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Omid Noroozi
Erdinc Cakir
Sabri Turgut

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Modeling Bivalves' Temporal and Spatial Variability via Self-Organizing Maps

Junalyn Navarra-Madsen

Texas Woman's University, Denton, https://orcid.org/0000-0001-7549-9764

Abstract: How can topology and GIS enhance the study of Asian green mussel (Perna viridis)? Topology is often described in layman's terms as rubber-sheet geometry. Why? Topologists cannot distinguish their coffee cups from their doughnuts. Topology is crucial in understanding geographical information systems (GIS). Topological data structures are central to GIS. What are the advantages of topological data structures? Storage for polygonal elements is reduced because boundaries between adjacent polygons are not stored twice; relations between features are maintained; and maps are improved by research-based methods. Topology is not needed for every GIS project, but, topology is valuable in finding the optimal path between a set of points, classes and features. Topologists have certain skills and training in filling gaps found in some of these information systems by applying mathematical research-based methods. In this paper, the author explains the application of basic topological rules in enhancing geodatabases applied to oceanographic studies. The use of self-organizing maps (SOM) method is explained. SOM, a powerful type of articial neural network, can mine patterns from a variety of quantitative data. Using SOM, the author describes the seasonal (monthly, inter-annual) pattern variability of spatfall settlement of Perna viridis (Asian Green Mussel) and links the output to ancillary variables by using several techniques in processing data of high dimensionality and complexity.

Keywords: GIS, Oceanography, Self-Organizing Maps, Kohonen Maps, Topological Data Analysis

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Introduction

Large volumes of mathematical papers published great results that may be highly beneficial to mankind. Unfortunately, there is a "gigantic gap" in terms of making it accessible. The language of mathematics can be overwhelming to those who are not studying it. This paper will minimize the presentation of mathematical formulas and focus more on making mathematics simpler by including more illustrations. The major objectives of this paper are to:

1. Illustrate the importance of topology in GIS.
2. Define the not-so-friendly mathematical tool called SOM and explain some of the important aspects of output

plots and graphs.

3. Demonstrate the ability of SOM to classify large data sets and still preserve topology.

What is a GIS? Worboys and Duckham's definition is, "A geographic information system (GIS) is a computer–based information system that enables capture, modeling, storage, retrieval, sharing, manipulation, analysis, and presentation of geographically referenced data" (Worboys and Duckham, 2004). A GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. A GIS helps us answer questions and solve problems by looking at our data in a way that is quickly understood and easily shared." What is topology? Topology or "rubber-sheet geometry" is the study of properties of space that are preserved under continuous stretching, twisting, and bending without ripping or making holes. Because continuous deformations without tearing are allowed, topology is valuable in finding the optimal path between a set of points, classes, and features. GIS and topology. Topology utility in GIS can be grouped into two broad areas. The first area is the support of database development. Knowledge of the topological conditions in a data set can be used to discover structural problems with the feature database, e.g., polygons that are not closed or are overlapping. It can also be used to automate feature creation and ensure feature integration. The second area is the provision of spatial analyses. These can include using connectivity for network analysis, area definition to determine containment, and contiguity for neighborhood analysis.

Self-Organizing Maps

What is a self-organizing map (SOM)? SOM is an artificial neural network (ANN) that is trained using unsupervised learning to produce a two-dimensional, discretized representation of the input space of the training samples by using a neighborhood function to preserve the topological properties of the input space. A Finnish professor Teuvo Kohonen was the first to describe SOM (Kohonen, 1998). SOM can extract patterns and learn via the training algorithm (Ultsch, 1990, Vesanto et al, 2000). Input data are presented successively to the network and after this iterative process, the nodes converge to positions that represent the input data. Bacao and others (Baca et al, 2004, 2005) reported in their paper that SOM is less prone to local optima than k-means and that the search space is better explored by SOM. How is SOM utilized in oceanographic and ecological studies? Chon has surveyed several ecological studies using SOM (Chon, 2011). Richardson and others have used SOM to extract patterns in satellite imagery (Richardson et al, 2003). Hardman-Mountford et al. have applied SOM to altimeter data and related it to Namibian sardine recruitment (Hardman-Mountford et al.2003). Liu et al. have studied ocean current patterns and sea surface temperature patterns using SOM using SOM (Liu et al, 2005, 2006). Why use GIS and SOM together? Interpretations of self-organizing maps are not easy. There is a need to improve visualization for better interpretation of results (Bacao, 2004; Finke et al. 2008). Fincke et. al have made use of GIS to visualize SOM results and shown a way to import traditionally created SOM into GIS so that 3-D spatial analysis can be performed.

What is SOM Algorithm?

SOM is usually classified as unsupervised learning with the goal of discovering some underlying structures of the data input. SOM as a topology-preserving map maintains neighborhood relations. This is classically written as

$$y_i \sim y_j$$

whenever

$$x_i \sim x_j$$

where x_i, x_j are input data which can be multidimensional, y_i, y_j are nodes from the output layer which is usually 2-dimensional, and ~ is read as "related to". As a rule, the connection within a group of similar or related input data is greater than the connection outside this group. Figure 1 provides the schematic diagram of this mapping.

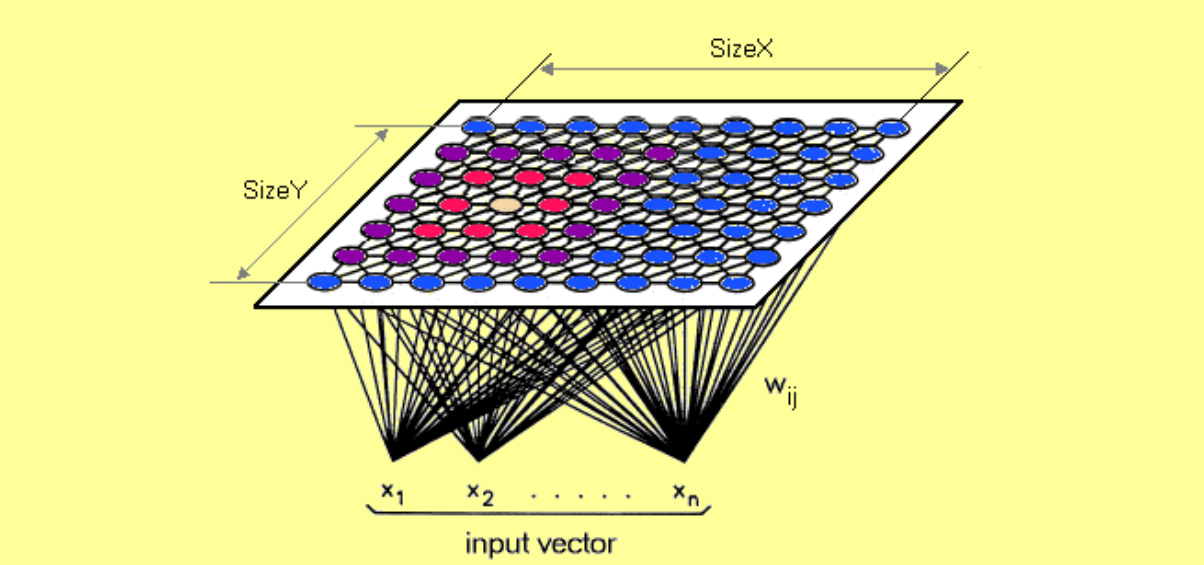

Figure 1: A Schematic Diagram of Kohonen Mapping (From "Self Organizing Maps", by Achraf Chazri, 2019, Towards Data Science, Original Research by Kohonen, https://sci2s.ugr.es/keel/pdf/algorithm/articulo/1990-Kohonen-PIEEE.pdf)

There are basic assumptions for this algorithm. They are: (1) Output nodes are connected as 1-dimensional or 2-dimensional array and (2) the whole network is fully connected, i.e., all input nodes are connected to all nodes in the output layer. Each output node is weighted. Given a randomly selected input vector x, the winning output node i is denoted by $W_i(x) \geq W_k(x)$ whenever the weights are normalized.

$$|w_i - x| \leq |w_k - x| \; \forall k.$$

Given the winning output node i, the weight update is

$$W_k(new) = W_k(old) + \mu N(i, k)(x - w_k)$$

where N (i, k) is a neighborhood function.

