-C(15) are 1.260(1) Å and 1.407(9) Å respectively.

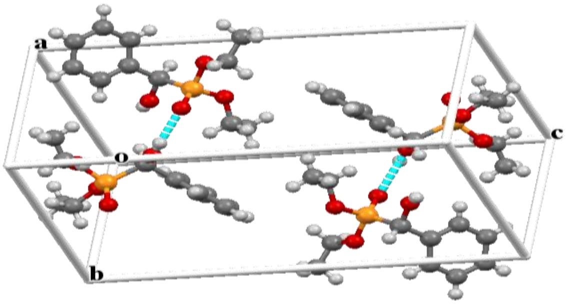


Figure 2. Packing of the molecules in elementary unit cell.

Spectroscopy analysis

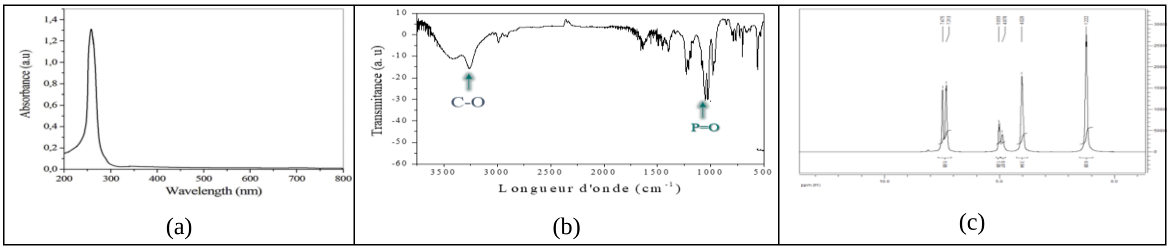


Figure 3. (a)UV-Vis (b) IR and (c) ^{1}H NMR spectrums.

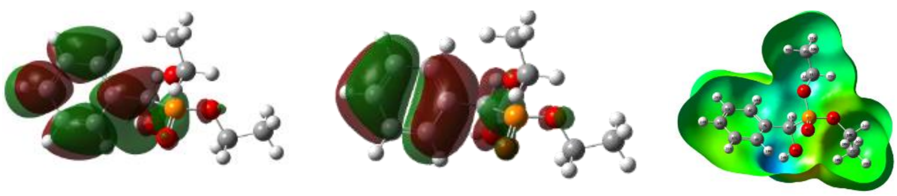
Quantum chemical calculations

Molecular electrostatic potential (MEP)

In this work and for molecular electrostatic potential and frontier orbital molecular calculations, a model of two molecules bonded by hydrogen bond was chosen, as shown in Figure 4. This model approaches the crystalline structure of DHPMP.

Frontier molecular orbitals (FMOS)

The electron donor distribution in the highest occupied molecular orbital (HOMO) and the electron acceptor distribution in the lowest unoccupied molecular orbital (LUMO) are calculate and the result is shown in Figure 4.



LUMO **ΔE gap = 5.74eV** **HOMO** **MEP**

Figure 4. Electrical and electronic properties of DHPMP.

Determination of the inhibition zone

Table 1. shows the inhibition zones around the paper disk impregnated with the compounds DHPMP on the strains.

Table 1. inhibition zone of DHPMP.

Compound		DHPMP		$DCNAA_{(+Ctrl)}$
C (µg/ml)		75	100	100
Gram(+)	*S.aureus*	R	11,0 ± 0,6	28,0 ± 0,1
	E.aerogenes	R	13,9 ± 0,5	27,3 ± 0,7
Gram(-)	*S.typhi*	R	09,0 ± 0,1	26,9 ± 0,1
	E.coli	R	10,2 ± 0,4	29,2 ± 0,3
	DMSO(-Ctrl)	R	R	R

Antimicrobial substances are considered as bacteriostatic agents when the ration MBC/MIC>4 , and bactericidal agents when the ration MBC/MIC≤4.

The MIC and MBC of DHPMP are shown in Table 2. The MIC values of DHPMP are between 30-60 µg/ml and the MBC values are 160-480 µg/ml and 60-40, respectively. µg/ml.

Table 2. MIC and MBC of DHPMP.

Bacterial strains		MI C (µg/ml)		MBC (mg/ml)		(MBC / MIC)	
		DHPMP	DCNAA	DHPMP	DCNAA	DHPMP	DCNAA
Gram(+)	S.aureus	20	15	40	30	8(-)	2(+)
	E.aerogenes	15	30	30	124	4(+)	4(+)
Gram(-)	S.typhi	25	15	100	30	16(-)	2(+)
	E.coli	25	15	100	30	8(-)	2(+)

MIC: Minimum Inhibitory Concentration. *MBC: Minimum Bactericidal Concentration*

Antifungal activity

Table 2. Antifungal results.

Composés	DHPMP	
C (mg/ml)	100	200
Candida Albicans	R	10,0 ± 0,8
Aspergillus Fumigatus	R	11,4 ± 0,6
DMSO	R	R

R : Résistance.

Docking results: antibacterial modeling

The best poses obtained after docking the DHPMP ligand with the 8H1B and 4HOE proteins are illustrated in

Figure 1, we chose these poses using their RMSD.

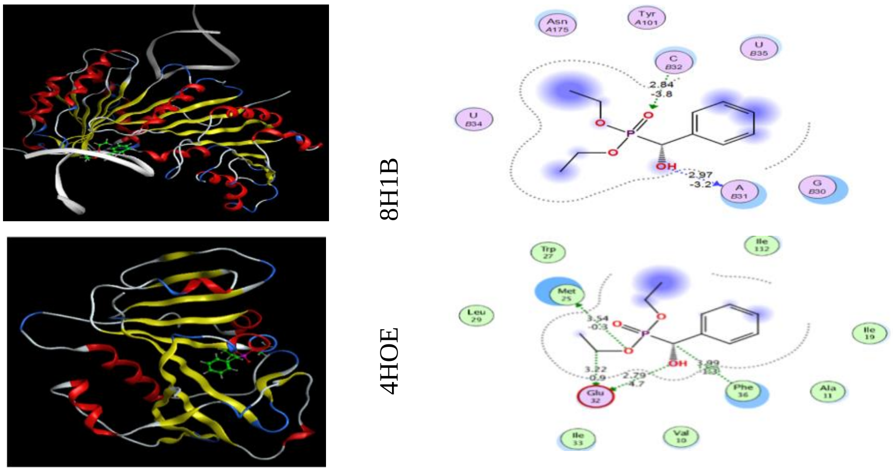


Figure 5. Best pose of the two proteins with DHPMP ligand (a) 3D (b)2D interactions.

Discussion

The optical absorption spectrum of DHPMP (Figure 3.a) exhibits a strong absorption band around 258 nm (ε258 ¼ 17626 L.mol-1.cm^{-1}) assigned to the aromatic systems or electronic excitation in this region (Shibaeva, 1975; Zahed et al., 2011).. In general, the absorption band of benzene are mainly located around 200 nm related to the energy required for p-p* transition. The absorption is negligible in visible range with a cut-off wavelength 292 nm, which is sufficient for laser frequency doubling and other related opto-electronic applications in ultra violet domain.

The broad band around 3626 cm^{-1} is due to symmetric stretching vibrations of O-H, while C-H aromatic and aliphatic stretching vibrations are observed at 3008 and 2925 cm^{-1} respectively. Sharp band observed at 1646 cm^{-1} is attributed to benzene ring stretching vibrations, whereas C-H deformation asymmetric mode of CH_3 and CH_2 occur at 1493 cm^{-1} and 1392 cm^{-1} . The medium IR band at 1362 cm^{-1} is assigned to O-H in plan bending mode of vibration. The band corresponding to P¼O stretching mode of vibrations appears at 1231 cm^{-1} .

The ^{1}H NMR spectrum of HPMPA molecule is shown in Fig. 3. The singlet (1H, s) signal at 5.21 ppm corresponds to C-OH proton. The doublet (1H, d, J ¼ 10.8 Hz) at 4.83 ppm corresponds to P-C-H proton, the five aromatic protons CH-Aromatic gave a multiplet (5H, m) between (7.5-7.29 ppm).

The biological study allowed us to demonstrate a remarkable antibacterial activity in the presence of DHPMP. From these results, it is clear that DHPMP exhibit significant antifungal activity against the fungi tested. The DHPMP ligand forms three bonds with the amino acids Met 25, Glu 32 and Phe 36 of the 8H1B Protein. It also forms two bonds with the amino acids Gly 95 and Qsp 182 of the 4HOE protein.

Conclusion

- ✓ Diethyl [hydroxy (phenyl) methyl] phosphonate (DHPMP) single crystal was synthesized and grown by slow solvent evaporation technique; its molecular formula was confirmed using single crystal X-ray diffraction to be $C_{11}H_{17}O_4P$.
- ✓ The optimized structure, vibrational frequencies, FMOs and MEP of the monomer and dimer were calculated and they explain the experimental results.
- ✓ The biological study allowed us to demonstrate a remarkable antibacterial activity in the presence of DHPMP.
- ✓ The DHPMP have a bacteriostatic effect and active at low concentration.
- ✓ The molecular docking calculations prove that the studied ester has an inhibitor effect against microbial diseases.

Acknowledgements

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Development of Open Source and Terminal Based Analog Circuit Simulator

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Abstract: Circuit simulators play a pivotal role in the domain of electronics and electrical engineering. These tools are sophisticated and their accuracy is deeply rooted in the precise modeling of electrical circuit components. Given the complex nature of these tools, the availability of open-source simulators can significantly impact the educational landscape. Therefore, employing an open-source circuit simulator within individuals' learning processes of electronics can be beneficial, as in both a stronger grasp of circuit components as well as circuit theory, and deeper understanding of software development. This paper demonstrates the development of an analogous circuit simulator of passive electrical components, aiming to provide a useful and open-source tool that can be used as a study project or be expanded by being further developed for practice purposes. In order to validate the correctness of the outputs of the terminal-based simulator, the simulation results of an exemplary circuit of the terminal-based simulator were compared to the simulation results of LTSpice for the same circuit. The code for the study is available on GitHub, complete with detailed documentation to assist those interested: https://github.com/miralab-ai/circuit-simulator.

Keywords: Circuit Simulator, Circuit Theory, Engineering Education, Open Source, Terminal-Based Simulator

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Introduction

Circuit simulators are software tools that calculate the expected behaviors of real-life applications of circuits and aim to provide detailed information per component. They rely on detailed modeling of electrical circuit components, which are elements with two terminals that make up a circuit (Najm, F. N., 2010), and they perform numerical methods to solve input circuits. They are widely used in the fields of electrical and electronics engineering. These simulators enable designers to analyze and optimize complex circuits before they are physically built, thus, reducing the cost and time required for product development.

The C programming language is known to provide more control over memory and execute tasks faster compared to the other languages (Kwame, A. E., et al. 2017). Hence, what it lacks in ease of development and its non-object-oriented nature, it makes up with execution speed and lower memory requirements. These properties would play a significant role in a software tool such as a circuit simulator. Hence, circuit simulators take advantage of these properties by employing ".c" files within their project files that carry out the computations. Therefore, the C programming language is an important part of the skillset of electrical engineers, as well as individuals who aim to work in related fields.

There are only a few circuit simulators whose source code is available online, and even fewer that are written in the C programming language. Most of the available simulators use object-oriented languages such as Java, which does not benefit the potential learners of C programming language. Additionally, many of these simulators are quite complex, with extensive circuit analysis capabilities and support for multiple types of analysis. This can make it difficult for users to choose where to start when trying to understand the code. Moreover, while there are some programming challenges for learners available online, many of them do not go beyond a certain level of difficulty and can be repetitive even when presented in different contexts. Therefore, it can be difficult for beginner programmers to find a project that challenges them to code an advanced program while teaching them various aspects of the language at the same time.

An open-source circuit simulator developed in C programming language can serve as an educational tool for individuals who have basic programming skills and aim to enhance their abilities by learning new concepts and developing complex algorithms. This software can provide a break from repetitive coding exercises and allow students or learners to engage in a substantial project, thereby gaining experience with circuit analysis methods and the application of formulas and concepts in an integrated development environment (IDE). Hence, by employing this simulator, individuals can reinforce their programming skills while expanding their knowledge of circuit analysis, which can ultimately serve as a valuable asset for future endeavors in the field.

In this study, the proposed idea is to facilitate the learning progress of individuals through an educational, open-source, and terminal-based circuit simulator that can run non-transient DC analysis for passive circuit components. In other words, the project aims to equip individuals with a higher level of proficiency in C programming, a better grasp of circuit analysis methods, and a deeper understanding of implementing circuit theory into the software. The simulator is not only an advanced programming exercise but is also a base for anyone who would like to further develop it by adding custom libraries or modifying the source code to implement various other circuit analysis techniques. Throughout the paper, several topics are discussed, such as implementing circuit theory in an integrated development environment, the workflow of SPICE simulators, and the benefits of using a simulator for educational purposes.

The educational value of the terminal-based simulator lies in its ability to facilitate learning about circuit analysis and programming simultaneously. While there are open-source circuit simulators available, such as the Falstad (Falstad, P. 2019) simulator, they can be complex and overwhelming for beginners to study and code themselves. This makes the terminal-based simulator a valuable resource for individuals who want to learn at their own pace.

There are numerous studies that have shown the benefits of using circuit simulators as educational tools. One study found that circuit simulators greatly assisted undergraduate students studying power electronics (Hart, D. W, 1993) and related courses. Another study compared the learning outcomes of a controlled group, where some members studied real circuits with the assistance of a simulator and some without it (Jaakkola, T., et al. 2008). The group using the simulator during the coursework achieved better results, highlighting the simulator's effectiveness in aiding individuals in studying circuits.

Furthermore, as many undergraduate students in electrical and computer engineering departments are concurrently taking courses in power electronics or circuit analysis as well as programming courses in C or C++ programming languages, the terminal-based simulator can be a valuable tool to help them learn and apply their knowledge across multiple disciplines. By taking up this educational project on their own, students can enhance their understanding of circuit analysis and programming and develop important skills and knowledge that can benefit them in their academic and professional careers.

The key contributions of this study can be summarized as follows:

- Employing advanced capabilities of C programming language to include a comprehensive set of C language constructs and making use of nearly all of the C language’s fundamental elements.
- Creating complex algorithms for making connections between circuit components, setting a ground (GND) node, node detection in circuits, and handling matrix operations of arbitrary sizes.
- Creating custom libraries for component models, matrix calculations, as well as user interaction with the terminal-based simulator.
- Implementing theoretical knowledge of circuit design into terminal-based simulation software.
- Facilitating the learning process for individuals who study electrical circuits and programming.

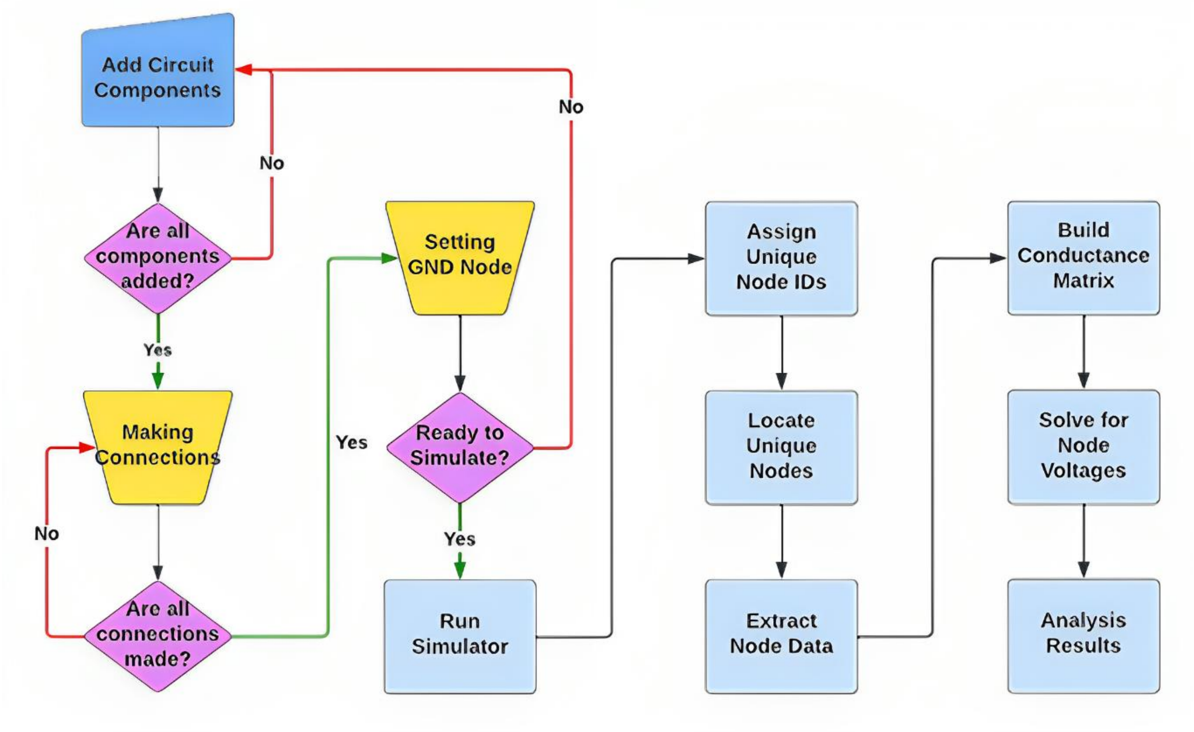

Figure 1. Workflow of the terminal-based simulator.