Asian Green Mussels

Asian green mussels (Perna viridis) belong to the family Mytilidae (Linnaeus1758). The family Mytilidae is characterized by two narrow, fan-shaped, thin valves; the absence of prominent hinge teeth and often the presence of byssal threads for anchoring to hard substrates. Perna viridis can grow between 80 to 100 mm with a maximum length of about 160 mm (Rajagopal *et al*, 2006).

Mussel Life Cycle

These mollusks have separate sexes and fertilization occurs externally. After 7 or 8 hours, free-swimming larvae are the results of fertilized eggs which remain free-swimming for 2-3 weeks. Using their byssus, 3-week-old larvae settle onto seaweed and later settle on rocky subtidal or intertidal flats (Yap, 2002). During their planktonic period, larvae will be widely dispersed by physical processes but may aggregate periodically at certain depths through a variety of biological processes, most notably diel vertical migration. Juveniles may be able to reach sexual maturity within 2-3 months and may live as long as 3 years. Adult populations may reach densities of 35,000 individuals per square meter.

Reproductive Cycle

Perna viridis become sexually mature after 12 weeks at 20-30mm shell length. The life span of Perna viridis is typically 3 years. Growth rates are influenced by environmental factors such as temperature, food availability and water movement. Several studies have been done on the closely related species Perna canaliculus (Alfaro *et al*. 2004, 2004). Figure 2 shows the life cycle of Perna viridis, https://lsintspl3.wgbh.org/en-us/lesson/ilwhyy18-il-ilmussels/4

Larval Transport, Recruitment and Settlement

Several researchers (Roughan *et al*, 2011) have reported that transport of the planktonic larvae of benthic invertebrates is mostly influenced by a few physical and biological factors. One of the important questions in most mussel ecological studies for aquaculture application is how to determine the location of adult brood stock mussels and the accompanying macroalgae assemblages that serve as initial habitat for recruitment and settlement. Although a few studies have been published about this topic, knowledge gaps still exist. For instance, more studies need to be done to describe the mechanisms involved in the transport, recruitment, and settlement of mussel larvae to bottom drifting macroalgal materials, e.g., the free-swimming larvae which are approximately .3mm in length undergo morphological changes and start attaching themselves to seaweeds. The morphologically transformed larvae accumulates which can sometimes cover the seaweeds, seaweeds containing spat arrive near certain surf zones in different parts of the world at specific times of the year. The next section explains the temporal variability of spat arrival using SOM.

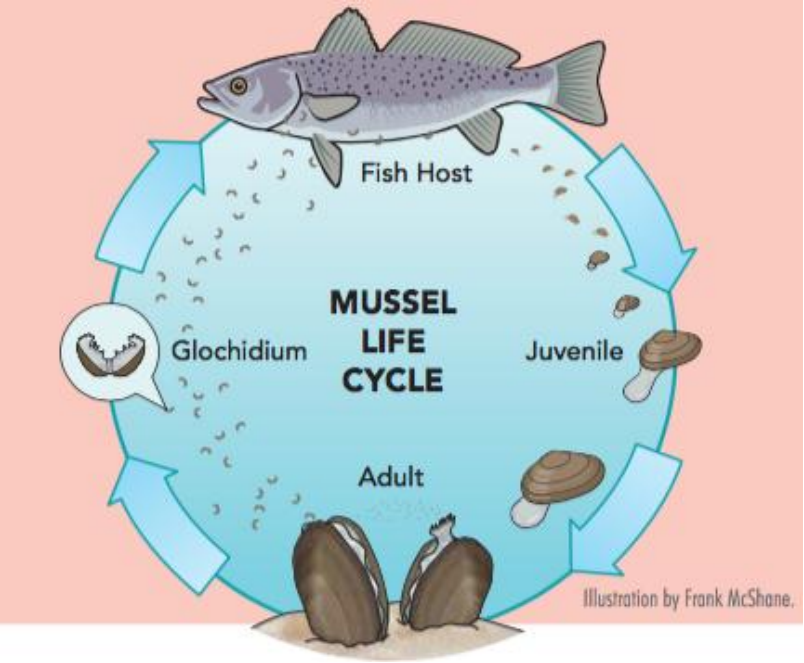

Figure 2: A Schematic Diagram of Mussel Life Cycle (From: https://lsintspl3.wgbh.org/en-us/lesson/ilwhyy18-il-ilmussels/4)

Significance of the Study (Mussel Aquaculture)

Mussel farming and aquaculture have economic and sustainability significance. Food and Agriculture Organization (FAO) reported that "estimated worldwide shelled mollusks production – essentially bivalves (i.e., mussels, clams, scallops and oysters) – was about 17.7 Mt (live weight); representing a value of USD 34.6 billion (Food and Agriculture Organization of the United Nations, 2020b). Avdelas, *et al (*2021) described in their paper the decrease in mussel aquaculture in Europe in contrast to the increasing production in the world especially in Asia. The paper reported that "Aquaculture production of mussels in the EU peaked in the late 1990s at more than 600 000 tonnes; by 2016, production volume had dropped by 20% to 480 000 tonnes." This decreasing trend prompted the study of economic and environmental factors via SWOT (strengths, weaknesses, opportunities, and threats) analysis. Medina Uzcategui *et al* (2022) emphasized the significant amount of waste for processing mussels for human consumption. There is a need to use "waste sustainable management alternatives, several proposed products (e.g., collagen, bio-adhesives, biopolymer, and adsorbent for pollutants)." Let us provide one example. Green mussels are abundant in the Philippines, especially in the middle part of the Philippines. The mussel market has grown since 2010. In Sorio, J. C., & Arcales, J. A. A. (2022), they emphasized the "development of value-added products from this resource will increase its utilization and marketability and showed that green mussels can be processed into meatloaf, noodles and spread." Given that mussel farming is now standard in the Philippines, there is a need to ensure sustainability and food supply in the next few decades. Apines-Amar *et. al.* (2022) verified "techniques on brood stock collection, spawning, and larval rearing, developed by the project in the laboratory during the experimental trials." These were then "applied and verified in a production run using industry-scale tank facilities."

Method

Describing Mussel Spat Arrival Variability via SOM

In Alfaro *et al.*'s papers (2004, 2006), certain statistical analyses describing the relationship between temporal patterns of arrival of Perna canaliculus spat in the Ninety Mile Beach in Northern New Zealand were presented. Various hydrodynamics and oceanographic factors such as wind speed and direction, tidal range, water temperature and swell height and direction were the explanatory variables utilized. Three models were generated, and several hypotheses were tested to study the 1990-1999 data set. The first logistic regression model fitted on the probability of spatfall events (any amount of algae and spat collected on a given day) contain the following parameters (1) mean wind speed (m/s), wind direction (onshore and offshore), tidal range (mm), and date (January 1990 to December 1998); water temperature (degrees C) was added to the first model; and swell height (m) in the onshore direction was added to the model. This study led to the conclusion that spatfall events and the amount of spatfall increased with strong offshore winds.

Modeling and Simulating via SOM and Hierarchical Clustering

How do we utilize SOM to gain insight about the variability of spat arrival of Perna viridis in surf zones of several islands in the Philippines? We start with the simplest model using three parameters and increase its complexity by adding a parameter at a time. Model 1 contains 200 randomly selected set of days in a 10-year period; has input vectors x_i, having three dimensions (physical factors: mean wind speed (ms^{-1}), wind direction (onshore or offshore) and tidal range (mm). See Figure 3.

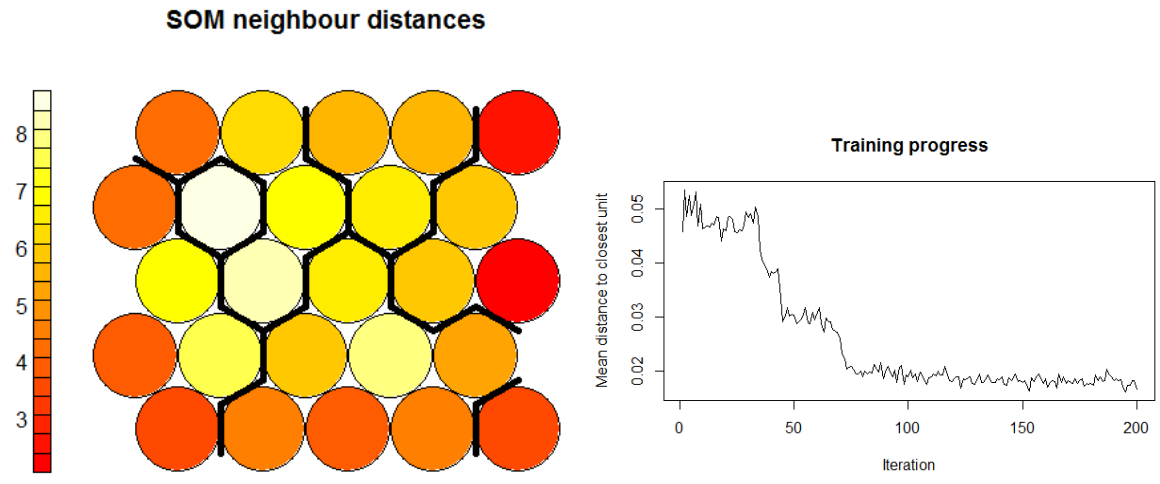

Figure 3 Training Progress and SOM Neighbor Distances" describing Model 1. The output layer is chosen to be a 5 × 5 hexagonal 2-dimensional lattices.

We use the packages (Berge *et al*. 2012) provided via software R and implement the simulations using the GUI, R Studio, to perform simulations.

We then add mean swell height (m) to Model 2 to obtain Model 3. Figure 5 shows the "Training Progress and SOM Neighbor Distances" describing Model 3.

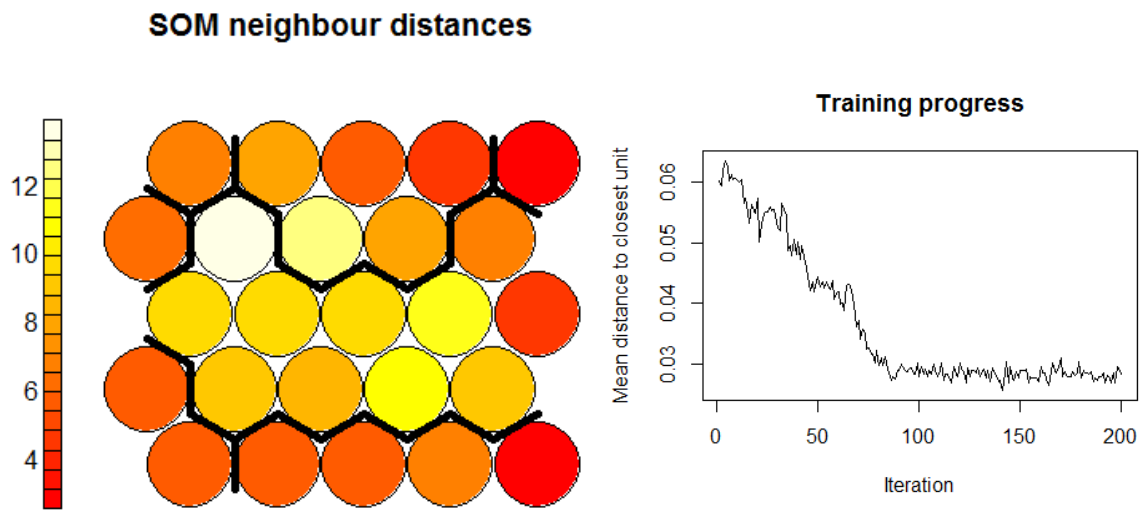

Figure 4 Training Progress and SOM Neighbor Distances" describing Model 2.

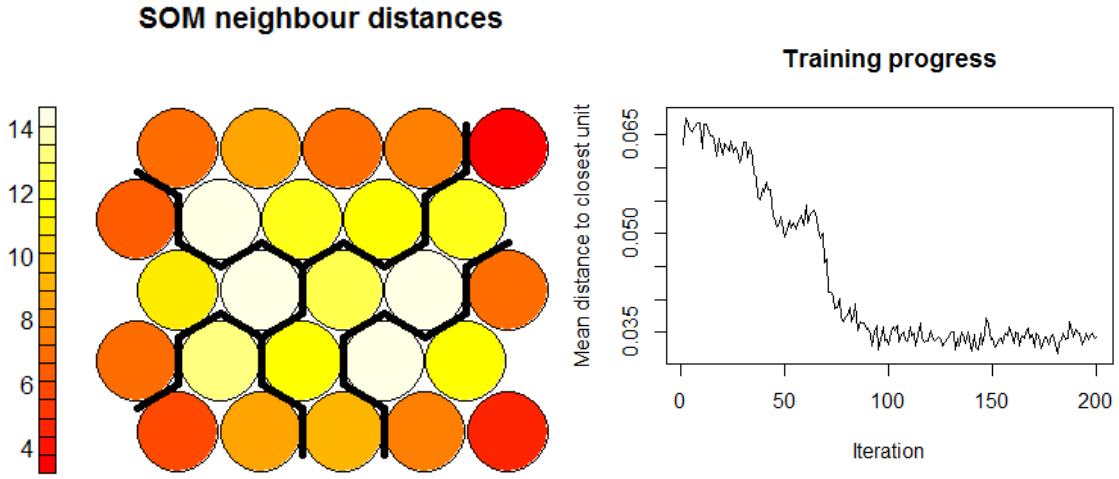

Figure 5 Training Progress and SOM Neighbor Distances Describing Model 3

Examining the three maps in Figures 3, 4 and 5 describing "SOM Neighbor Distances", the distances between neighbors increase as the number of parameters increases. Model 1 has the smallest distance range of only 5 between neighbors while Model 3 has the largest (10). The presence of a more whitish-yellowish color in Model 3 map can be interpreted as a better map in distinguishing one cluster from another. The variability of these three colored lattices demonstrates the need for additional input parameters to improve the delineation of different clusters. Using hierarchical clustering, we added the cluster boundaries. Please refer to the black boundary hexagonal-shaped segments between the nodes of the SOM output layer in Figures 3, 4 and 5. Reading and interpreting cluster dendrograms as output graphs of certain model simulation containing large number of inputs can sometimes be complicated and unreadable. Figure 6 illustrates this scenario.