The terminal-based simulator follows a similar, but a rather less complex, approach to SPICE simulators, as in using Kirchhoff's Current Law (Node Analysis) to analyze the input circuits. The terminal-based simulator can be thought of as a stripped-down version of other circuit simulators, such as SPICE simulators, due to its lesser scope of non-transient DC analysis. This would be to the benefit of individuals as it means neither the programming part nor the circuit theory behind the simulator is overly complex and would encourage beginners to work on it. The flowchart of the terminal-based simulator's workflow can be seen in Figure 1.

Methods

Background on Computer-Aided Circuit Analysis

A typical algorithm of a SPICE program, which was one of the first simulators (Pederson, D., 1984), would be following the steps of initialization[1], creating of linear component models[2], matrix formulation[3], calculation[4], and output[5], with some conditional steps of going back to step 2 in cases where output does not converge. To briefly explain these points, initialization refers to the arrangement of circuit topology and specifying some default values -unless user input on it is available- such as operating temperature. Creating linear component models is a step that is omitted in linear circuit analysis' which is replacing non-linear device models with an equivalent model that is linear. Matrix formulation and calculation consists of using the Gauss Elimination Method to solve the matrix composed of, say, voltage values of circuit nodes, and lastly, the output is where the user is provided with the analysis results. As far as the terminal-based simulator in this paper is concerned, step

2 of creating linear component models for non-linear devices is skipped as it is out of scope, and the rest of the steps are demonstrated in the following subsections of methods section.

Modeling Components

The modeling of circuit components requires several parameters of different data types. Therefore, a composite data type, otherwise referred to with the “struct” keyword in the C programming language, is used for modeling. Elements of the struct are variables that store component and analysis-related information such as component type, component value, or the current flowing through the component. Moreover, component models have two elements of the same type called *nodeInfo*, which are models created for circuit nodes. The node models have three properties that are: a node ID, the node’s ground status, and node voltage.

Circuit elements are stored in the form of a singly linked list, which is the simple, unidirectional type of linked list. This facilitates the development process as it allows for the components to be located easily, as well as making it possible to perform an operation on every circuit component simply by providing the address of the head node and running the operation in a loop, performing it on each component one by one. Hence, one of the elements of the component model is a pointer to the next circuit element in the list, that is to form the linked list. The component model created for the terminal-based simulator can be seen in Figure 2.

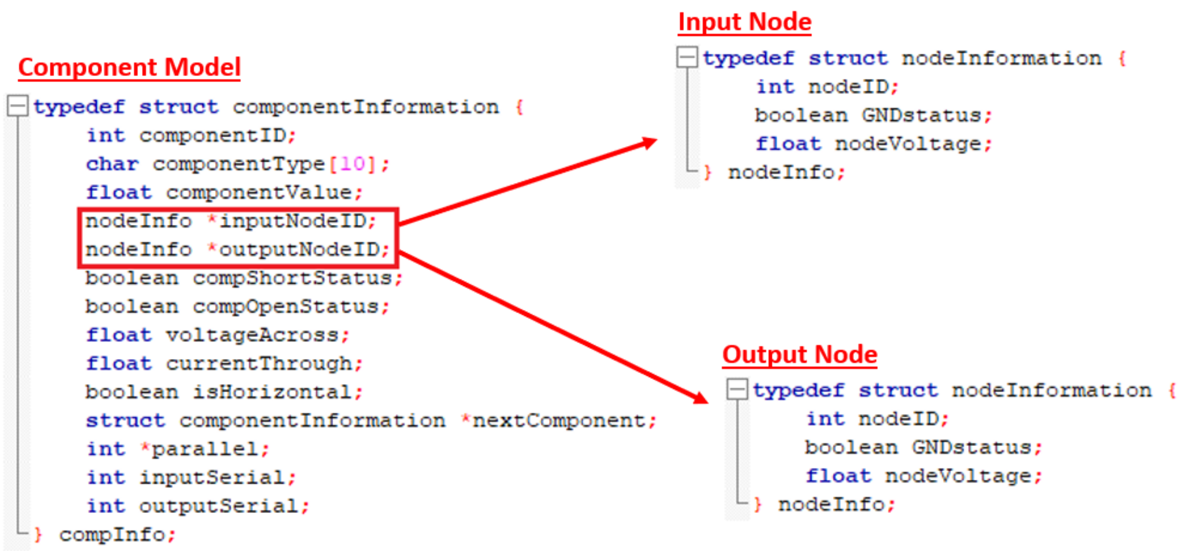

Figure 2. Component model and its input/output node model.

Building Custom Libraries

Designing a software tool that simulates circuits involves performing a multitude of operations, ranging from implementing circuit analysis methods like nodal analysis into software, to doing numerous matrix operations. To accomplish these operations, custom header files were developed that store functions that perform tasks of similar contexts, namely <components.h>, <topology.h>, <calculator.h>, and <visual.h>. The component library, for instance, contains dedicated functions for adding components, identifying circuit nodes, and assigning nodes as ground (GND) nodes, for which the GND node assignment can be seen in Figure 3 below. The topology library, on the other hand, contains functions that determine the connections of parallel or series. The calculator library comprises mathematical functions for analysis, while the visual library contains the functions for displaying the main menu, sub-menus and switching between the sub-menus and the main menu.

```
void initializeGND(int compID, boolean terminal)
{
    int nodeToGround = labelAsGround(compID, terminal);
    compInfo *testComp = findComponentByID(compID);
    compInfo *comp = createSearchComponent();

    for(int i=0; i<countComponentNumber(); i++)
    {
        if(comp->inputNodeID->nodeID == nodeToGround)
        {
            comp->inputNodeID->nodeVoltage = (float)0;
            comp->inputNodeID->GNDstatus = TRUE;
            comp->inputNodeID->nodeID = 0;
        }
        else if(comp->outputNodeID->nodeID == nodeToGround)
        {
            comp->outputNodeID->nodeVoltage = (float)0;
            comp->outputNodeID->GNDstatus = TRUE;
            comp->outputNodeID->nodeID = 0;
        }
        else
        {
            puts("F: could not find terminal to initialize as ground");
        }

        comp = comp->nextComponent;
    }
}
```

Figure 3. A simple operation of setting -or connecting- either end of a component as GND.

Operational functions

The terminal-based simulator employs a heavy usage of what can be referred to as operational functions. These are functions which are neither the implementation of circuit theory, nor mathematical functions that carry out calculations during the analysis, however, they are the backbone of the program and lay a strong foundation that allow the development of the simulation-related part of the program. Purposes of each function can vary from creating an empty component model that is used to loop through a component list, to search for and return the information of a component once given its ID, count the number of components in an input circuit, and many more. To give insight on a few of these functions, Figure 4 below shows a code snippet containing a few of them.

```
int countComponentNumber(void);
int countTrivialNodeNumber(void);
int generateStaticNodeID(void);
compInfo *createSearchComponent(void);
compInfo *findComponentByID(int compID);
boolean uniqueNodeIdentifier(int *nodeIDptr, int nodeID, int currentNodeCount);
uniqueNodeData countUniqueNodeNumber(void);
nodeInfo *findNodeInformation(int nodeID)
uniqueNodeData countUniqueNodeNumber(void)
nodeConnectionData listComponentsOfNode(int nodeID);
```

Figure 4. Code snippet displaying a few operational functions that are critical to the development of the terminal-based simulator.

Regardless of how simple or complex these functions are or can get, they handle all the rough work throughout the entire process that starts from a user running the executable file of the terminal-based simulator, to the end where they receive the analysis results of a desired circuit of choice. Two of the most used operational functions are *countComponentNumber* which returns the number of components found in a circuit of type *int*, and **createSearchComponent* of type **compInfo* that creates and empty and uninitialized component model, that allows for a more detailed search when looping through available circuit components. A more complex example of an operational function can be the function *uniqueNodeIdentifier* of type *boolean*. This function takes an input list of unique node IDs, a node ID of choice, and the number of nodes within the input list. The function then goes through the list of IDs that are all unique and checks whether the input node ID exists among them or not, returning *TRUE* if it does not exist already and is a unique node ID itself too, or *FALSE* if it already exists it the list. These types of relatively more complex functions still make use of the functions of lesser complexity that are more fundamental such as the two mentioned previously. The collective capability of operational functions are critical to the development of the project, as in means of easier tracking of program flow, more compact and modular approach to individual parts of a broken down program structure, and overall, facilitating the development process.

It can also be seen that most of the operational functions are of custom data types such as *compInfo*, *nodeInfo*, *uniqueNodeData*, and such. It should also be noted that the type *boolean* is also a type-defined variable type, as boolean variable type does not exist in ANSI C and was only added later in C99 standard in the library "*<stdbool.h>*" (ISO/IEC 9899:1999). These custom data types are a good practice for learners that prefer to utilize this project as an educational work, since complex programming tasks such as building of a circuit simulator as explained in this paper, require sophisticated models to handle many of the operations.

Modeling the Circuit

Nodes and Terminals

The simulator employs two distinct node definitions, namely trivial nodes and unique nodes. Trivial nodes represent node IDs that are assigned to newly added components by default, and do not correspond to the actual nodes of the circuit. For instance, if a user adds two resistors, the input and output terminals of the resistors will be assigned the node IDs *(1,2)* and *(3,4)*, respectively. In a physical sense, considering the case where these resistors are connected in series, the trivial node IDs of *2* and *3* would refer to the same node. However, for programming purposes, the terminals of circuit elements must receive IDs that differ in ID, even though they may represent the same node in reality. Hence, these IDs are referred to as trivial. Unique nodes, on the other hand, represent the actual understanding of a node in a circuit, and are assigned to nodes only after users establish the connections between components. In other words, a unique node ID overwrites multiple trivial node IDs to comply with the definition of a circuit node. Consequently, in the aforementioned example, once the user connects the two resistors, the simulator overwrites the IDs of *2* and *3* with a new and unique node ID of *5*. Figure 5 explains the trivial and unique node definitions of the simulator where trivial nodes are labeled as *t4*, *t5*, and *t7*, and the unique node is labeled as *u16*.

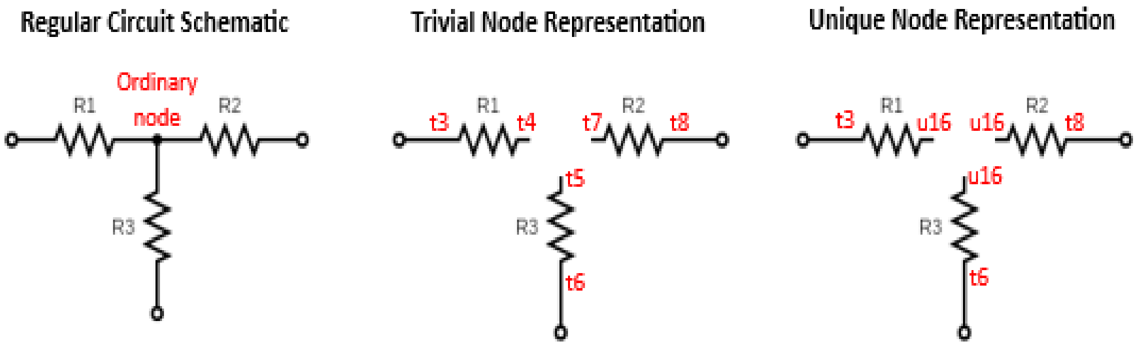

Figure 5. Circuit node in theory (left), trivial node representation of a node (middle), unique node representation of a node which is the actual representation of circuit nodes in theory (right).

Adding Components to Circuit

Building a circuit by adding components is achieved by a simple function that fills in the information for a component model. Some of this information is generated by the program, such as the components trivial node IDs, component ID, ground status of its terminals which is *FALSE* by default, and the other are user inputs, such as component type and component value. Users can add components by typing in component values such as *1000 pF* or *25 mH*. Afterward, the program will parse the input string to obtain the information as in the component value being *1000*, order magnitude being *p* which refers to *pico* that is 10^{-12}, and lastly, the component type being *F* which stands for *Farad* which would indicate that the input component is a capacitor. Furthermore, for safety purposes, component models do not store the component type in variables of type char, and instead use a more explicit way of storing a descriptive word about the component type. For example, if a user adds a component by typing in *30 mV*, the program multiplies 30 by 10^{-3} due to the order of magnitude being *m* as in *milli*, and assigns the value to the variable *componentValue*, and then copies a string of *voltage* into the char array type of variable *componentType*.

Node Combining and Grounding

The process of connecting two components in either series or parallel in the terminal-based simulator is similar to that of using a circuit simulator with a user interface (UI). In order to connect two components in a simulator with a UI, the user selects the *draw net* tool, clicks either terminal of the first component, and then clicks a terminal of the second component to make the connection. Similarly, in the case of the terminal-based simulator, users can choose the *draw net* option from the main menu, provide an array of component IDs, as well as an array of terminal IDs that specify whether the *INPUT* or *OUTPUT* terminal of the component would be connected.

The simulator then proceeds to make the connections. During this process, the program first pulls all trivial and unique node IDs, generates a new and unused node ID that will be a unique node ID by definition, and overwrites the old node IDs. Neither trivial nor unique node IDs can be assigned the ID of zero, as the node ID of zero is exclusively reserved for the ground node. The process of assigning a node as the ground node is relatively simple.

Users can select the *set GND* option from the main menu and provide a component ID and specify which terminal of the component to label as ground. The program then pulls all component information and overwrites node IDs that match the user input as zero, effectively designating the node as the ground node. The reason the program pulls all component information while setting a ground node is due to the nodes not being connected in reality, but being individual nodes of the same unique node ID. It is recommended to make all connections in the circuit before setting a ground node. If a user sets a trivial node as the ground node before making connections, the ground node of ID zero may be overwritten by a unique node assignment resulting from connecting the components, leading to unexpected behavior in the circuit simulator. Figure 6 shows an example circuit that is used for test purposes during development, where the trivial nodes are denoted by a lowercase *t* followed by their trivial node IDs, and the unique nodes are denoted by a lowercase *u* followed by unique node IDs generated by the program after connections are made between the components.

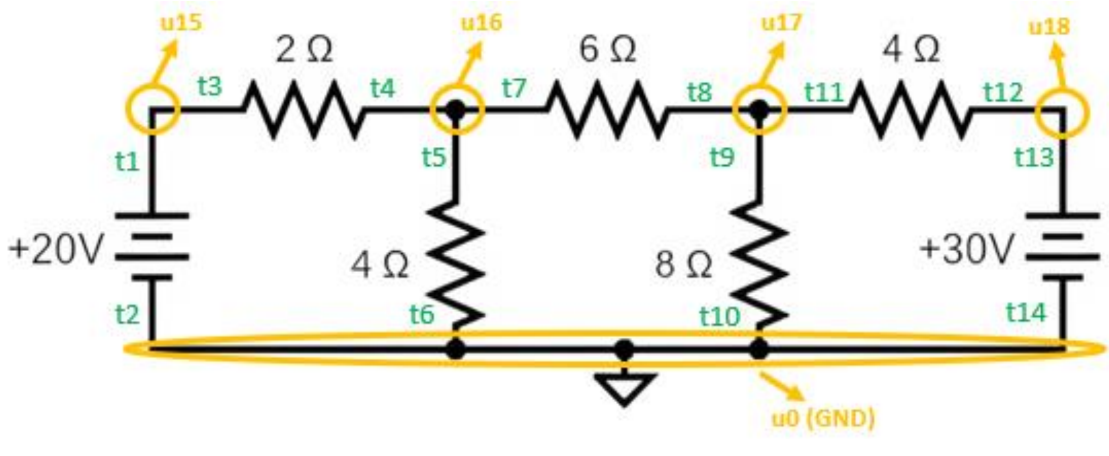

Figure 6. Trivial nodes (green) and unique nodes (orange) shown on an example circuit, where the unique node *u0* is the unique node ID designated for the GND node in any circuit.