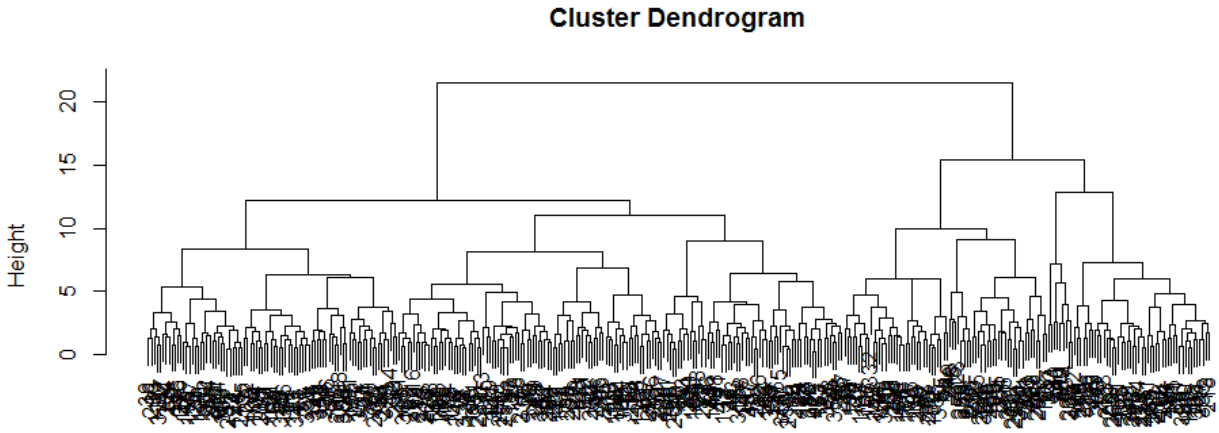

Figure 6. Not-So-Readable and Not-So-Easy to Interpret Cluster Dendrogram

For the sake of making the explanation simpler and constructing more readable graphs, let us take a sample of 50 input vectors and via hierarchical clustering we obtain its corresponding cluster dendrogram shown in Figure 7. It is then easy to look at small clusters and find out which of the small clusters a certain input vector of interest belongs to.

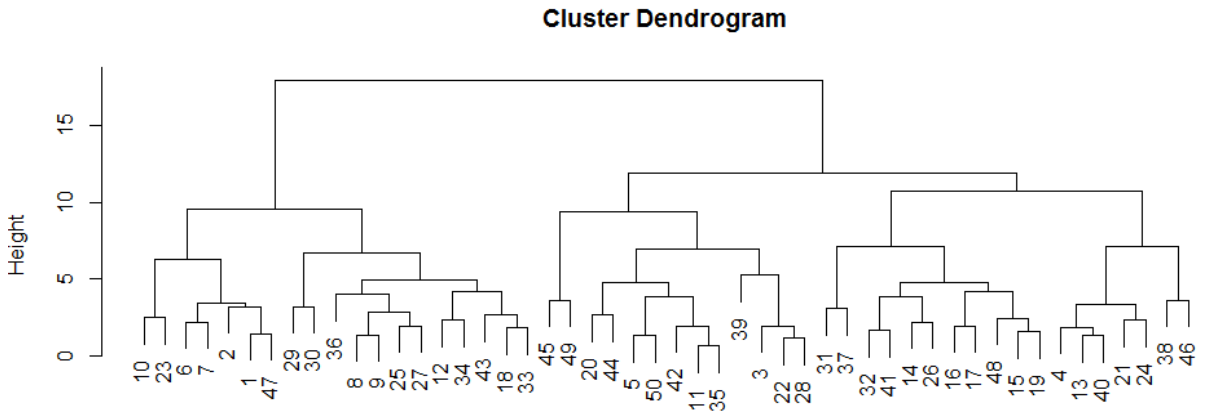

Figure 7. A More Readable and Easier to Interpret Cluster Dendrogram

Clustering via Mapping Plots

How do we know that we have truly mapped to each node in the output layer each input vector in the raw data set? Figure 8 shows two hexagonal mapping plots where each node of the 25 output layer nodes (except Node 13) contains classified input vectors. The grid used for this is 5 × 5 hexagonal grids because the sample is large enough to cover all 25 nodes in the output layer for better clustering. The two background colors signify two seasons: gray for “dry season” and pink for “rainy season”. Although these plots look similar in terms of the predicted background colors of gray and pink, if we check closely each node memberships, we can visually determine that these two plots have differences. There are three colored shapes (red circle, green triangle, and black square) representing the classification of the input vectors.

Smaller Sample Size - Smaller 2-Dimensional Output Lattice

The choice of the size of the 2-dimensional output lattice depends on the input data complexity and bulk. A group of researchers who have a good understanding of the factors affecting the certain phenomenon of interest can brainstorm and decide how large a lattice to utilize and whether to have a hexagonal or a rectangular shape to visualize the clusters. Figure 9 shows two rectangular-shaped mapping plots where each node of the 9 output layer nodes contains 3 or more input vectors. The grid used for this is 3 × 3 hexagonal grids because the sample size is only 60. The node memberships are visually tractable and hence provide a better approach.

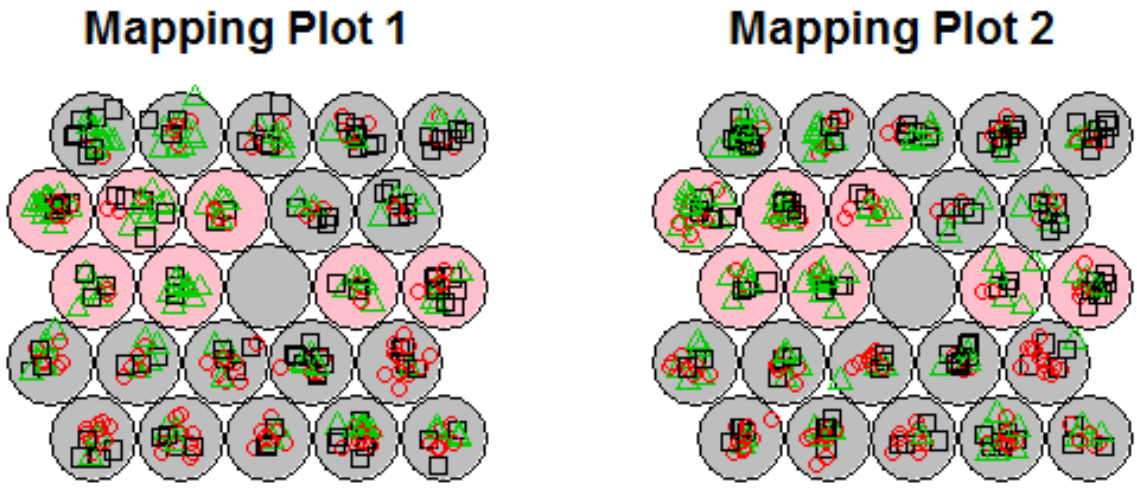

Figure 8. Almost Similar Mapping Plots (Quick Glance); Different Plots (Close Inspection)

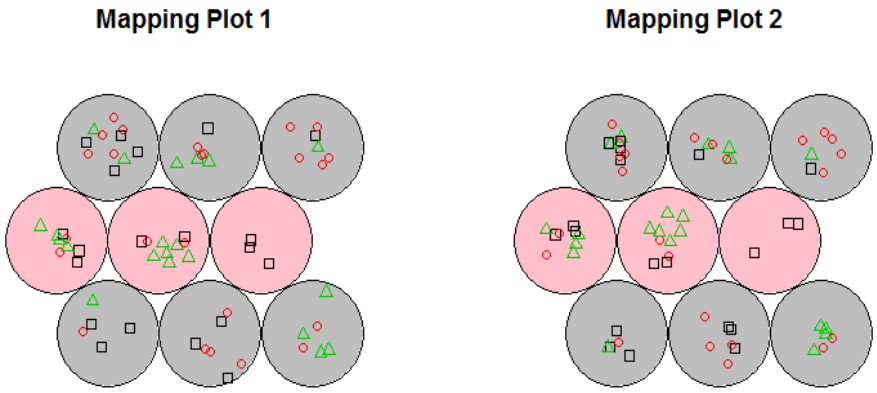

Figure 9. Again, Almost Similar Mapping Plots (Quick Glance); Different Plots (Close Inspection)

GIS and SOM Combined

Mussels are considered part of the staple food of the Filipino people. Napata and Andaleci0 (2011) studied the "exploitation and management of brown mussels (Modulus philippinarum) in Iloilo, Philippines". Cebu (2014) presented the "green mussel industry of Samar Philippines from 2004 to 2014." Cebu, E. H. and Orale, R. L.

(2017) presented the "characteristics of the green mussel belts including the seawater physicochemical parameters as well as a qualitative assessment of water quality from 2004 to 2013 as observed by 92 residents." Mussel farming became one way for local islanders to earn a living. In 2009, there was a higher mortality death of green mussels. Cebu, E. H. and Orale, R. L. (2018) examined the cause and reported that "volume of sediments produced and the water current in the different green mussel farms in various bays and sea of Samar." Fuertes, V.N., *et. al.* (2021) "investigated the spread of non-indigenous mussel species, Mytella strigata" in the middle islands of the Philippines. They even gathered data via area surveys to assess the distribution and utilization of M. strigata. There are several Asian green mussel landing sites in the Philippines. See Figures 10 and 11. Figure 10 zooms in on the Visayan islands (middle portion of the Philippines) where the study occurred, and Figure 11 shows the whole Philippine archipelago.

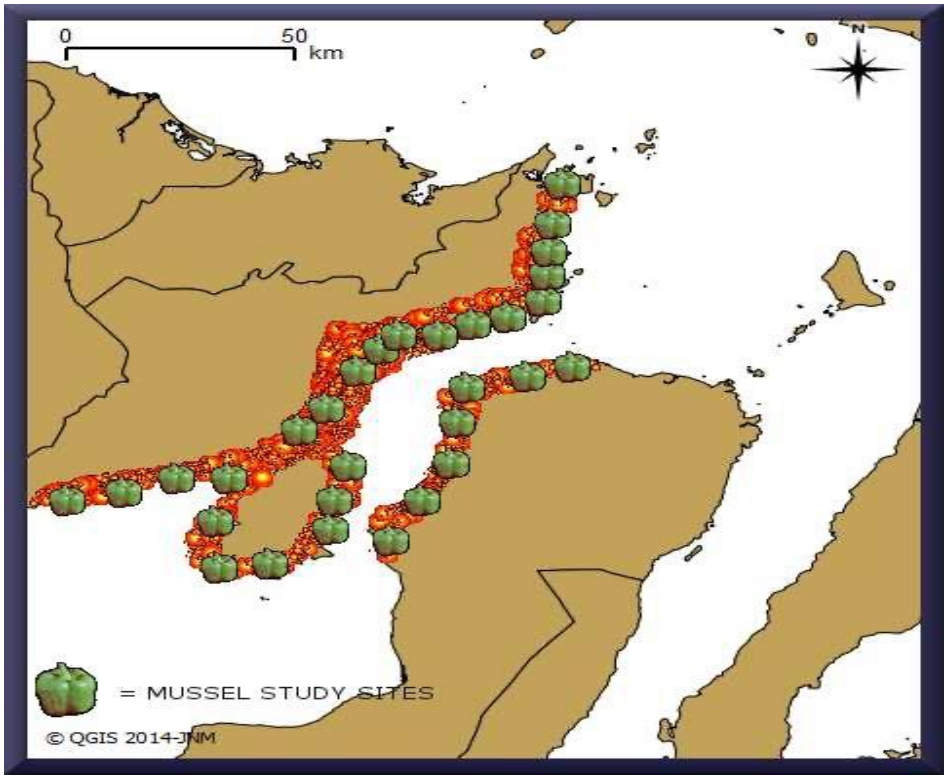

Figure 10. The Visayan Islands of Negros and Panay were ideal for studying Mussel Spat Variability

Using an open-source GIS software, QGIS (2014), we illustrate very briefly how to study of mussel spat arrival. Figures 10 shows the Philippine archipelago with 7,641 islands and the zoomed-in box illustrating mussel landing and study sites. Spat (millions of tiny green mussel larvae attached to seaweed and other debris) arrive daily in the shores of these islands. This large collection can sometimes go unnoticed and untapped. With some initiative, some fishermen harvest the spat to start a mussel farm. SOM can be utilized to start classifying which surf zones mussel spat occur the largest for optimization purposes. GIS with SOM can be utilized to find the mussel and other economically important invertebrates landing sites to improve the Philippine (shellfish or otherwise) mariculture. GIS can also pinpoint specific favorable areas (rocky intertidal surf zones) as marine protected areas for sustainability and conservation studies and purposes.