Locating Unique Nodes and Initializing Node Voltages

The program stores two types of node data, namely, trivial and unique. During the analysis, only unique nodes are used as they are the actual representations of real circuit nodes. Therefore, unique nodes are needed to be located in the circuit topology. First, a temporary search variable of type **compInfo* is created, which is a pointer to the component model type. Then, a function loops through the entire linked-list of components through this search variable whilst temporarily storing the node IDs related to each component in a pointer with adequate memory allocated beforehand. The first component's input and output node IDs are assumed to be unique by default, since there are no other node IDs during that time of execution. The program then checks the node IDs of the other components, building up the unique node ID list while comparing them to the current list to ensure they are unique. If any node ID matches an ID that is on the list already, it is discarded; otherwise, it is added to the list as a unique node. Once the function finishes execution, it returns a struct data type called *uniqueNodeData*, which has two elements: a pointer to the list of unique node IDs and an integer that stores the total number of unique nodes.

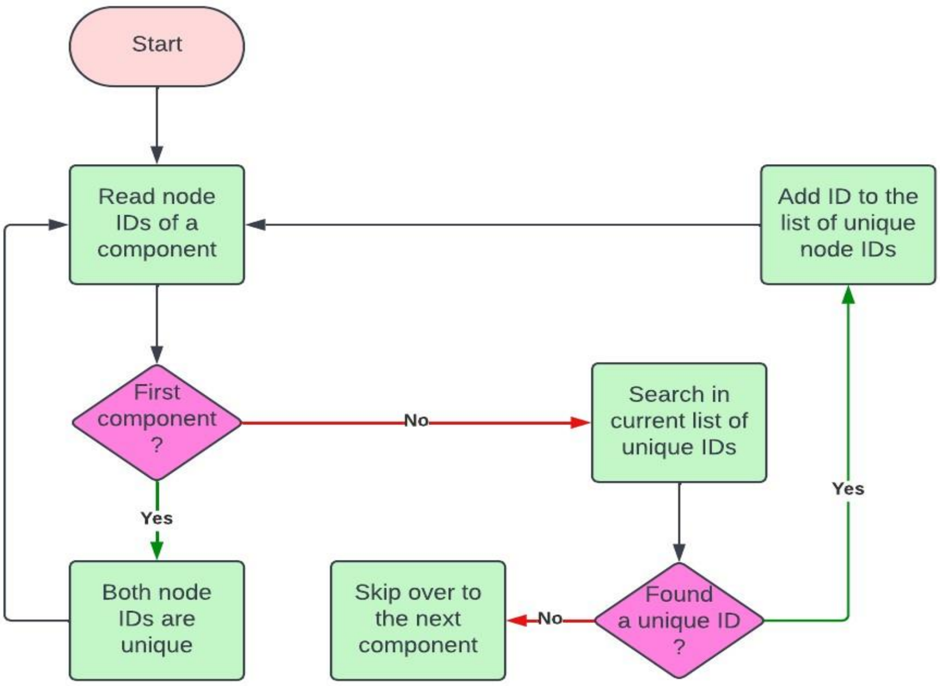

Figure 7. Visualization of the approach the program takes when generating a unique node ID list.

To ensure proper circuit functionality, the presence of a source is necessary. This means that the node voltages of nodes that have voltage sources connected to them are known pre-analysis, including the ground node, which is zero Volts (0 V) by default. The program initializes these known node voltages by iterating through the linked-list and checking every component to determine if it is a voltage source. If any are found, the voltage value of the voltage source is written to its positive terminal's node voltage. Additionally, since the simulator replaces multiple trivial nodes with the same number of identical unique nodes, initializing the voltage for other components having the same unique node ID at either of their terminals is crucial. A dedicated function checks all components and assigns the appropriate voltage value to those with a matching node ID to the one subject to the operation of voltage initialization, ensuring that the simulator does not overlook any voltage values in the circuit. Similarly, the function that initializes ground nodes operates in a similar manner. Users provide a component ID and which terminal of the component to label as ground, and the program sets the voltage of all components connected to that node to 0 V, as well as assigning the node ID to zero, which is reserved for the ground node. It is recommended to initialize the ground once after adding all components, and making all connections, so as not to have the reserved node ID for GND nodes of zero overwritten by unique node assignments. Figure 7 below shows the block diagram on how unique node ID list is generated.

Extracting Node Data

The circuit analysis process starts with some preparation steps, one of which is the extraction of node data. Extraction of node data may refer to several operations in the program, depending on where it is employed. The types of data extraction can be generating a list per node, of every other node of unknown voltage, of the components connected to it. Other types can be a list of component IDs that are connected to the input parameter node ID, as well as lists of unique node IDs and lists of nodes of unknown voltages in the entire circuit. These data play a crucial role in the analysis part of the program, and lay a base for the simulator to be able to support possible future additions of performing analysis on more complex circuits. As an example of node data extraction, the following description explains the working behavior of how to list every other node of components that join on a common node. The program, first, loops through the available components and returns a list of component IDs that have either of their terminals connected to a given node ID. This operation lists an array of components that are directly connected to a particular node. Afterward, the program sorts the ID list in ascending order by using the bubble sort algorithm, which is a simple sorting algorithm that repeatedly swaps adjacent elements if they are in the wrong order. The sorting step is not necessary, but it helps with development and bug-tracking, more specifically in the analysis part. Next, the program goes through the sorted list of components and finds the second node IDs of the components that are connected to the node of interest. This operation creates a list of adjacent nodes for a given node, which is then used to build a conductance matrix for further analysis. Figure 8 below depicts an abstract version of the process of extracting node data that is to be used to build a conductance matrix at the next stage in the program.

The additional data extraction process involves identifying components connected in series or parallel, which may require data extraction and is intended to provide a foundation for potential future program expansions. Within the terminal-based simulator, there are specialized functions designed to identify the component IDs connected to a specified reference component, whether in series or parallel. These functionalities, integrated into the custom header file “*<component.h>*”, which was later moved into a new header file "*<topology.h>*", utilize sorting algorithms to process the entire list of circuit elements input by the user, returning distinct sets of component IDs. Hence, these are the only set of operations under the name "*node data extraction*" that are implemented, yet not actively employed within the program. Figure 9 below indicates in its most basic form, how the aforementioned functions which returns the IDs of the components connected to a reference component, specifically in series form.

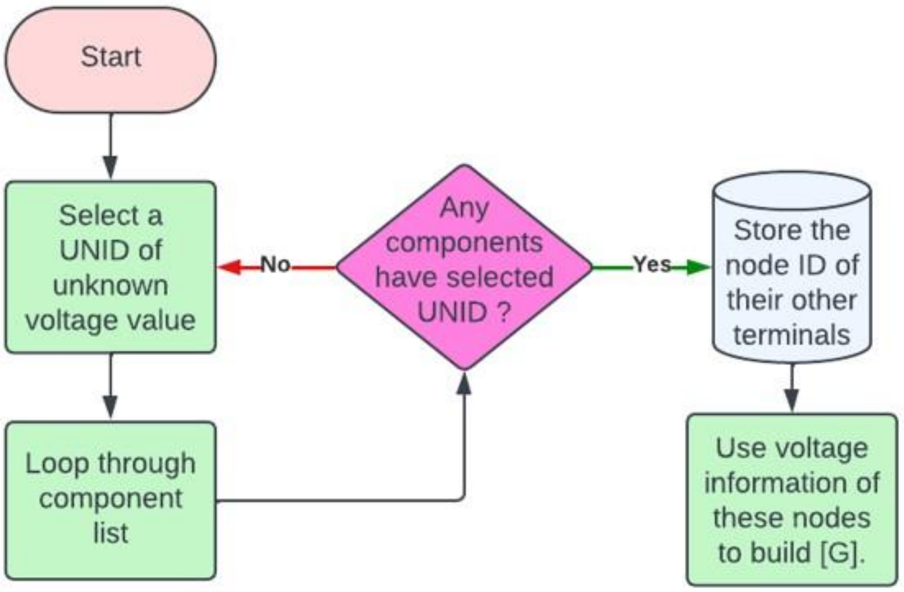

Figure 8. Block diagram of the process which extracts every other terminal's node ID of the components that are joined on a unique node. UNID in the block diagram is short for "Unique Node ID".

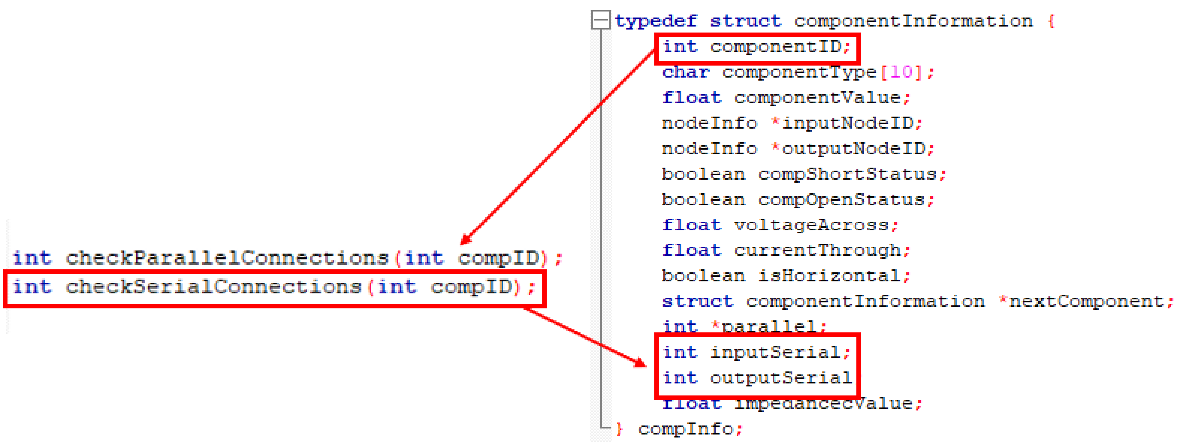

Figure 9. A basic explanation over a code snippet on how serial component(s) is/are detected in a circuit.

It is worth mentioning that in the above figure, component model *compInfo* has an extra element named *impedanceValue* of type *float*, which was not the case in Figure 2. This is one of many additions that are not actively employed in the current version of the terminal-based circuit simulator, yet, are small additions throughout the project for which their collective presence adds another layer to the upgradable and freely customizable nature of the terminal-based simulator.

This section of the terminal-based simulator concludes the parts involving the development of component models, implementation of circuit theory in software and building of generative functions that extract information from a given input circuit to later be used during calculations. The following sections focus on the mathematical processes that complete the analysis of a circuit, building further on the structure created so far and using the gathered information during the process.

Building Conductance Matrix and Solving the Circuit

The program uses matrix operations to do the analysis on input circuits, similar to SPICE simulators (Gajab, K. D., & Chitturi, A. K. 2013). Therefore, a conductance matrix has to be formed to be able to perform the analysis. A conductance matrix calls for the information obtained from node equations, where the number of nodes can be an arbitrary number of *m*. Hence, the conductance matrix must be of arbitrary size. The arbitrary matrix size of *m* in this case, is essentially the number of nodes for which the node voltage is not known. Thus, the number of nodes with unknown voltage values that is determined by extracting the circuit's node data sets the matrix size for this operation. The conductance matrix, the current matrix and the matrix of unknown voltages can be seen in equation (1).

$$\begin{bmatrix} G_{x1} & G_{x2} & \cdots & G_{xn} \\ G_{y1} & G_{y2} & \cdots & G_{yn} \\ \vdots & \vdots & \ddots & \cdots \\ G_{m1} & G_{m2} & \vdots & G_{mn} \end{bmatrix} \times \begin{bmatrix} V_x \\ V_y \\ \vdots \\ V_m \end{bmatrix} = \begin{bmatrix} I_x \\ I_y \\ \vdots \\ I_m \end{bmatrix} \quad (1)$$

The program takes a different approach to build the conductance matrix than it is done by hand. Instead of writing node equations and putting the coefficients of unknown node voltages in a matrix, the program pulls node data for the current node, which includes IDs of all components connected to that specific node and node IDs of every other node. Next, it loops through the list of adjacent node IDs whilst checking if they are of a known voltage value, or unknown, which have the value *NaN*, a special value in the default library <math.h> of GNU that stands for *Not a Number*. If the voltage value is known, the program divides that value by the component's resistance that is in between the two nodes and writes the value into the current matrix. If not, it writes the conductance value of the component into the conductance matrix. For example, in the case of the unique node of ID 16 of the test circuit, the program calculates the conductance value for each component whilst looping through the adjacent node list, all the while adding up the conductance values, such as (½) + (¼) + (⅙) to get 0.916667 which is the G_{11} element of the G matrix. This way, the program builds rows to be fed into the conductance matrix, as well as elements to feed into the current matrix. Later, to build the matrices, a function loops through all the nodes, whilst storing a list of conductance rows in a pointer that has been allocated memory for, enough to store *m* number of conductance values, as well as the current values to be assigned to the current matrix. These pointers and current values are then fed into their respective matrices. Though this process of building the matrices step by step may seem different from the traditional way of filling out a matrix that is done by hand, it is nothing but the same exact way, with a few extra steps to be implemented into a software application.

During the analysis process, through the preparation made beforehand, a few functions that do matrix operations are enough to calculate the analysis results for the input circuit. First, forward and backward Gauss Elimination is performed on the conductance matrix. Then, through basic matrix algebra, the conductance matrix is multiplied from the left side by its inverse matrix, and so is the zero matrix on the opposite side of the equation. This yields the unknown voltage matrix being equal to the inverse of conductance matrix, as seen in equations (2) and (3).

$$[G]^{-1} \times [G] \times [V] = [G]^{-1} \times [I] \quad (2)$$

$$[V] = [G]^{-1} \times [I] \quad (3)$$

The reason why the program does both Gauss Elimination and inverse matrix operations, when either could have been enough to calculate the results, is for the goal of laying the basis for future upgrades to the simulator. Users who want to customize the terminal-based simulator can choose to go with either Gauss Elimination, or inverse matrix and matrix multiplication. Though this does not have a big impact on matrices of sizes up to 3 by 3, which is the default maximum size, there may occur significant differences in the development process as well as the execution time, depending on the matrix size of the operation.

The voltage matrix that is solved for, as mentioned previously, can be considered as the analysis results only partially. For the next step, the program applies Ohm's law of $V / R = I$ to find the current values. As all node voltages are known at this point, and so are the component values, the program subtracts the input and output node values of components from each other, and divides by the component value, only to finish off by assigning the calculated current value to the dedicated variable for that in the component model, for every component. This part concludes the non-transient DC analysis of passive circuit elements. Figure 10 shows the analysis results for the aforementioned example circuit, in order to provide the complete analysis results for comparison with LTSpice results of the same circuit, which are provided in the next section.

It is essential to underscore that the terminal-based simulator serves as a pivotal educational resource, designed not only for the benefit of aspiring engineers but also for those individuals who are actively pursuing self-guided learning endeavors. Within this section of the paper, we explore the intricate process of integrating circuit theory into software, exemplifying the symbiotic relationship between theoretical and practical studies. This demonstration showcases the potential to develop valuable, real-world applications by harmoniously blending these two essential components of learning.

```
Here are the analysis results:
For the voltage component of ID 7
potential difference between its terminals is 30.000000
inVoltage: 30.000000, outVoltage: 0.000000

For the resistor component of ID 6, current through it is -2.944444
and potential difference between its terminals is -11.777777
inVoltage: 18.222223, outVoltage: 30.000000

For the resistor component of ID 5, current through it is 2.277778
and potential difference between its terminals is 18.222223
inVoltage: 18.222223, outVoltage: 0.000000

For the resistor component of ID 4, current through it is -0.666667
and potential difference between its terminals is -4.000000
inVoltage: 14.222223, outVoltage: 18.222223

For the resistor component of ID 3, current through it is 3.555556
and potential difference between its terminals is 14.222223
inVoltage: 14.222223, outVoltage: 0.000000

For the resistor component of ID 2, current through it is 2.888888
and potential difference between its terminals is 5.777777
inVoltage: 20.000000, outVoltage: 14.222223

For the voltage component of ID 1
potential difference between its terminals is 20.000000
inVoltage: 20.000000, outVoltage: 0.000000

Process finished with exit code 0
```

Figure 10. Terminal-based simulator outputs for the example circuit.

Discussion and Conclusion

Exemplar Circuit

The example circuit mentioned in the paper is a resistive circuit with two fixed and independent DC voltage sources. The circuit has two nodes whose node voltages are unknown, which are the unique nodes with IDs *u16* and *u17*. Figure 11 shows the results of calculations regarding these nodes, and their voltage values as 14.22 V and 18.22 V respectively which are marked inside a red rectangle on the bottom right of the screenshot. For comparison, on the left side of the figure, can be seen LTSpice outputs of the same circuit.

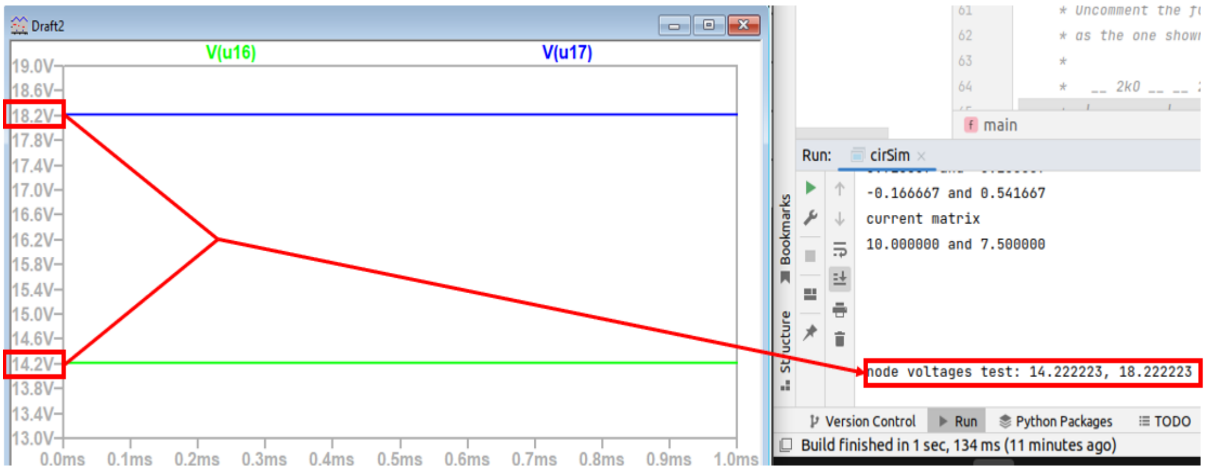

Figure 11. Comparison of the previously unknown node voltages between LTSpice and terminal-based simulator.

Except for very specific operations such as being forced to use a data type double to comply with the input parameter types of a function from a default C library, all data types used for circuit-related calculations and the storage of values in the terminal-based simulator are of the "float" type. In contrast to professional circuit simulation environments like LTSpice, which employ specialized methods for calculating and storing values, this project takes a more straightforward approach to maintain a balanced level of complexity, conducive to the learning process of individuals. On the flipside, the terminal-based simulator can handle a precision of up to 7 digits after decimal point, in other words, down to 10^{-7}. However, this, can easily be modified per choice, through modifying the data type of corresponding variables in the program from type float, to type long double. In this case, the program will be able to handle accurately, up to 15 digits after the decimal point, that is a decent improvement to 10^{-15}. In return, this sudden and drastic increase in accuracy would come at a cost of higher RAM usage, higher CPU usage, and few other downsides such as increased execution time and CPU temperature. Even though these downsides would not affect any of the modern computers as the terminal-based circuit simulator is not a resource-heavy program, these changes must be made with caution in larger scale projects as the downsides would be amplified along with the increased project size.

Simulation Results

In any circuit simulator, such as LTSpice, current values in analysis results sometimes tend to be negative numbers, which is nothing but an indicator of the direction in which the current flows. This tends to happen due to the nature of modeling of a component, which does not meet exactly the real-life versions of them (C. C. McAndrew, 2003). In reality, there are circuit components that do not have polarity, such as resistors. However, in programming, for the purposes of modeling a component, the two terminals must be assigned different IDs that result in a component such as a resistor appearing as if it is a polarized circuit element. Therefore, the negative values of currents only represent the flow direction of the current and may differ from simulator to simulator, as well as from circuit to circuit on the same simulator. Figure 12 shows the currents flowing through all of the five resistors in the example circuit and was obtained by running a simulation on LTSpice. Comparing the results on this figure to the simulator outputs provided under section 2.7 validates the outputs of the terminal-based simulator.

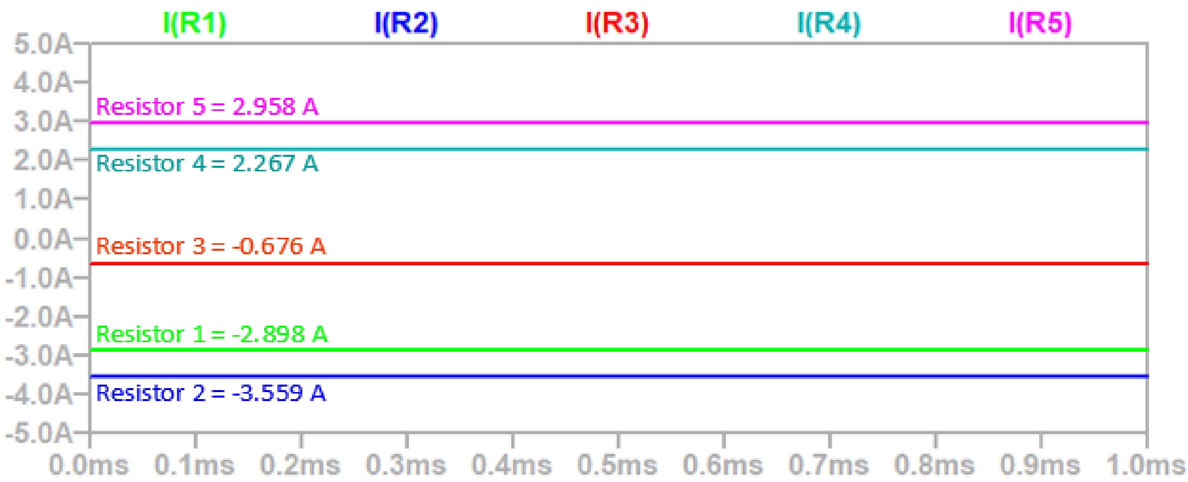

Figure 12. LTSpice results for comparison with terminal-based simulator outputs in section 2.7.

Possible Improvements

In the implementation of the terminal-based simulator discussed in this paper, Nodal Analysis is utilized for each node of unknown voltage. Additionally, matrix operations, including forward and backward Gauss Elimination, the inverse of a matrix, and matrix multiplication are employed. The program's ability to handle matrices of varying sizes determines the complexity of circuits it can solve. For instance, adding a function to perform matrix operations for an *n*-by-*n* matrix, where *n* is a positive integer, would enable the simulator to solve circuits with up to n nodes with unknown voltage values. The default limit in the simulator is set to 3 by 3 for simplicity, which allows for the solution of simple circuits that have up to three nodes whose voltages are not known pre-analysis.

Understanding the limitations and capabilities of the simulator is essential for users when selecting and designing circuits to be simulated, as well as choosing how to make their own additions to the simulator. In terms of flexibility, the terminal-based simulator is designed to support the addition of upgrades to expand its capabilities beyond the default limit of 3 nodes of unknown voltages. Specifically, the program was developed in a way that it would support the pre-calculation part of the analysis, and the limit only applies to the dedicated matrix operation functions found in *<calculator.h>*. This means that users who study this educational tool can add a few functions that would handle larger matrices, such as four by four or larger, allowing the terminal-based simulator to solve more complex circuits. In fact, the ability to add upgrades to the simulator is one of its greatest strengths.

The program was developed with a modular architecture, allowing users to easily modify or extend its functionality by adding new features, such as additional analysis methods or support for new types of circuit elements. This flexibility makes the simulator a valuable educational tool for students or individuals interested in the subject, as it allows them to explore and experiment with different circuit designs and analysis techniques. In addition to its existing functionality, the terminal-based simulator also has functions that can detect components connected in series or parallel. This feature provides a strong foundation for future expansion, as users could potentially incorporate additional circuit analysis techniques that involve identifying components in series or parallel. Furthermore, the simulator has the ability to include capacitors and inductors in circuits, making it possible to analyze circuits with AC sources and perform AC analysis. This expansion of capabilities further enhances the educational value of the simulator, as individuals studying it can apply the concepts of AC circuits and analysis to their work.

The flexibility of the simulator means that it can be used in a variety of settings, from academic classrooms to personal projects, and can be adapted to meet the needs of different users. Figure 13 below displays a few ideas in which the terminal-based simulator can be further improved by making the addition of shown features. While all of these features would be fairly uncomplicated to add onto the existing version of the terminal-based simulator, a relatively easier option to pick to take up as a challenge can be the addition of a digital library. Since the circuits on the terminal-based simulator, much like any other simulator, are software defined, working on developing models for digital devices may be less-complex and better to begin with as they function over TTL voltage levels that correspond to, and be modeled as, binary values.

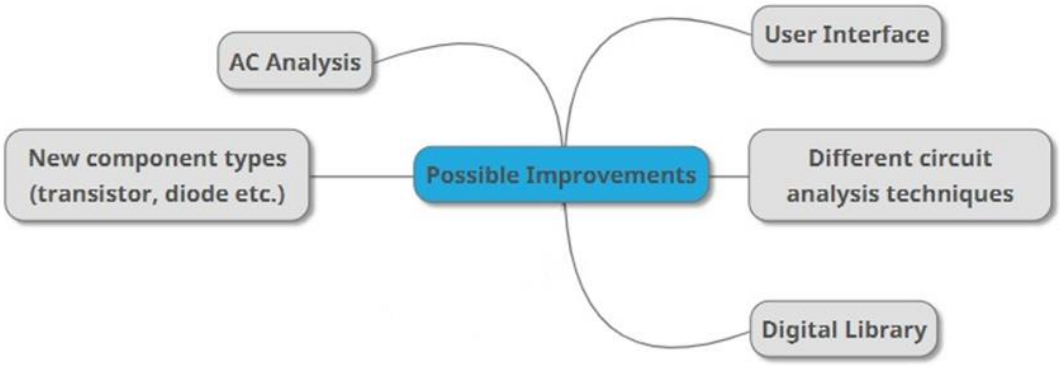

Figure 13. Possible improvements that can be made to the terminal-based circuit simulator.

Educational Approach

Throughout the paper, an open-source and terminal-based circuit simulator has been presented that can run non-transient DC analysis for passive circuit components, developed using the C programming language. The terminal-based simulator's intended purpose is to facilitate the learning process of individuals studying it in many subjects such as circuit analysis and circuit theory, C programming language, implementing theoretical knowledge in a software platform, and complement any other related work individuals may have. As the online resources for learning how to develop software are limited not in number but in the level of complexity, the terminal-based simulator aims to pose as an advanced and rather sophisticated project that facilitates ones learning process, and come as a complete project which help a learner develop or examine it in increasing complexity and assist them over any obstacles through its thorough commenting which outline any relevant information they may require.

The terminal-based simulator is a beneficial educational tool due to its open-source nature. The source code can be downloaded and modified to create user-custom versions, providing individuals with a deeper understanding of how theoretical knowledge can be implemented into software programs. The project files contain detailed and explanatory comments that provide guidance on each function's purpose and how they are tied together to meet the program's intended use. By reviewing the building blocks of the program, individuals can gain a better understanding of how software engineering concepts and practices are applied from real-world scenarios.

Furthermore, instructors of programming courses can also adopt the terminal-based simulator as an educational tool. The source code can be broken down into parts to be completed weekly, and students can be assigned these parts as weekly lab work, to have programmed a functioning circuit simulator by the end of the course or term. This would enable students to apply the theoretical knowledge they have learned in the classroom to practical scenarios, leading to a better understanding of the subject matter.

In summary, it would be highly beneficial for individuals studying circuit theory, power electronics, or related subjects to follow along with the provided steps needed to program a circuit simulator of their own, either at their own pace or through assignments given by an instructor. By doing so, they can gain a deeper understanding of the subject matter, improve their programming skills, and be better equipped to apply theoretical knowledge to real-world scenarios.

Conclusions

The terminal-based simulator is a useful educational tool for individuals interested in learning about circuit analysis and programming. It provides users with the ability to input circuit schematics and analyze them using Nodal Analysis, as well as perform matrix operations using Gauss Elimination and basic matrix algebra such as the inverse of a matrix or matrix multiplication. The termina-based simulator, by default, is designed to handle circuits with up to three nodes that are of unknown voltage but has the foundations to be expanded to handle more complex circuits by adding additional functions, or modifying already existing functions to further extend their capabilities such that they would be able to handle more complex analysis'. This can be done in many ways such as adding extra features related to a desired application or simply extending the range of functions that carry out matrix calculations so that they can compute for larger or varying sizes of matrices.

A simple DC circuit with several resistances and independent voltage sources of fixed values is considered and analyzed using the proposed method of nodal analysis by inspection. The node voltages and the associated currents are calculated. The same circuit is designed in LTSpice, and the results of both simulators were compared, in order to validate the terminal-based simulator's operation.

The terminal-based simulator has significant educational value as it allows individuals to learn about circuit analysis and programming simultaneously. By using the simulator, users can experiment with different circuit configurations and analyze their behavior in a safe and controlled environment. Furthermore, the program's modular design and use of custom libraries provide users with insight into software engineering concepts and practices. In the future, the simulator can be expanded as it includes additional features such as the ability to detect components connected in series or parallel, which would allow for different types of circuit analysis methods. Moreover, the program has component models for capacitors and inductors, allowing for the future addition of AC sources and AC analysis.

Last but not least, a digital library can be added that may include models for digital devices such as latches, registers, or logic gates, as well as corresponding functions that carry out the operations these devices perform. With these additions, the terminal-based simulator can be used to analyze a wider range of circuits and provide a more comprehensive learning experience for users. Overall, the terminal-based simulator is a valuable educational tool for individuals interested in learning about circuit analysis and programming. Its modular design and use of custom libraries make it easy for users to understand and modify the program, and with the potential for future expansions, the simulator can continue to provide users with a comprehensive learning experience in the fields of both circuit analysis and programming.

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Secondary School Students' Views on the Use of Virtual Reality Technology in Historical Subjects in Social Studies Course

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Abstract: Today, although technology has triggered a major transformation in the field of education, it is clear that this transformation does not offer equal opportunities for everyone. With the acceleration of digitalization, significant problems and inequalities of opportunity have emerged in access to education. Understanding middle school students' views on the use of virtual reality technology in social studies courses on historical topics can help us better evaluate the impact of this technology in education. Students' views on this issue are likely to offer a variety of perspectives. This study was prepared with a semi-structured interview form from qualitative research methods. The study group of the research was 15 middle school students. The data were interpreted with descriptive analysis. According to the results obtained; results such as making learning more fun, helping us understand historical events better, making lessons more interesting, concretizing concepts and making the use of technology easier were obtained. In line with these views, the following recommendations are presented; reflecting the advantages and potential challenges of using virtual reality technology in history lessons. These insights can be an important resource for educators to consider how to effectively integrate this technology. By considering student perspectives, they can develop strategies to provide a more inclusive and engaging learning experience.

Keywords: Virtual Reality, Technology, Social Studies.

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Introduction

Technology has experienced a great change and transformation in the field of education in recent years. Virtual reality (VR) technology has become an important part of this transformation (Godett, 2022; Sichterman et al., 2023; Talan & Kalınkara, 2022). The use of VR technology, especially in history lessons, offers students the opportunity to understand and experience historical events in more depth. In this article, a study will be presented to examine the views of middle school students on the use of virtual reality technology in social studies courses on historical topics. Technology is rapidly developing in the field of education, helping teachers to teach students more effectively.

Virtual reality (VR) technology is one of the most innovative and impressive developments in this field. Social studies course teaches students important topics such as history, culture, geography and society. In this article, we will examine the views of middle school students on the use of virtual reality technology in the social studies course on historical topics (Choi, Dailey-Hebert &Estes, 2016).

Virtual Reality and Education

Virtual reality is a form of technology that transports users into a computer-generated simulation (Erbaş & Demirer, 2015). These simulations give students the chance to experience different historical periods and events. In history classes, VR technology allows students to go beyond just learning information from books or slides. It offers the opportunity to explore historical places and events in three dimensions, recognize historical figures and better understand historical contexts (Yeşiltaş, 2019).

Students' views reflect the advantages and potential challenges of using virtual reality technology in history lessons. These views can be an important resource for educators to consider how to effectively integrate this technology. By considering student perspectives, they can develop strategies to provide a more inclusive and engaging learning experience. Virtual reality (VR) is a technology that allows the user to feel themselves in a computer-generated environment (Süral, İ2008). This technology offers students the opportunity to learn history lessons in a more engaging and effective way. VR allows students to touch past eras, historical events and cultures. This makes abstract historical concepts concrete and promotes in-depth understanding. Furthermore, VR offers students an interactive learning experience and makes the lesson more enjoyable (Şimşek, Özdamar, Uysal, Kobak, Berk, Kılıçer & Çiğdem, 2009).