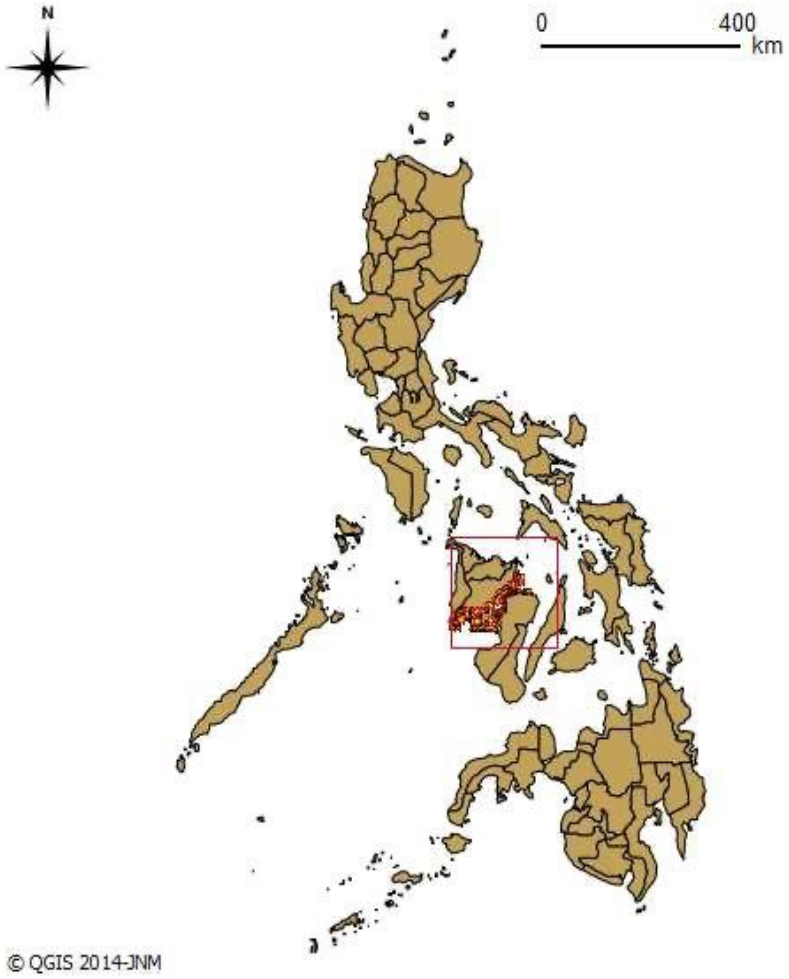

Figure 11. The Philippine Archipelago and the Zoomed-in Mussel Study Sites

Conclusion

Given the fast evolution of model technological advancements (software and hard- ware), researchers all over the world gather immense amounts of data every second. The mathematics of “Big data” will be crucial in answering basic scientific questions. The neural network technique approach in this paper (SOM) can be a powerful technique to find hidden structures (topological or otherwise) in small or large data. SOM can “learn” (unsupervised, semi-supervised, or supervised); can deal with incomplete and noisy data.

We do not claim that the modelling of mussel spat arrival given only five physical factors is perfect and will explain everything. Every model has flaws. Ocean scientists believe that there are also biological factors (e.g. species pelagic larval duration and swimming capability) to consider. In this paper, instead of presenting one hard-to- understand formula after another and bore readers with too much attention to mathematics, we spend time explaining the graphs and interpreting results to make modeling via SOM more accessible. Gaining insights from these plots and maps prepares the readers to appreciate its application to georeferencing using GIS tools.

In ecology or other scientific fields, classification and prediction are two main problems. Given the basic and simpler description of SOM and interpretation of output graphs in this paper, scientific researchers (oceanographers, marine biologists, climatologists, etc.) will employ GIS combined SOM or other artificial neural network tools in investigating data for possible patterns and important biological and physical dynamics.

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Notes

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Equity-Minded Teaching and Open Educational Resources

Junalyn Navarra-Madsen

Texas Woman's University, Denton, https://orcid.org/0000-0001-7549-9764

Abstract: "A nation that leads the world in science and engineering research and innovation, to the benefit of all, without barriers to participation," p. 9, NSF 2022-2026 Strategic Plan, is the guiding principle behind this research paper. Justice, diversity, inclusion, and equity are the four important components that need to be addressed carefully to authentically discuss the state of mathematics education in the United States and deliberately achieve the goal of incrementally improving the low baseline success rates reported by 50 states. In this paper, equity and access will be utilized as lenses when discussing Open Educational Resources (OER). Given the data-driven world we live in, the crucial need of effective mathematics education is quite evident. The COVID-19 pandemic stunted the growth of students' mathematical skills at all levels. Then the academic community, especially the mathematics community had to scramble and try new ways to continue delivering mathematical content with some success and rigor. In this paper, OER implementation in a Calculus course will be examined through the lenses of equity and access, i.e., what level of effectiveness has been achieved by OER in terms of learning outcomes of students Calculus courses given that students have access to OER the first week of the semester and that equity in terms of modes of delivery have slowly been improved.

Keywords: Equity, Mathematics, OER, Open Access

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Introduction

What is equity? Bensimon started the systematic study of "equity-mindedness" in higher education almost two decades ago and is still actively researching the area (Bensimon, 2007). Bensimon and Dowd (2015) defines equity-mindedness as a "way of approaching educational reform that foregrounds the policies and practices contributing to disparities in educational achievement and abstains from blaming students for those accumulated disparities." In Dowd and Bensimon's *Engaging the Race Question* book (2015), all curious tax-paying citizens are encouraged to read about the "substantial disparities in college participation, persistence, and completion rates among racial and ethnic groups in the United States."

Bensimon, Dowd and Witham (2016) stated in their Five Principles for Enacting Equity by Design that,
"In America's Unmet Promise: The Imperative for Equity in Higher Education (Witham et al. 2015b), we affirmed that effective higher education reform efforts must be infused with an awareness of the ways in which

many groups within US society have been historically excluded from educational opportunities or marginalized within the structures and institutions that house those opportunities."

In the same paper, they wrote "Principle 4: Enacting equity requires a continual process of learning, disaggregating data, and questioning assumptions about relevance and effectiveness." In this paper, the importance of some of these important aspects of equity will be discussed and highlighted. Equity-mindedness describes the "cognitive schema that administrators, faculty, and staff need to develop to address racial inequity on their campuses" (Bensimon *et al*, 2023).

Martin (2019) wrote that "equity for Black learners in mathematics education is a delusion rooted in the fictions of white imaginaries, contingent on appeasing white logics and sensitivities, and characterized at best by incremental changes that do little to threaten the maintenance of racial hierarchies inside or outside of mathematics education." Riegel-Crumb, C. *et al* (2019) used a national data Beginning Postsecondary Study (BPS) and found that "research results reveal evidence of persistent racial/ethnic inequality in STEM degree attainment not found in other fields." Callahan *et al* (2022) indicated that "amidst the ever increasing racial, cultural, and socioeconomic diversity of students in US higher institutions, inequities persist at all levels, e.g., retention and degree completion rates." Abdrasheva *et al* (2022) reported that the COVID-19 pandemic "has exposed multiple levels of inequalities" that include how students are treated depending on their background.

Are There Equity-Minded Initiatives Being Done?

There are encouraging scenarios that can be gleaned from all the nationally data-driven reports. Eduardo Bonilla-Silva (1997) published an impactful article that stated that "the only way to 'cure' society of racism is by eliminating its systemic roots." Arday, Mirza and Safia (2018) described the roots of "structural racism that limit social mobility and equality within Britain for Black and ethnicized students and academics in its inherently white Higher Education institutions." UNESCO's Final Report of the International Forum on Inclusion and Equity (2020) recommended that "All children and young people should learn together, wherever possible, regardless of any difficulties or differences they may have. Ellsworth *et al* (2022) reported that "institutions have the potential to use their roles in teaching and learning, research scholarship and creative expression, and service to the community to collectively work toward greater equity." Education is a right for every human being crucial to every person's self-efficacy and self-respect. In this modern society, the freedom to learn to read and write is as basic as a natural right to live. The National Student Clearinghouse Research Center Persistence and Retention Report (2023) found that "nearly 76% of the 2.4 million students who started college in Fall 2021 returned for their second year, an equivalent of 0.9 percentage points."