Using VR Technology in Social Studies Lessons

The social studies course includes history lessons as well as topics such as geography, culture, society and politics. These topics can be taught in a more tangible way with VR technology. Here are some examples of using VR technology in social studies: (Suh & Prophet, 2018).

1. History Journeys: With VR, students can take a journey into historical events and periods. For example, they can be in a trench during the Second World War or visit the height of the Roman Empire (Sürücü & Başar, 2016).

2. Geographical Explorations: In geography lessons, students can take virtual tours of the world map. They can visit the Amazon jungle or explore the pyramids of Egypt (Sulak, & Sönmez, 2018).

3. Cultural Interaction: VR offers students the opportunity to experience different cultures and communities. Students can visit festivals in other countries or learn about different beliefs and traditions.

4. Simulations: By using VR simulations in social studies class, students can visually understand how historical events unfolded (Demir, 2019). For example, they can be part of the American Revolution. Understanding middle school students' views on the use of VR technology in social studies is important to evaluate the impact of this technology (Tepe, Kaleci & Tüzün, 2016). These opinions can help educators better tailor VR content and meet student needs. Questionnaires, interviews and observation can be used to collect opinions. The following questions can be used to understand middle school students' views on the use of VR technology: (Tuncer &Taşpınar, 2008).

1. Do you find history lessons with VR technology more attractive, why or why not?

2. Do you think VR technology helps you understand historical events better? Give examples.

3. Which historical topics do you think could be better taught with VR?

4. Would you like to see VR technology used more in social studies classes? Why or why not?

5. Are there any difficulties or shortcomings of VR technology in social studies courses? What are your suggestions on this subject?

Method

This research was prepared using content analysis technique, one of the qualitative research methods. The study group of the research was carried out with 13 pre-service social studies teachers studying at Süleyman Demirel University Faculty of Education. The data were collected through a structured interview form. The collected data were subjected to content analysis.

Results

Secondary school students' views on the use of virtual reality technology in social studies courses on historical topics can vary widely. These views may vary depending on their experiences, expectations, and personal attitudes toward the technology. The students evaluated the following issues:

1. Learning Experience: Students can express how VR technology helps them to better understand and remember historical topics.

2. Motivation: VR technology can help students to be more interested in the lessons and increase their motivation.

3. Challenges: Students can also indicate the difficulties and shortcomings they experience when using the technology.

4. Historical Awareness and Empathy: VR experiences can enhance students' ability to develop a deeper understanding of historical events and periods and empathize with historical figures.

4. Concretizes Concepts:

- "Virtual reality can make abstract concepts concrete. For example, walking around ancient Rome would give a better idea of the Roman Empire."
- "A virtual tour of historical sites and events can be more immersive than the pictures we see in class."

5. Provides More Exposure to Technology:

- "Learning using virtual reality technology provides the opportunity to use technology more."
- "Combining history lessons with technology can help us develop our technology skills."

6. Cost and Access Issues:

- "The cost of virtual reality equipment can be high and may not be accessible to everyone."
- "Not every student may have access to this technology at home, so it may not be fair for all students."

7. Instructor Guidance is Important:

- "Guidance from a teacher is important when using virtual reality. Our teacher needs to teach us how to use it."
- "Working with virtual reality can give better results with the help of our teachers."

Conclusion

Virtual reality technology has the potential to teach historical topics in social studies courses in a more engaging and effective way. Secondary school students' views on this technology can provide an important roadmap for educators to develop and better utilize this method. This research can be an important step in how virtual reality technology can be better integrated in education and contribute to students' deeper understanding of historical topics using this technology.

Virtual reality technology can make social studies lessons more effective and engaging. Understanding middle school students' views on the use of this technology can help educators better tailor VR content and meet student needs. Students' thoughts and feedback help us better understand the importance and impact of using VR technology more in the social studies classroom. Based on this feedback, educators can develop more effective teaching strategies and support students to have a better understanding of history, culture and society.

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A Review of Cyber Security Threats Against RE Infrastructure and Mitigation Approaches

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Abstract: Renewable energies are growing industries with enormous potential. However, like any other industry, it is not without its risks. One of the biggest dangers facing Renewable energy industry is cyberattacks. Hackers could target solar and wind turbine energy companies in order to steal customer data, sabotage operations, cause financial loss and physical damage to equipment. The threat landscape is constantly evolving, and the consequences of a successful attack could be catastrophic. The industry must remain vigilant and continue to invest in cybersecurity in order to protect this vital infrastructure. Energy producers must be vigilant in protecting their systems from cyberattacks. They should have strong security protocols in place, such as firewalls, data encryption, train their employees in cybersecurity best practices and update system software and hardware against vulnerability. In this paper will present an overview of cyber threats for renewable energy industries and some solutions especially solar and wind turbine.

Keywords: PV (Photovoltaic), IoT (Internet of Things), VPN (virtual private network) IAM (Identity and Access Management), MFA (Multifactor authentication)

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Introduction

In the middle of a global shift towards environmentally and sustainable friendly energy sources, the renewable energy sector has developed as an inspiration of hope for a cleaner, more sustainable future. solar installations, Wind farms, and additional renewable energy services have thrived, contributing significantly to the decrease of greenhouse gas emissions and our dependence on fossil fuels. Nevertheless, as we embrace the promise of renewable energy, we must also distinguish and address a growing and often overlooked threat of cyberattacks targeting renewable energy infrastructure. Although the attention on the environmental benefits of renewable energy is well-deserved, the critical role that cybersecurity plays in ensuring the resilience and reliability of these energy sources cannot be understated.

The interconnectivity and digitization of renewable energy systems have ushered in a new era of control and efficiency, but they have also presented vulnerabilities that malicious actors can exploit. Cyber threats against renewable energy infrastructure pose not only operational and economic risks but also threaten the constancy of our energy grid and the security of our societies. A good example of this is Al-Kharsaah solar photovoltaic (PV) power plant Solar power to produce 30% of total electricity by 2030 in Qatar with a peak capacity of 850 Megawatt (MW) (The Peninsula, 2022). Solar is one of the major electric generating methods utilized on the grid, contributing to both large-scale and small-scale distributed energy resource (DER) generation, including rooftop installations, storage systems, and micro grids (Office of Energy Efficiency and Renewable Energy's Solar Energy Technologies Office, n.d.).

Fig. 1. Qatar’s Al-Kharsaah Solar PV Power Plant with 1.5 million PV panels (The Peninsula, 2022)

Large scale RE plants like Al-Kharsah present an enormous potential in offsetting carbon footprint and aiding in meeting United Nations Sustainable Development Goals (UNSDG). Besides the stochastic nature of these electrical energy sources, a new threat of cyber criminals that has not been envisioned in the past has recently surfaced. Energy sector was the top target for cyberattacks in 2019, attracting 16% of all assaults globally (Ferris & Renssen, 2022).

Since the first cyberattack on a RE installation was revealed in the United, the threat of cyberattacks is not merely theoretical. Several links between its main control center and outlying power producing sites were lost (IT Pro, 2020). The upsurge in ransomware attacks across the energy segment incited the Australian, UK, and the US, the authorities to issue a joint notice concerning ransomware attacks on serious nationwide infrastructure (Tilly Kenyon Feb 11,2022). 87 % of critical infrastructure segments in the US were hit by ransomware (Avertium, n.d.). Hackers are targeting RE systems to gain control or to sabotage it. This can have a major impact on the operation of the system and can even lead to safety issues.

PV systems communicate to utilities, and other grid operators over the public internet, making these systems vulnerable to cyberattacks. Simultaneously, solar energy systems are equipped with a range of grid-support functions, which if programmed and controlled inadequately present a risk of power system disturbances (Goetz et al., 2018). U.S. Department of Energy's Solar Energy Technologies Office released a report on the state of solar PV cybersecurity (Office of Energy Efficiency and Renewable Energy, n.d), (Kriaa, S., Piette, M.-A., & Hadji, M. 2015). The report, based on a survey of PV industry stakeholders, found that while the industry is aware of cybersecurity threats, it lacks a comprehensive approach to addressing them and power system attack surface has greatly increased.

The rapid growth of solar energy has led to an increase in the number of IoT devices which make them vulnerable to cyberattacks. These attacks can disable or damage solar panels and can also disrupt the flow of electricity to the grid. In some cases, attackers have also been able to gain control of the systems that control the flow of electricity from solar panels to the grid. These attacks could disable solar energy systems, causing blackouts and other disruptive consequences.

Wind turbines are commonly used as plants with a huge number of turbines to make this source reliable and efficient. Thus, IoT is required to monitor this big number of turbines and control them, which will make these turbines open to many cyber-attacks. It works by converting the kinetic energy of the wind into mechanical power, which is then utilized to spin a generator to produce electricity. These turbines may be on- land or offshore wind turbines. Nowadays the wind turbines are monitored and controlled by the internet and networks. In November 2021, Vestas, a Danish wind turbine manufacturer, was targeted by cyber criminals and saw its internal IT infrastructure and data compromised (Vestas cyber-attack, 2021).

Threats

The increased connectivity and digitalization of renewable energy infrastructure such as wind, solar, and hydropower has made them vulnerable to cyberattacks. Motivations for attacking renewables include financial gain, causing disruptions, gathering intelligence, and damaging equipment. Some of the threat the RE infrastructure might face include Lock-Picking, Encryption Attacks, and Supply Chain Attack.

Lock-Picking

Lock-Picking: Cyber-attacks can start from lock picking into a wind turbine’s back. The back contains the system’s data, IP and other valuable information that hacker could use to their advantage. According to

Freudenberg researcher connected the laptops through the server of that singular turbine to instantly access IP addresses representing every single turbine in the network (DNV, 2020). It’s ironic how a software attack only starts when a physical intrusion initially happens. University of Tulsa researchers have hacked a wind turbine in the United States. They took less than a minute to unlock the metal door of the turbine's server closet by picking the straightforward pin-and- tumbler lock. Immediately unplugging a network wire and connecting it to a Raspberry Pi minicomputer, they returned to their vehicle, where one of them opened his laptop while the researchers peered up at the towering contraption, turned on the Pi and connected a second Ethernet connection from the minicomputer to an available port on a programmable automation controller. Then they entered commands into the command line on the laptop, and a list of IP addresses for each networked turbine in the field appeared. A little while later, they entered another order, and the hackers observed as the only turbine above them first let out a muffled shriek before slowing down and stopping (DNV, 2020).

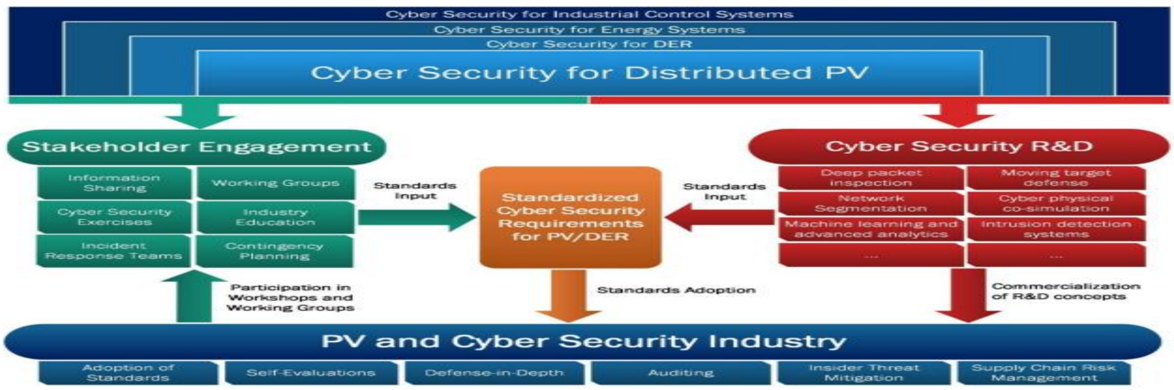

Fig. 2 Process for achieving cyber security of PV systems (Jay Johnson, 2017)

Encryption

Encryption attacks are kind of attacks that finds and preys on the weaknesses in the codes, protocols, and others related to the system. Not only is this an issue within the turbines being manipulated, but it’s also a problem within the IoT. Man-in- the-middle attacks are most probably the direction of their attacks. In order to stop the attack from spreading, it was obliged to disable remote access to the managed turbines and IT systems after being hacked with ransomware.

Supply chain

A supply chain attack happens when malicious actors target and compromise a contractor or service provider within a supply chain to gain unauthorized access, data and control larger organization's network or systems. Access can be obtained via viruses or malicious software that is very difficult to trace. supply chain silos can make up cyber threats difficult to identify and monitor (Cybersecurity Hub, 2021). For example, Hacker group known as darkSide interrupted Pipeline’s access to its server for Colonial Pipeline which is the main pipeline for transporting refined petroleum products in the United States (Tsvetan Tsvetanov, Srishti Slaria (2021).

Integration

Incomplete integration of systems is a combination of legacy and current technology. It's also difficulty to manage since some systems would not be able to be patched. Security systems such as firewalls provide extra defense in computer networks and creating separate networks for solar inverters makes them much more secure (RatedPower, 2022). U.S. power grid organization impacted cyber-attack due to a known firewall vulnerability that went unpatched. Controlling access to networked resources such as equipment, information technology, equipment, and networked resources is vital. Identity and Access Management (IAM) is a framework of technologies, processes and policies that ensures the appropriate individuals within an organization have the right access to the right resources, under the right conditions, and at the right time. It's fundamental component of cybersecurity and data protection (Smith, J., & Johnson, A. (2020).

Fig. 3 Cyber Risks for Solar and Wind Installations (Jay Johnson, 2017)

Solutions

The best way to prevent cyber threats in RE systems is to be proactive and have a good cyber security plan in place. This should include having strong passwords, encrypting data, and making sure that all systems are up to date. Additionally, it is important to be aware of any potential threats and have a plan to respond to it when it occurs.

Install and maintain comprehensive security software on all devices connected to the internet, including solar energy systems. Also, maintain software and system patches and minimize legacy systems. Encryption can block hackers from retrieving sensitive data, systems often transmit data without encryption, making it easy for attackers to intercept and readinformation and personally identifiable information. Business must have a clearly defined authorization framework, so each user has the access rights they need to execute a function only. It is essential for most security strategies and is explicitly required by many compliance standards. Multifactor authentication combines more independent authorizations like what the user knows such as password and ID, what the user has (security token), and what the user is (for biometric verification). MFA create a layered protection that makes it hard for an unauthorized person to access. For example, if one factor is compromised the attacker still has at least one or more barricades to breach before successfully breaking into the target (Imperva, n.d. Johnson, M., & Smith, L. (2019).

Staff should be given appropriate cyber understanding training. They need to be assisted in thoroughly and realize that they play an essential role in organizational cybersecurity so they can be the ones preventing a ransomware attacks. No access on a network ought be trusted, regardless of whether it is public or private (Wu et al., 2016). ensure sensitive assets on the network are isolated from other assets we need to use micro segmentation.

Conclusion

Cyber threats to RE systems are becoming more and more common, as the industry grows. Hackers are targeting RE systems in order to gain control of them or to sabotage of them. This can have a major impact on the operation of the system. It is important to have a strong security system in place. This includes both physical and cyber security. Physical security measures should be taken to protect the system from unauthorized access, while Cyber security measures should be taken to protect the system from attack.

Recommendations

There are several steps that can be taken to improve the security of RE system. These include encrypting data, using strong passwords, and restricting access to authorized personnel, also it is important to keep the system up to date with the latest security patches. Additionally, it is also crucial to be aware of the potential threats and have a plan to respond to them if they occur. The threat landscape is constantly evolving, and the consequences of a successful attack could be catastrophic. The industry must remain vigilant and continue to invest in cybersecurity in order to protect this vital infrastructure.

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Behavior Assessment of Pavement over Expansive Clay Soils Undergoing Cyclic Shrinkage and Swelling Conditions

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Abstract: Expansive soils, susceptible to environmental influences, exhibit expansion with water infiltration and subsequent shrinkage during drying. These continuous volumetric changes can induce differential movements, leading to structural cracks. This research delves into characterizing the performance of pavements constructed on expansive clays undergoing swelling and shrinkage cycles. Laboratory direct shear tests and oedometer tests were conducted on samples subjected to these cycles. The experimental results highlight a significant decrease in shear strength, evident through reductions in shear parameters (internal friction angle, cohesion), and a diminishing modulus of elasticity with an increasing number of cycles. Complementarily, a numerical model utilizing the finite element method was developed to simulate pavement behavior on an expansive clay substrate. Model outcomes indicate escalating total displacements as the number of shrinkage-swelling cycles increases, indicating a progressive degradation in the soil's mechanical attributes. This study advances our understanding of the intricate phenomena governing expansive soil behavior, providing a foundation for the development of effective management and mitigation strategies for road infrastructures.

Keywords: Differential soil displacement, Expansive soil, Pavement, Shear strength, Shrinkage-swelling cycles, Soil degradation behavior

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Introduction

Pavements, acting as vital conduits within modern transportation systems, play a crucial role in facilitating the movement of people and goods across extensive networks of roads and highways. These indispensable elements of infrastructure face various challenges, from the constant wear of vehicular traffic to the unpredictable forces of nature. Among the significant challenges encountered in pavement engineering is the presence of expansive clay subgrades, found ubiquitously in many global regions. These soils are renowned for their susceptibility to substantial volume changes in response to variations in moisture content, commonly known as shrink-swell behavior. This phenomenon poses a considerable threat to the stability and durability of pavements and other structures built on such soils.

This study delves into the intricate realm of pavements constructed on expansive clay subgrades experiencing cyclic shrink-swell conditions. Addressing the interplay between infrastructure and the forces of nature necessitates a comprehensive, multidisciplinary approach spanning geotechnical engineering, pavement design, construction techniques, and ongoing maintenance. The investigation covers various aspects of this challenge, from understanding the fundamental characteristics of expansive clay soils to implementing engineering strategies to mitigate their effects.

Expansive clay soils, characterized by elevated concentrations of montmorillonite, smectite, or other clay minerals, exhibit shrinkage and swelling with changes in moisture content. These volumetric changes can lead to significant damage to pavements or other infrastructures unless properly managed. Due to their prevalence worldwide, these soils pose a series of threats to lightly loaded structures due to their differential deformations, primarily driven by variations in moisture content. Climate conditions, particularly evapotranspiration in drought seasons and infiltration in rainy seasons, can substantially influence soil moisture changes. Therefore, it is imperative to explore the cyclic shrink-swell effect on the behavior of expansive soil.

Previous investigations by Md et al. (2016), Basma et al. (1996), Louati et al. (2021), and Bertrand et al. (2021) have examined the effects of drying-wetting cycles on various soil properties. Md et al. observed changes in the saturated shear strength characteristics of residual soil, noting a decrease in shear parameters and modulus of elasticity with an increasing number of cycles. Basma et al. highlighted the influence of cyclic swelling-shrinkage on the expansive behavior of clays, indicating a decrease in swelling ability and fabric destruction with more cycles. Louati et al. studied the impact of wetting-drying cycles and cracks on the permeability of compacted clayey soil, noting an increase in permeability with cracking. Bertrand et al. conducted oedometer tests on expansive clay subjected to cyclic wetting-wetting, revealing changes in compressibility and permeability with an increasing number of cycles.

Considerable research has delved into expansive soil modeling, yielding models with diverse objectives and advantages. Notably, Alonso et al. have introduced the widely accepted BExM model, skillfully characterizing swelling-shrinkage behavior during wetting-drying cycles through a formalism rooted in double structures (Alonso et al., 1999, 2005). Within the BExM framework, separate hydro-mechanical mechanisms are employed for each structural level, enabling distinct assessments of micro and macromechanical effective stresses (Mašín, 2013; Soltani et al., 2022).

Recent progress in this field has extended the BExM approach to tackle complex stress paths, integrating intricate coupling effects among thermal, hydraulic, and mechanical behaviors (Li et al., 2020; Romero, 2013; Alonso et al., 2011; Gens et al., 2011; Li et al., 2021, 2020). However, these models often introduce a relatively high number of parameters, posing challenges for accurate quantification. Consequently, there is a rising demand for alternative and simplified models capable of offering effective solutions to this inherent complexity. This study aims to fill a critical gap in understanding the effects of multiple drying-wetting cycles on the shear strength and consolidation behavior of undisturbed expansive clay, a crucial aspect that has not been thoroughly explored in previous investigations.

Method

Study area and sampling

The initial phase of the site investigation involved consulting the soil map of the Pobe municipality in the Republic of Benin, depicted in Figure 1. Subsequent on-site visits were conducted to identify optimal sampling locations, emphasizing areas where the phenomenon is most pronounced in the study region. Collection of materials took place within the Pobe municipality, situated in the southeastern part of Benin, specifically in the Issaba and Ahoyeye districts. Table 1 provides the precise geographical coordinates for each designated sampling site.

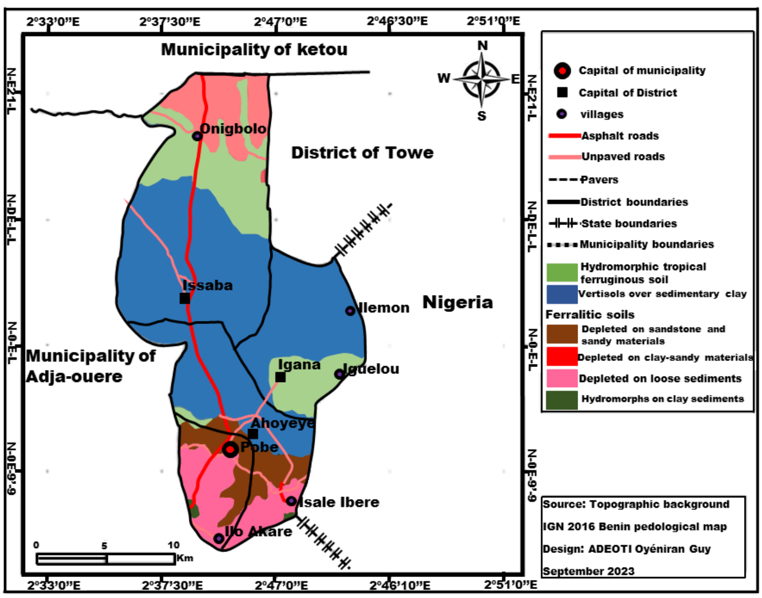

Figure 1. Pedological Map of Pobe

Table 1. Location Information

Locations	Coordinates			
	X	Y	Latitude	Longitude
ISSABA	459660	783707	N 07°05'23.8"	E 02°38'04.9"
AHOYEYE	465361	774802	N 07°00'33.9"	E 02°38'04.9"

Sampling techniques

To carry out the required tests, encompassing both identification and mechanical assessments, a blend of disturbed and undisturbed samples was procured. The undisturbed samples were carefully extracted using cubic boxes specifically designed for this purpose, along with a compaction hammer and wooden containers for secure transportation. In each designated study area, a total of four (04) undisturbed samples were cored, with one sample extracted from each of the following depth intervals: 0 to 0.50m, 0.5 to 1.0m, 1.0 to 1.50m, and 1.50 to 2.0m.

Test descriptions

Soil characterization was carried out through geotechnical testing, encompassing the identification of both physical and mechanical properties.

Identification tests

Physical tests were performed on the disturbed soil samples, encompassing the following procedures:

- Determination of moisture content, in accordance with standard NF EN ISO 17892-1 (BS EN ISO. 17892-12, 2018).
- Atterberg Limits tests, conducted following standard NF EN ISO 17892-12 (CEN ISO TS 17892-1: 2014).
- Evaluation of specific gravity of solid particles, in line with standard NF EN ISO 17892-3 (DIN EN ISO, 2017).
- Organic Matter Content Determination Test, complying with standard NF P94-055.
- Analysis of particle size distribution, adhering to standard NF EN ISO 17892-4 (EN ISO 17892-10: 2018).

Mechanical tests

The undisturbed soil samples, having experienced cycles of drying and wetting, underwent testing using the oedometer test as outlined in NF EN ISO 17892-5 (EN ISO 17892-3, 2015) and the direct shear test, conducted in accordance with NF EN ISO 17892-10 (EN ISO, 2016).

Wetting and drying procedure

Wetting procedure

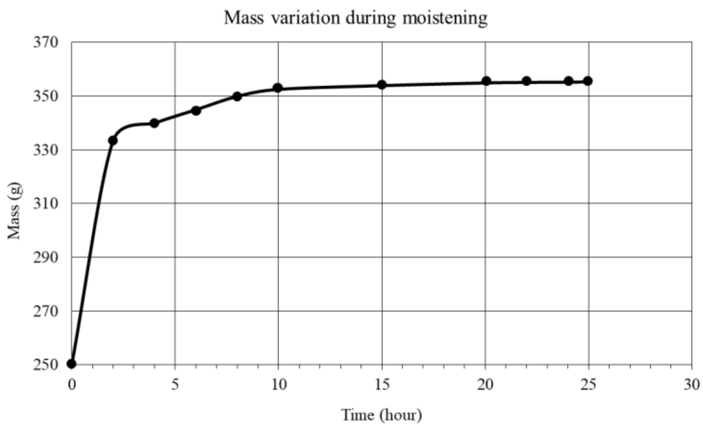

Figure 2. Moistening Kinetics

(1) Undisturbed soil samples are acquired using shear rings and oedometer rings. These rings are first weighed when they are empty and then re-weighed after coring. To ensure precise calculations of wetting water content, a reference core is obtained for each sample type.

(2) These cores are then placed carefully inside containers, each of which has a label providing details about the material, the initial weight of the ring, and the total weight of the ring and material. Rings intended for controlling moisture content and saturation are segregated into a separate container, while those designated for testing are placed in another. Each container is equipped with a perforated plate that acts as support for the cores. This support contains multiple openings to allow water within the container to circulate freely, ensuring thorough moistening of the cores from below.

(3) Water is gently poured into the container until the cores are fully immersed, and the container is sealed with its lid.

(4) Control cores are meticulously weighed every hour for a period of 48 hours. To minimize any potential influence of water movement on core mass, the combined support and material are handled with utmost care during removal. While weighing, a mass-versus-time curve is generated for each core, enabling continuous monitoring of mass changes over time. The saturation level reaches 100% when three consecutive mass measurements show no significant fluctuations, and variations remain within 0.2 grams. For each sample, a dedicated control core is placed in a drying oven to determine moisture content after wetting. Cores allocated for testing undergo natural sunlight exposure during the drying phase, with a control core used to determine drying moisture content.

Figure 2 visually depicts the gradual increase in soil sample mass during the wetting process.

Drying procedure

Following the wetting phase, a simulated drying process is initiated in the laboratory to replicate the conditions prevalent during the dry season. The drying is conducted under natural sunlight with temperatures ranging approximately from +26°C to +36°C. Morning temperatures start at a minimum of 26°C, gradually reaching a peak of around 36°C in the afternoon, as recorded by temperature measurements taken over a 3-day period. During the 9-hour daily drying phase, the cores are exposed to sunlight. The target drying moisture content is set at 14%, a value chosen based on an extensive literature review of moisture levels observed in expansive soils in the la Lama depression during the dry season.

Figure 3 visually illustrates the drying kinetics, depicting the evolution of moisture content over time.

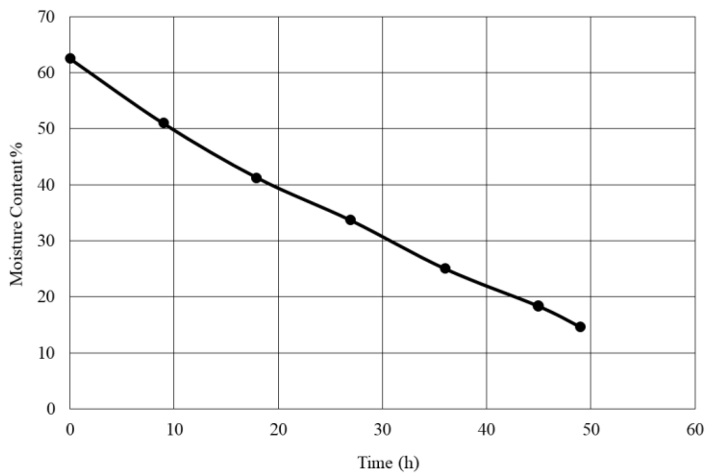

Figure 3. Drying Kinetics

Overall progression of moistening and drying cycle

To evaluate the impact of different drying-wetting cycles on the soil under investigation, a set of undisturbed samples underwent a series of oedometer tests and direct shear tests. These samples were subjected to the following cycle conditions:

- C0: Undisturbed samples that remained unaffected by drying-wetting cycles.
- C1: Undisturbed samples exposed to a single (01) drying-wetting cycle.
- C2: Undisturbed samples subjected to two (02) consecutive drying-wetting cycles.
- C3: Undisturbed samples subjected to three (03) consecutive drying-wetting cycles.

Results

Identification tests

Figure 4 depicts the grain-size distribution of the clayey soils collected in the ISSABA area. Various criteria have been utilized to classify these soils, including the Highway Research Board (HRB) American soil classification system, which takes into consideration the percentages passing through 0.2 mm, 0.4 mm, and 80 µm sieves, as well as the plasticity index (PI) and the liquid limit (LL). Additionally, the GTR classification (NF P11-300) relies on granulometric characteristics such as the largest grain size (Dmax), the proportion passing through the 80 µm sieve, and either the methylene blue value or the plasticity index (PI). The diverse outcomes obtained through these distinct identification tests are detailed in Table 2.

Table 2. Identification test results

Parameter	0.0-0.50 m	0.50-1.0 m	1.0-1.50 m	1.50-2.0 m
Passing by 80µm (%)	92	93	95	96
In-situ moisture content w (%)	51.53	56.58	46.1	42.41
Liquidity Limit LL (%)	92	93	93	95
Plasticity Limit PL (%)	51	52	52	57
Plasticity Index IP	41	41	41	38
Consistency Index IC	0.95	0.89	1.84	1.38
Organic Matter OM (%)	0.8	0.7	0.6	0.8
Specific Density γ_s (kg.m^{-3})	2.23	2.29	2.40	2.29
Class acc. GTR	A4	A4	A4	A3
Class acc. HRB	A7-5	A7-5	A7-5	A7-5

As per the GTR classification, the soils in Issaba fall under category A4 (highly plastic clays and clay marls), except for the soil at a depth of 1.5 to 2 m, which is classified as A3 (clay marls and clays, highly plastic silts). In accordance with the Highway Research Board (HRB) classification, Issaba samples are designated as A7-5, indicating a clayey soil.

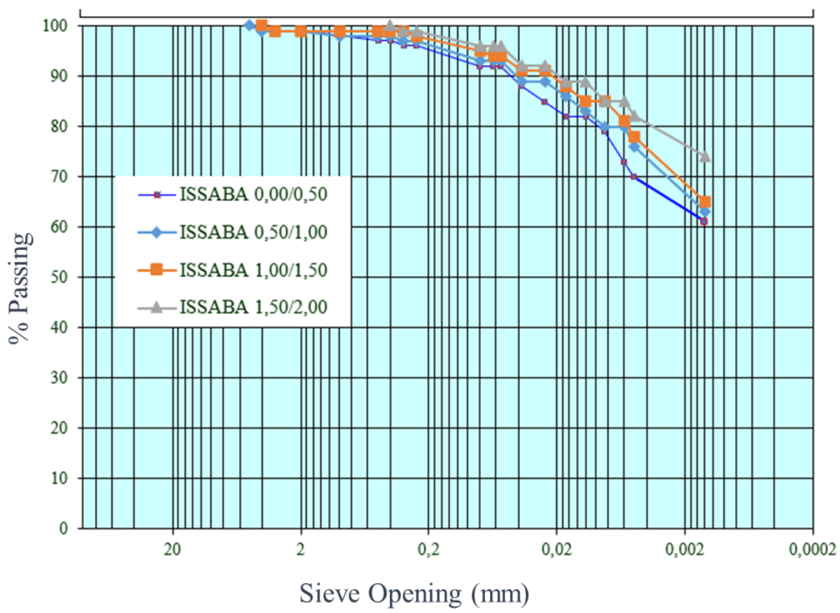

Figure 4. Grain size distribution of expansive clay

Wetting and drying cycle tests

Sample textures after swelling-shrinking cycles

Observations of the samples following various cycles reveal distinctive textural patterns:

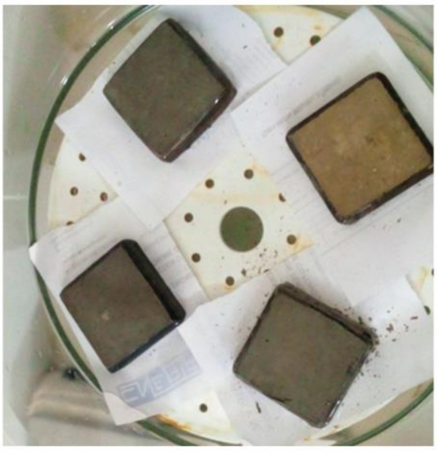

Figure 5. Samples from Cycle 0

(1) Cycle 0: Samples from Cycle 0 are in a wet condition and exhibit no signs of swelling or cracks, as depicted in Figure 5.
(2) Cycle 1: However, during Cycle 1, minor swelling becomes apparent after wetting. After the drying phase, cracking and shrinkage are observed, as illustrated in Figure 6. This pattern persists in subsequent cycles.
(3) Cycle 2: The same trend continues in the second cycle. Figure 7 demonstrates increased swelling after wetting and more pronounced cracking after drying, compared to Cycle 1.
(4) Cycle 3: Similarly, as shown in Figure 8, samples from the third cycle exhibit further degradation. This highlights the progressive deterioration of the samples as they undergo repeated shrink-swell cycles.

a) After Moistening b) After drying

Figure 6. Samples from Cycle 1

a) After Moistening b) After drying

Figure 7. Samples from Cycle 2

a) After Moistening b) After drying

Figure 8. Samples from Cycle 3

Shear test results

The direct shear test results are detailed in Table 3. Upon analyzing Figures 9 and 10, it becomes apparent that the cohesion values at each depth exhibited an increase from Cycle 1 to Cycle 2. However, there was a subsequent decrease in cohesion values from Cycle 2 to Cycle 3. Meanwhile, the friction angle values consistently decreased from Cycle 1 to Cycle 3. This observation suggests a diminishing shear strength of the expansive clay with an increase in the number of cycles.