Montell (2023), in her open access Education Trust article exhorted "to end glaring racial disparities in education". There are two steps she recommended: "1) recognize students of color start with fewer advantages face more obstacles than their white peers; (2) put equity first in adopting solutions." Salazar and Jacquette (2023) strongly recommended the dismantling of "the racist structures that determine whether and where

students enroll in college."

Equity-Minded Teaching and Learning

Despite all the forward and upward diversity of students in higher educational systems, much work is needed to genuinely improve the plight of students from marginalized groups of society. Fenwick (2015) used a portal "PLA as a way to foster inclusive classroom practice to further enhance student learning." In similar veins, Wood, and Su (2021) wrote in their book that excellent teachers often employ "inclusive pedagogy which encompasses learners of all ages who come from different social classes." Cavazos and Chapa (2023) proposed that "to challenge systemic inequities, we must see students as essential partners in the development and revision of teaching and learning practices." For STEM classrooms, Duncan *et al* (2023) concluded in their meta-synthesis study that to effect progressive modification, it "takes incorporating classroom-focused approaches and faculty's reflective resolve to understand and change how dominant and privileged identities are reflected for classrooms to be equitable and inclusive in STEM." In this paper, the author describes how she implemented one approach to show appreciation of each student's unique assets in her class. This will be expounded under the Method section.

Open Educational Resources (OER)

What are Open Educational Resources? Hilton (2016) described the successful implementation of open educational resources instead of commercial textbooks. Hilton posited that the same student learning outcomes were achieved using OER and students saved some money. Ossiannilsson (2019) emphasized how OERs could improve lifelong learning (LLL) and continuous professional development (CPD) materials and therefore "establish legal and political frameworks that promote social justice, collaboration, and coordinated partnerships." Bossu et al (2019) described "the processes and findings of scoping diversity, equity, and inclusion (DEI) in the context of Global OER Graduate Network (GO-GN) initiated and founded in 2013. They "presented some of the project findings and provided the foundations of GO-GN guidelines for DEI." De Rosa (2020) wrote in her article published in New England Board of Education Journal and reused Colvard's result. See Colvard et al (2018). Clinton-Lisell et al (2021) reported that the use of OER enhanced equity in the classroom given that students were given access to materials the first day of the semester. Markin (2021) while describing OER in the context of open access noted Berti's result (2018), that "the perceptions of OER are likely closely associated with the expected efficacy of their deployment, despite their expected contribution to teaching quality and learning outcomes." The ability to revise and tailor content to improve teaching and learning was another way to foster equity. Cummins and Mason (2023) wrote "that the COVID-19 pandemic has changed our understanding of education, especially regarding access to technology (e.g., fast, consistent WiFi)." They exhorted the academic community to "take advantage of the lessons learned to increase accessibility where and how we can." Mickel and Scida (2024) underlined "the development and delivery of a learning community focused on OER and Open Pedagogy and the relationship between open practices and educational equity," and described the process of going beyond cost saving, i.e., the consideration for important

"aspects of a diversity, equity, inclusion, and accessibility in OER community building initiatives."

Creative Commons (CC) is an international nonprofit organization that empowers people to grow and sustain the thriving commons of shared knowledge and culture we need to **address the world's most pressing challenges** and **create a brighter future for all.** CC defined "OER as teaching, learning, and research materials that are either (a) in the public domain or (b) licensed in a manner that provides everyone with free and perpetual permission to engage in the 5R activities – retaining, remixing, reusing, and redistributing the resources." Hewlett Foundation defined "Open Education" to "encompass the myriads of learning resources, teaching practices, and education policies that use the flexibility of OER to provide learners with high quality educational experiences."

Peter Suber (2012) wrote in his book published by MIT Press about Open Access (OA) and the movement has grown this past decade. In the mathematics community, these resources come as e-books, videos, and other online resources such as 100% online homework platforms freely available to everyone with internet access. Rice University's OpenStax started in 2012 and has since improved access of quality e-books to students. OpenStax, formerly labeled as OpenStax College, has provided mathematics books to students freely. In an article, Education for All, OpenStax's Journey and Impact, Sept. 2023, "OpenStax has grown to offer an impressive range of 65 textbooks, a testament to our commitment to providing comprehensive learning materials. Since our first textbook launched in 2012, we've already saved more than 36 million students an astounding $2.9 billion. Our impact extends far beyond the United States, with 150 countries reporting the adoption of OpenStax textbooks, contributing to a global learning community. In the United States, OpenStax resources are used in 70% of higher education institutions and more than 6 thousand K-12 schools."

Katz and Van Allen (2022) reviewed "a brief history of OER and the practices employed. Open Educational Practices (OEP)"; discussed the "integration of equity pedagogy within open education"; elaborated on the "rationale and process for developing the special issue and concluded by "identifying challenges and ongoing conversations for the field as a response to the need for social justice action." They found that "despite increasing acceptance of OER, educators are not aware of how to implement OER and OEP with equity in mind. As OER and OEP continue to expand, teachers across all educational sectors need examples of how to teach effectively with these resources and practices. There is also a rising focus on culturally relevant and sustaining teaching practices, which OEP can complement." There is an enormous need to do more scalable research on what works best (Acikgoz & Akman, 2023). Additionally, more ongoing conversations must be done in all fields of study to ensure that challenges by all parties involved are genuinely presented and thoroughly discussed.

OpenStax Calculus Textbooks

In this research paper, the author emphasizes the use of OpenStax Calculus textbooks and how they:

- Provided cost savings to all students,

- Afforded early access on the first day of the semester, and
- Bestowed equity in higher educational mathematics courses, especially in the very first Calculus course in college which is necessary to enter STEM programs.

The OpenStax Calculus textbook series is available in three volumes and is designed for the typical two- or three-semester general calculus course. The book is available in English and Spanish and is published under a CC BY-NC-SA 4.0 license, which means that you can use and adapt the book, but not for commercial purposes.

Classroom Innovative Transformation to Achieve Equity and Inclusion

How do we walk the walk and ensure that our talk jives with our walk? Brandle et al (2019) published "survey results yield rich data about how positively students feel about their Zero Textbook Cost (ZTC) courses as well as ways to improve the design and delivery of Zero Textbook Cost courses to make them more beneficial for student learning." Gonzalez et al (2022) introduced "Remixing Open Textbooks through an Equity Lens (ROTEL)." This project developed "accessible intentionally inclusive OER that reflect students' local and lived experiences." ROTEL's OER "affirm cultural identities, elevate historically marginalized voices, and multiple expressions of diversity (e.g., race, social class, gender, language, sexual orientation, nationality, religion, ability)." Craghead and Norton (2023) facilitated a 2-hour virtual training on analyzing the inclusivity and equitability of OER. The feedback provided by participants was quite enlightening. In this webinar, Craghead and Norton did not provide upfront any definition of what is inclusive and equitable, and the responses of the different groups' participants provided more information on how OER could be presented and delivered with the intent of being more inclusive and equitable to all teachers and learners. La Croix et al (2023) communicated that OER are "emerging as an effective equity practice that positively impacts students' perceptions, performances, and perseverance while also alleviating some of the financial burdens associated with higher education." They described "a cross-institutional collaboration to create a high-quality OER to enhance early educators' professional knowledge." Ghaderi (2023) described a large research study done to design OER with equity in a statistics course. Students' needs were assessed and in the course redesign, these needs were addressed, and equity was integrated in the content by ensuring that basic principles of social justice and culturally relevant teaching strategies were employed."