Table 3. Shear test results

Depth (m)	Cycle 0		Cycle 1		Cycle 2		Cycle 3	
	C_u (kPa)	φ_u (°)	C_u (kPa)	φ_u (°)	C_u (kPa)	φ_u (°)	C_u (kPa)	φ_u (°)
0−0.5	16.4	1.6	24.5	21.5	26.6	10.1	17.5	5.3
0.5-1	21.9	0.7	15.7	26.1	27.7	14.5	9.5	9.7

1-1.5	22.0	3.1	9.0	24.9	18.9	12.2	16.0	12.2
1.5-2	26.0	5.5	20.3	24.4	25.4	15.3	7.8	10.8

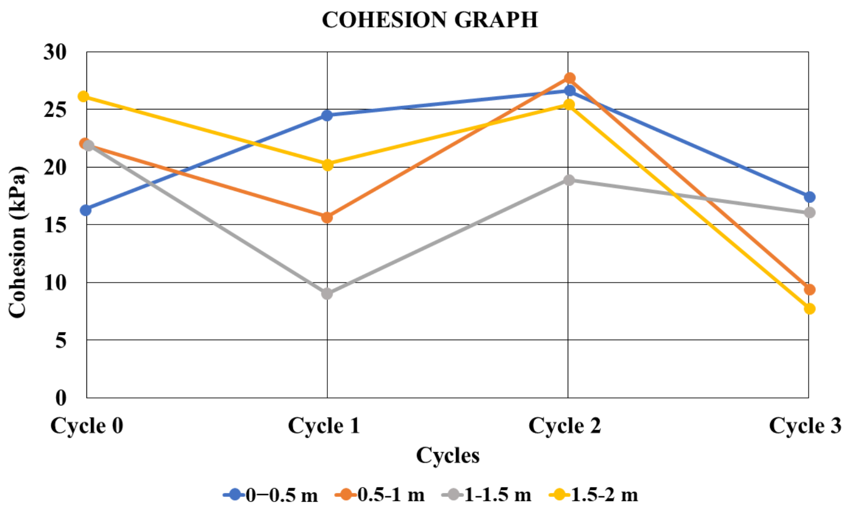

Figure 9. Cohesion Evolution across Cycles

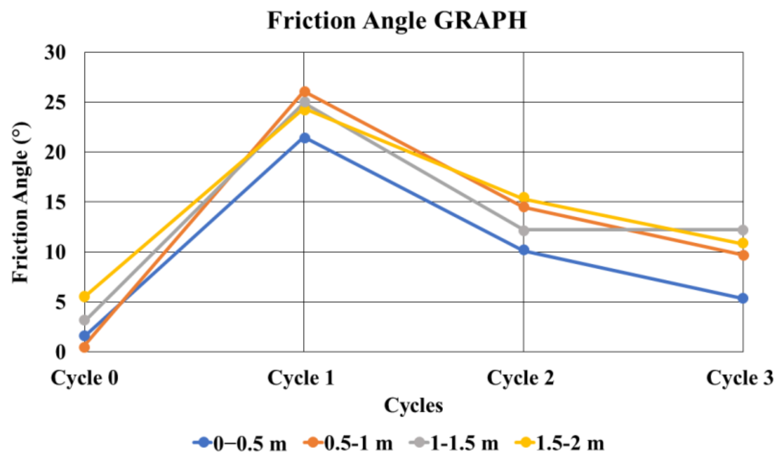

Figure 10. Friction Angle Evolution over Cycles

Oedometer test results

Table 4 provides a comprehensive compilation of geotechnical parameters derived from Oedometer tests conducted at varying depths and cycles. The Oedometer test is employed to evaluate the consolidation behavior and compressibility of soils. The table is structured into four distinct segments, corresponding to different testing cycles: Cycle 0, Cycle 1, Cycle 2, and Cycle 3. Each segment is associated with specific depth intervals—0-0.5m, 0.5-1m, 1-1.5m, and 1.5-2m—enabling an analysis of the vertical variability in soil properties.

In Figure 11, which illustrates the evolution of the compressibility index across cycles, a consistent trend becomes evident across all depths.

Figure 12 illustrates the progression of the swelling index throughout cycles, while Figure 13 outlines the changes in the oedometer modulus across different cycles.

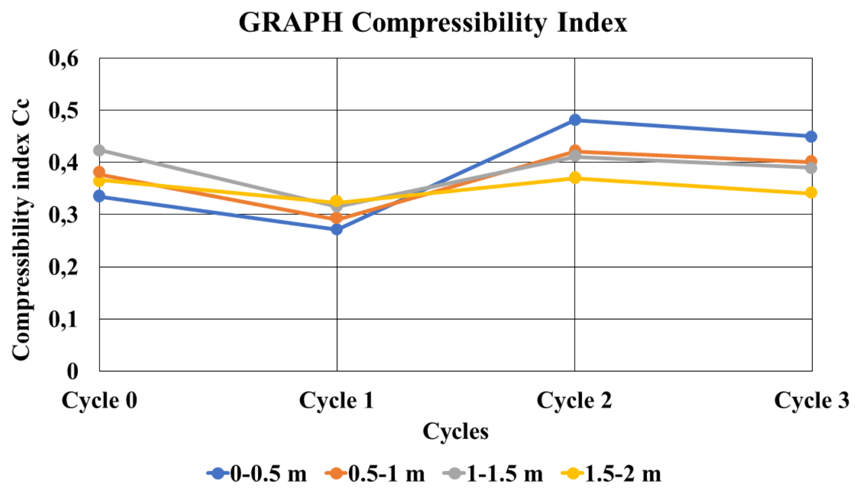

Figure 11. Evolution of Compressibility Index over Cycles

Table 4. Oedometer test results

Depth (m)	Cycle	σ'$_p$ (kPa)	E_{oed} (MPa)	Cc	Cs
0-0.5	0	115	8.2	0.334	0.103
	1	1550	10.0	0.271	0.106
	2	50	6.6	0.480	0.140
	3	40	6.5	0.450	0.100
0.5-1	0	83	7.0	0.377	0.118
	1	700	11.1	0.290	0.118
	2	210	6.1	0.420	0.140
	3	49	7.4	0.400	0.100
1-1.5	0	130	6.9	0.423	0.139
	1	210	10.8	0.315	0.107
	2	170	6.2	0.410	0.150
	3	49	6.9	0.39	0.100
1.5-2	0	69	10.0	0.366	0.123
	1	700	10.3	0.323	0.134
	2	209	6.9	0.370	0.130
	3	50	6.6	0.340	0.090

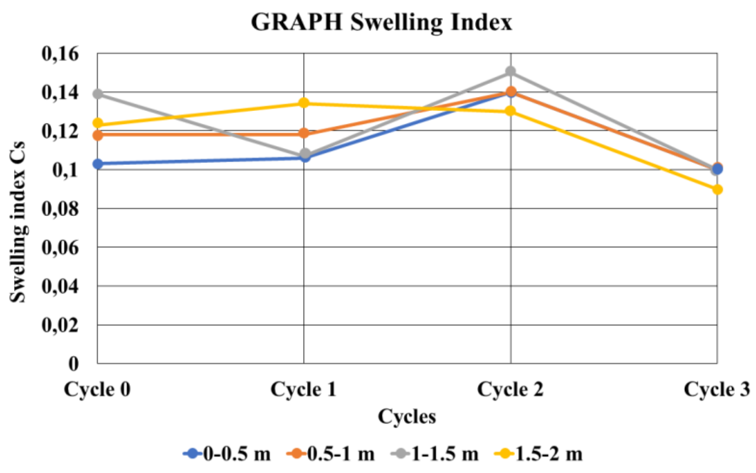

Figure 12. Evolution of Swelling Index throughout Cycles

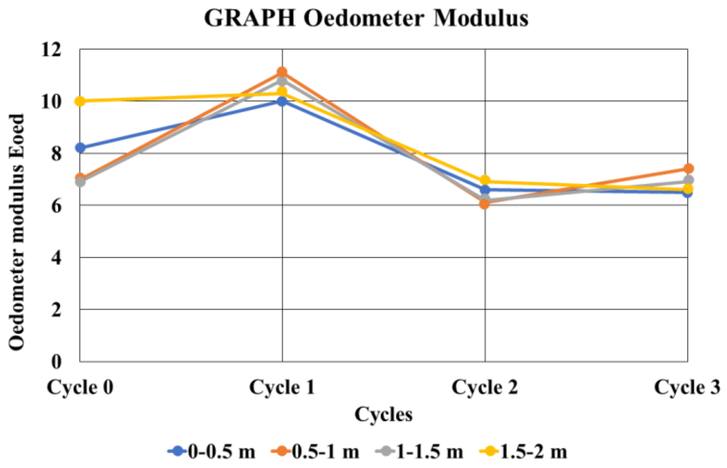

Figure 13. Evolution of Oedometer Modulus Curve

Discussion

Shear test

These findings prompt further exploration into the factors contributing to variations between cycles and depths. Variables like moisture content, loading conditions, and the soil's stress history can influence shear properties. Additional geotechnical tests and analyses, such as consolidation tests, triaxial tests, or soil sampling, may be imperative for a more comprehensive understanding of soil behavior and the refinement of engineering designs.

In summary, the insights provided by Table 3 into soil shear properties under diverse testing conditions and depths are valuable for engineers and geotechnical specialists. This data can guide informed decisions and adjustments in geotechnical designs, ensuring the safety and stability of infrastructure projects in areas with similar soil characteristics. Further investigations and analyses are recommended for a deeper understanding of the underlying factors driving these variations.

Oedometer test

In summary, Table 4 furnishes valuable insights into the mechanical properties, compressibility, and swelling potential of soil at varying depths and during different testing cycles. This comprehensive analysis underscores the dynamic nature of soil behavior under diverse loading and environmental conditions. This data informs decisions about soil suitability for construction projects, facilitates assessments of foundation settlement, guides construction processes and soil stabilization techniques, and aids in designing appropriate foundations and earthworks.

In general, deeper soil layers exhibit increased stiffness and reduced compressibility, a consistent trend observed across all testing cycles. This suggests that deeper soils offer enhanced stability and are less susceptible to compression. For example, in projects involving the construction of heavy structures, engineers may prefer deeper soil layers (1.5-2m) due to their higher stiffness and lower compressibility.

Figure 11, illustrating the evolution of the compressibility index over cycles, reveals a distinct pattern across all depths. It depicts a decrease in the compressibility index from the initial cycle (cycle 0) to cycle 1, indicating reduced compressibility after the first wetting and drying cycle. This change could result from the initial rearrangement of soil particles, leading to denser packing and a reduced void ratio following the first cycle. However, as the soil undergoes a second wetting and drying cycle from cycle 1 to cycle 2, there's a notable increase in compressibility. This heightened compressibility may be attributed to further soil aggregate breakdown and the potential emergence of new microcracks, rendering the soil more susceptible to volume changes.

Between cycle 2 and cycle 3, a subtle decrease in the compressibility index is noted. While the soil remains more compressible than its initial state in Cycle 0, it appears to be stabilizing somewhat after the third cycle. This could be attributed to the soil approaching a state of equilibrium after undergoing multiple wetting and drying cycles or possibly due to the partial closure of previously formed microcracks.

Figure 12 illustrates the changes in the swelling index across cycles. Initially, the swelling index remains relatively consistent from Cycle 0 to Cycle 1. However, by Cycle 2, a noticeable increase is observed, indicating a greater likelihood of the soil expanding when exposed to moisture. This could be due to the breakdown of soil aggregates and the potential formation of new microvoids. However, as we progress to Cycle 3, the swelling index tends to decrease, suggesting a potential stabilization in the soil's swelling behavior.

Figure 13 depicts the evolution of the oedometer modulus over cycles. The transition from Cycle 0 to Cycle 1 shows an increase in the modulus for most depths, indicating a stiffer response from the soil. This may be attributed to the initial compaction or rearrangement of soil particles. However, as the cycles progress from Cycle 1 to Cycle 3, there is a general decline in the modulus, indicating a softening of the soil. This softening behavior could be attributed to the gradual breakdown of soil structures or the weakening of bonds between particles due to repeated wetting and drying.

The cyclic swell-shrink phenomenon contributes to the deterioration of the expansive clay. This degradation is associated with the reduction of both physico-mechanical and microstructural properties of the expansive clay as the number of cycles increases.

FE modeling

In the effort to gain insight into the intricate dynamics of pavement systems, we have constructed a two-dimensional finite element model. This model incorporates expansive clay as a foundational layer, along with various other pavement layers as outlined in Table 5. To simulate real-world conditions as accurately as possible, we utilized the PLAXIS 2D Foundation software. To optimize computational efficiency, we modeled only half of the pavement width and the supporting soil, capitalizing on the geometric and loading condition symmetries.

Table 5. Pavement layer and materials

Layer Thickness	Materials
0.07 m	Bituminous Concrete
0.15 m	Untreated Gravel
0.20 m	Gravel Treated with Cement
0.20 m	Lateritic Gravel

Table 6. Properties of pavement materials

Parameter	Value
Bituminous Concrete	
Type of Behavior	Linear Elastic
Young's Modulus E (kN/m^2)	500,000
Coefficient of Poisson ν	0.35
Untreated Gravel	
Type of Behavior	Linear Elastic
Young's Modulus E (kN/m^2)	400,000
Coefficient of Poisson ν	0.35
Bituminous concrete	
Type of behaviour	Linear Elastic
Young's Modulus E (kN/m^2)	500,000
Coefficient of Poisson ν	0.35

Initial analyses were performed to establish the model geometry and mesh size, ensuring result accuracy and mitigating the influence of boundary conditions. This led to a soil model with dimensions of 10 meters by 10 meters, as illustrated in Figure 14. The Mohr Coulomb soil material law was utilized to simulate soil behavior, while the pavement materials were represented using linear elastic material properties.

Figures 15, 16, and 17 depict the deformed mesh and total displacement of the finite element model across different shrink-swell cycles (n=1, n=2, and n=3). The overall displacement increases with each successive cycle of shrink-swell, indicating a degradation of shear parameters, particularly the constraint or oedometer modulus, with each cycle of shrink-swell.

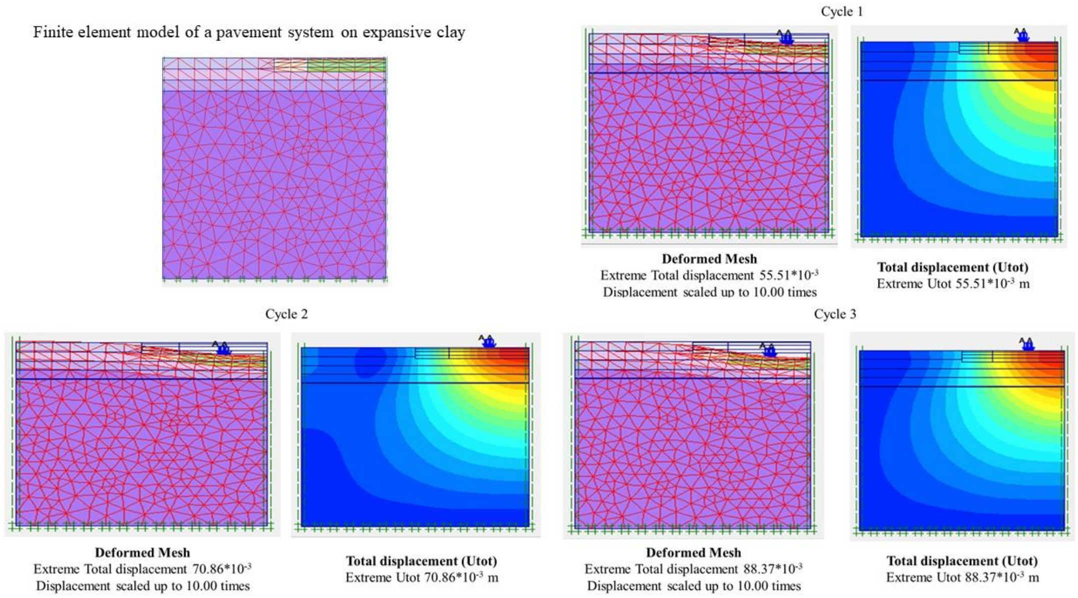

Figure 14. Finite element analysis of a pavement system on expansive clay

Conclusion

This study focuses on examining the impact of drying-wetting cycles on the saturated shear strength of undisturbed expansive clay. It involves a series of oedometer and direct shear tests to explore how these cycles affect the soil's properties. The results consistently reveal a decline in the shear strength of undisturbed expansive clay as the number of wetting-drying cycles increases.

Specifically, both the angle of friction and cohesion, crucial components of shear strength, diminish with each successive wetting-drying cycle. Additionally, the oedometer modulus, a measure of soil stiffness, decreases as the cyclic number of swell-shrink cycles rises. Furthermore, the compressibility index rises, while the swelling index decreases with an escalation in the number of cyclic wetting-drying events.

To delve further into the implications of these findings, a finite element model simulating a pavement constructed on expansive soil has been developed. The outcomes of this model indicate a notable increase in total displacement as the cyclic number of shrink-swell cycles intensifies.

These findings are essential for comprehending how shear strength and compressibility behavior change in expansive clay subjected to periodic drying and wetting due to climatic variations. Moreover, this research provides valuable insights for aspiring geotechnical engineers and decision-makers dealing with infrastructure resilience and potential damage.

Recommendations

Further Study: Conduct more in-depth investigations to understand the underlying factors contributing to variations in soil behavior across cycles and depths. Variables such as moisture content, loading conditions, and stress history should be explored to gain a comprehensive understanding.

Additional Testing: Consider conducting additional geotechnical tests, such as consolidation tests and triaxial tests, to complement the findings and provide a more comprehensive analysis of soil behavior. These tests can help refine engineering designs and foundation recommendations.

Engineering Design: Engineers should account for the dynamic nature of soils, as observed in shear property variations, when designing foundations or structures. The favorable increase in shear strength from Cycle 0 to Cycle 2 is promising for stability, but the decline in Cycle 3 should be carefully considered in project planning.

Soil Suitability: Evaluate soil suitability for construction projects based on the observed mechanical properties, compressibility, and swelling potential. Deeper soil layers (1.5-2m) exhibit increased stiffness and reduced compressibility, making them preferable for projects involving heavy structures.

Foundation Considerations: For projects in areas with expansive clay soils, exercise caution when dealing with soil layers displaying higher compressibility (Cc) values, as they may experience significant swelling when exposed to moisture. This can pose risks to structures, and appropriate foundation design and soil stabilization techniques should be employed.

Monitoring and Maintenance: Implement monitoring and maintenance protocols for infrastructure built on expansive clay soils. Regular inspections can help identify any adverse changes in soil behavior and allow for timely interventions to ensure safety and stability.

Climate Considerations: Given the sensitivity of expansive clay soils to wetting and drying cycles, consider climate variations when planning construction projects in the region. Develop strategies to mitigate the impact of seasonal weather changes on soil behavior.

Knowledge Sharing: Share the findings and insights from this study with geotechnical engineers, construction professionals, and decision-makers involved in infrastructure projects in areas with similar soil characteristics. Disseminating knowledge can lead to more informed decisions and improved construction practices.

Continued Research: Encourage continued research in the field of geotechnical engineering, particularly in regions with expansive clay soils, to expand knowledge and refine engineering practices. Long-term monitoring of soil behavior can provide valuable data for future projects.

Environmental Impact Assessment: Consider conducting environmental impact assessments when planning construction projects in areas with expansive clay soils. Assess the potential impact of construction activities on soil quality and the surrounding ecosystem, and implement mitigation measures as needed.

By following these recommendations, engineers and decision-makers can make informed choices when dealing with expansive clay soils, ensuring the safety and stability of infrastructure projects in the region. Additionally, ongoing research and knowledge sharing will contribute to advancements in geotechnical engineering practices for similar soil conditions.

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Defending Higher Education from Cyber Threats Review

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Abstract: Higher education institutions are increasingly becoming targets of cyber-attacks due to the sensitive nature of the information they hold, such as personal information of students and faculty, research data, and financial information. These attacks can come in many forms, including phishing scams, malware, and ransomware. Additionally, higher education institutions may be vulnerable to nation-state-sponsored attacks or attacks from cyber-criminal organizations. To protect against these threats, higher education institutions should implement robust security measures, such as firewalls, intrusion detection systems, and regular security audits. With the cumulative amount of delicate information Shared and stored electronically, universities must take proactive measures to protect against cyber threats, they should also educate students, faculty, and staff about the risks of cyber-attacks and how to protect themselves and the institution from them. this paper offers a comprehensive method to mitigating cyber threats in higher education. It highlights the reputation of proactive risk assessment, security awareness programs, and the expansion of incident response plans personalized to the academic environment.

Keywords: distributed denial of service (DDOS), advanced persistent threats (APTS), content delivery network (CDN)

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Introduction

The effects of the pandemic and the vulnerability have made educational institutions more vulnerable to attacks. Limited resources and budgets make higher education institutions easier targets for cyberattacks, which can result in data breaches, compromised student data, exposure of research information, and even theft of government data.

Distributed Denial of Service (DDoS) actors use to overwhelm a target network or website with fake traffic. This prevents legitimate access and functionality. For example, UMass Amherst experienced a series of DDoS attacks that repeatedly disrupted access to university websites and application (Kristal Kuykendall 03/22/22) s. The attacks flooded servers with junk traffic, preventing legitimate access. IT staff had to implement mitigation measures.

Impact

Ransomware Attacks: Ransomware attacks have been a prevalent and concerning issue for higher education institutions in recent years. The following incidents demonstrate the severity and impact of ransomware, DDoS, and social engineering attacks on higher education:

University of California: In 2020, the IT team discovered malware in the system and decided to unplug all the computers to stop the virus from spreading, but it was already too late. To crack the encrypted data and get the stolen information, they had to pay 1.4 million dollars to the hackers. (Lisa Morgan 2021).

Michigan State University: The attackers threatened the University that the student's personal information would be leaked if they did not pay the ransom. The University's IT division also claimed that hackers obtained access because IT department staff neglected to apply a patch for a virtual private network. However, the University could not catch the hacker and had to pay 1 million dollars. (Emily Bamforth (2021).

University of Utah: A ransomware attack occurred at the University of Utah against the College of Social and Behavioral Science. The University said in a statement that the group blocked access to the University's computers for several hours as employees pulled servers offline to stop the malware from infecting other computers connected to the school's network. However, the University had to pay the ransom of 467k dollars to prevent the release of student's personal information from being exposed by the attackers. (BÎZGĂ, 2020)

	PAID THE RANSOM	USED BACKUPS	USED OTHER MEANS
Lower education	45%	76%	35%
Higher education	50%	70%	34%
Global average	46%	73%	30%

Fig.1 (Sophos Whitepaper. May 2023)

Howard University: Howard University canceled classes; they say a ransomware cyberattack hit the school. The incident was discovered on 2021 September 3, when the school's information technology department said they detected unusual activity on the University's network. (D. Howard Kass, 2021).

University of California: A Ransomware Attack hit the University of California in March 2021. This attack provided the hackers with stolen data that included the personal information of faculty and students. (Morgan, 2021).

Myerscough College: In 2021, Myerscough College contacted the Cyber Resilience Centre after first contacting Lancashire Police to report the crime when they found themselves dealing with a targeted ransomware attack. (Thompson, 2022).

Kellogg Community College: On May 2, 2022, A Ransomware attack disrupted the end of Kellogg Community College's term, so the college shut down until IT investigated the damage done by the ransomware attack. (Weissman, 2022).

Bristol Community College: Bristol Community College: Bristol Community College in Attleboro, Massachusetts, reported on December 30, 2022, that internet and networking operations had been affected due to a possible ransomware assault. (Brumfield, 2023).

College of the Desert: A ransomware assault that happened in July 2022, which prevented the college's phone and web services from functioning for about a month, prompted College of the Desert, a community college in Palm Desert, California, to inform about 800 persons who may have been affected by a ransomware attack. (Brumfield, 2023).

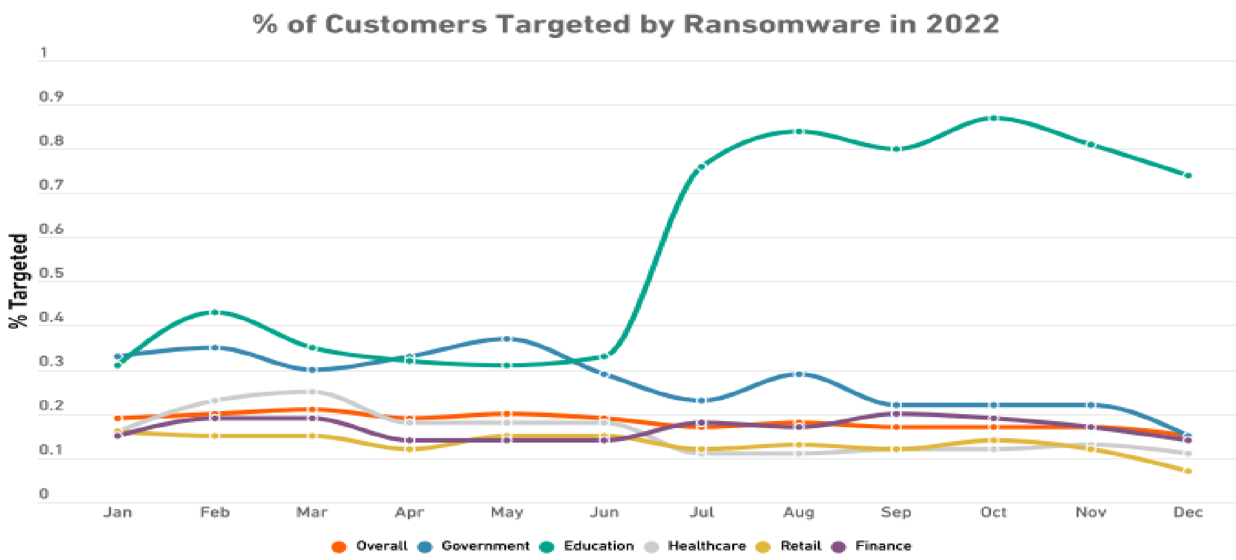

Fig. 2 Sonic wall (2023)

Lincoln College: Lincoln College was a victim of a cyberattack in December 2021 that thwarted admissions activities and hindered access to all institutional data. (Collier, 2022).

Austin Peay State University: In 2022, Austin Peay State University was the target of a ransomware attack that threatened the students and staff to shut down their devices and disconnect from the server, affecting 11 thousand students. (Jonathan Greig, 2022).

Kaiserslautern University of Applied Sciences: A Ransom attack hit Kaiserslautern University in 2023. It resulted in the University's infrastructure shut down, including email accounts and the telephone system, impacting almost all its facilities and services. (Ransomware attack leads to massive disruption in German university, 2023).

Okanagan College: A cyber-security incident was found in January 2023 by Okanagan College's IT Services staff, which led to an urgent network shutdown. They hired outside specialists while the network services, public website, Moodle, and email communication remained down because of the ransom attacks. (Fassina, 2023).

Southeastern Louisiana University: Following a security breach, Southeastern Louisiana University shut down its network on February 23, 2023. Students and professors could not use the school's website, email, and assignment portal for almost four weeks. (NICHOLSON, 2023).

Gaston College: Gaston College reported a ransomware incident involving possibly private student and faculty data on March 3, 2023. Over 20,000 students attend Gaston College's three campuses, all impacted by the ransomware outbreak. (Richard Console, 2023).

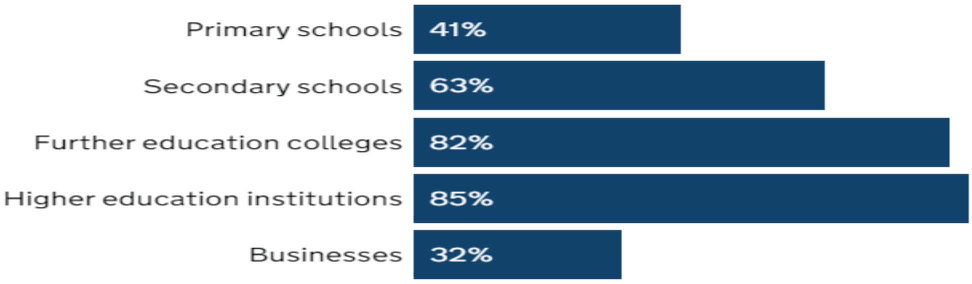

Fig. Percentage of organizations that have identified breaches or attacks in the last 12 months (19 April 2023)

Mitigation

Recent incidents demonstrate how vulnerabilities in network security, authentication, and other controls enable attackers to infiltrate systems, extract sensitive information, and disrupt operations. By implementing layered defenses tailored to higher education's needs, institutions can significantly improve cyber resilience.

Network segmentation provides protection by isolating critical systems and data stores. Firewalls actively monitor and filter network traffic to identify anomalies and block threats. Multifactor and risk-based authentication protocols make it far more difficult for unauthorized users to access accounts or resources.

Encrypting sensitive data limits the impact of any breach by making stolen records useless. Ongoing cybersecurity training engages all students and personnel as agents to detect phishing, social engineering, and other attacks. Cyber insurance helps offset financial damages and costs if incidents do occur.

Firewall implementation can prevent an attacker from injecting malicious packets into the network. For example, firewall file blocking feature allows you to block specific types of files, such as executable files, which they are commonly used to distribute ransomware. Installing a firewall and intrusion detection system on the network can help prevent unauthorized access and detect malicious activity.

Multifactor and risk-based authentication protocols make it far more difficult for unauthorized users to access accounts or resources. Even if hackers steal user passwords, they can't access accounts without the second authentication factor, significantly decreases risk of phishing and stolen credential it also convenient for users with smart devices.

Secure User Endpoints: To monitor and secure many endpoints and lower the danger of hackers entering through human mistakes, endpoint security platforms and detection solutions are essential.

Recovery Plan: Institutions should establish a system for backing up important data and recovering it in the event of a cyber-attack. Offline backups provide an isolated copy of critical data outside the network, accessible if primary systems are compromised, Regular testing restoration from backups proves they are working and recoverable when needed. All copies should be encrypted to protect against unauthorized access if stolen.

Provide Security Training: It is essential to provide employees, instructors, and students with the required security education. Simple instructions can stop costly mistakes that can risk network security. Ongoing cybersecurity training engages all students and personnel as agents to detect phishing, social engineering, and other attacks.

Security awareness programs are also vital in educating faculty, student, and staff about cybersecurity best practices and the importance of protection sensitive information.

Purchase Cybersecurity Insurance: Costs like consultancy, risk evaluations, and data recovery that are related to ransomware attacks might be covered with the help of cyber insurance. Cyber insurance helps offset financial damages and costs if incidents do occur. Together, these technical and administrative safeguards create overlapping zones of protection. While no single solution is perfect, their combined application significantly raises the complexity for infiltrators and reduces attack surfaces.

Conclusion

As cyber-attacks continue to pose a significant threat to higher education institutions, it is crucial for these institutions to prioritize cybersecurity measures. By implementing preventive measures, raising awareness, and collaborating with stakeholders, colleges and universities can enhance their cyber risk preparedness and protect sensitive data from potential cyber threats.

Recommendations

For University Leadership: Make cybersecurity a strategic priority with engagement from senior leadership and boards, conduct regular risk assessments to identify vulnerabilities, develop comprehensive incident response plans, allocate sufficient funding for security resources, technologies, and staff training, Create a cybersecurity governance structure with clear policies and oversight. Purchase cyber insurance tailored to institutional needs.

CIOs, CISOs

Implement defense-in-depth tools like firewalls.
endpoint detection, and intrusion prevention systems.
Segment networks to isolate sensitive systems and data.
Require multifactor authentications for all institutional systems.
Deploy automated patch management and vulnerability scanning.
Develop secure system architectures and software development lifecycles.
Provide ongoing cybersecurity awareness training for all students and employees.

Faculty and Staff

Complete required cybersecurity training every year.
use strong passwords and change them regularly.
|Be vigilant against phishing attempts.
Report suspicious activity immediately.
Safeguard sensitive student data and research.
Follow institutional protocols on remote work, device security, and collaboration tools.

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