Open Access and Open Knowledge: Successes and Failures

Ossiannilsson *et al* (2019) listed all the positive OER movements in the world, e.g., UNESCO's Sustainable Development Goal #4 which pinpoints the "educational access, equity, equality, inclusivity, quality, and lifelong learning, and integrates the many elements of open education, including the use of OER to support improved access along the continuum of lifelong learning." In their abstract, they lamented that "there has been no organized effort to document and disseminate best practices for OER lobbying and implementation in different

organizations and at different levels." Zaid and Alabi (2021) provided and proffered "recommendations and suggestions for all libraries interested in growing OER initiatives focusing on development, implementation and assessment for universities operating with limited resources." Galvez and Yood (2022) described "how the HyFlex platform, which allows students to access their courses digitally or in person, proved inhospitable to and dangerous for critical, community-based teaching and learning." Harlow *et al* (2022) provided a warning about claiming that social justice and equity are the results of having open access to course materials. The paper recommended that instead of social justice, "redistributive justice, recognitive justice, and representational justice" be the phrases to use. Baker and Sibona (2022) found that "support for student motivation and open instructional materials as positive influences on student learning outcomes."

Best Open Educational Practices (OEP)

Ehlers (2011) traced the emergence and development of OEP from several publicly and privately funded OER initiatives. Cronin (2017) defined Open Educational Practices as "practices that include the creation, use, and reuse of open educational resources (OER) as well as open pedagogies and open sharing of teaching practices." Her research articles stressed that "empirical research on individual educators' use of OEP for teaching in higher education" has been studied less." Her paper suggested that "research-informed policies and collaborative and critical approaches to openness are required to support staff, students, and learning in an increasingly complex higher education environment." Zhadko and Ko (2019) wrote a book on best practices in designing courses with OER. Part III of this highly useful book, Teaching and Learning with OER, is a must read for all educators and learners. Waltje and Zerangue (2020) presented that higher educational institutions could build strong faculty community via OER by "rewarding and recognizing these efforts, while at the same time creating excellent opportunities for faculty collaborations and community building."

OER and OEP Beyond Cost Saving

Ehlers (2011) recommended that "to provide educational opportunities for all citizens," there is a need to "extend the focus beyond access, to include innovative open educational practices." Most of the research such as Bliss *et al* (2013) and Hilton (203) done in the last decade concentrated on the Cost, Outcomes, Usage and Perceptions (COUP) framework. Hegarty (2015) proposed eight characteristics that best described OEP. Based on the COUP framework, Hilton (2017) wrote that "the usage of OER is the least studied" of the four aspects. Wiley and Hilton (2018) defined OER-enabled pedagogy and differentiated it from OEP. Nusbaum and Cuttler (2020) presented in their paper that "instructors assigned to use OER were rated more positively that those assigned a commercial textbook, and students were more likely to select courses that had no course cost." Nascimbeni and Burgos (2019) surveyed 724 university educations and sorted the respondents as to the actual use of OER and OEP and found that "a strong (positive) relationship exists" between OER and OEP. They listed specific OEP activities that cover designing the course, creating content, implementing successful digital pedagogy and embedding research-based assessment and evaluation. Tietjen and Asino (2021) tried to clarify what open pedagogy (OP) is for the academic community and tried to identify commonalities. OP has been

perceived by most educators as an extension of OER and then connected this to OEP. They then presented the 'Five-Circle Framework' of OP. Davidson Squibb, Salmo, and Yam (2023) gathered OER usage data and found that students "reported using OER textbooks less frequently than commercial textbooks." Why is this the case? To answer this question, one question to answer is, "How do institutions effectively support teachers and learners to optimize the use of OER, in this case, mainly free textbooks?"

Method

In this paper, the author describes how OpenStax Calculus Volume 1 (Single Variable Calculus) was utilized to improve equity and access by every student of a Hispanic-Serving university in Texas which focused largely on women. Larson and Edwards, Calculus, is the main Calculus 1 textbook used from 1990s to 2019. This textbook cost about $200 given that this book covers Calculus 1-3, where Calculus 3 is the multivariable calculus. Yes, most definitely, upon implementation in 2019 the obvious result is cost saving for students. The author is the coordinator of Calculus 1-2 courses at this university. She and other Calculus 1 instructors collaborated, and this collaboration ensured that the new OpenStax textbook has topics aligned with the previously used Larson and Edwards' textbook which guarantees that there is also the alignment of specific student learning outcomes (SLOs). The main difference was that on day 1 of the semester, every student has access to the OER (free OpenStax) e-book, Calculus Volume 1. How was this book utilized? An online HW platform, MyOpenMath, has been utilized to deliver the course contents to all students. This online platform has been populated with useful content such as lecture videos shared by several generous mathematics professors, HW and quiz and exam templates for each Calculus instructor can create, use, revise, share, remix, and reuse ensuring that each SLO is assessed for each class.

Open Educational Practice vs. OER-enabled Pedagogy

Amid COVID-19 pandemic, the author started using the OpenStax Calculus textbook in Fall 2020 and her students registered in two sections of Calculus 1 were participants of the case study. The students were given the step-by-step orientation video on how to use both the OpenStax textbook and MyOpenMath HW platform where all materials including an e-copy of the textbook as well as webpage link had been uploaded. Important useful features of the online accessible textbook were described and hints on how to efficiently use them. OpenStax has gathered feedback from instructors on how to improve these features and this feedback was instrumental on improving the latest version made available online. The same can be said about the MyOpenMath platform. The instructors can create their own materials for assessment and can upload these online to be shared to the whole community of instructors who use the platform. The author (instructor) ensured that both sections have accessed to the same set of orientation materials, lecture videos, HW, quizzes and exams. The first day of the semester, using the discussion board, students were requested self-introduce themselves (written or video form) answering basic questions such as name, major, level (freshmen to sophomore or even post-bac), the math courses they have taken and completed within the past two years, what grades they are

aiming for the course and how to achieve this grade, and anything fun each one of them are willing to share to get to know them better. Each student could read other students' introductions and respond if they want to. The very first week of the semester, a special survey was administered to find out each student's level of technology needs. The instructor then reached out to students who expressed the possibilities of certain issues occurring, e.g., unstable internet access or WiFi, limited access to desktop, laptop, tablet with stylus, table, and cell phone. Certain recommendations and solutions were provided such as making use of local libraries, borrowing tablet or laptop of friends and families, and providing extra time, increasing the number of online late passes, and ensuring that materials as Americans with Disabilities Act (ADA) friendly. Other non-technology questions were utilized. Questions regarding essential obligations or constraints that may interfere with the students' participation in the course and other concerns that students would like the instructor to be aware of.

OER and OEP: Creating Learning Outcomes

The author (instructor) is the Calculus 1 course coordinator. She and other Calculus 1 instructors ensured that the competencies and skills needed to successfully complete Calculus 1 are clearly aligned with the specific learning outcomes of the course. Ehlers (2011) wrote that a spectrum of open and flexible practices can influence the design of more open student learning outcomes. OER and OEP both contributed to the clear statements-goals or student learning outcomes (SLOs). The author presents one specific SLO that was driven by both the OER and OEP: *Upon successful completion of the course, students will be able to apply knowledge of derivatives and antiderivatives to real-world problems.* Most students in Calculus 1 and other mathematics courses usually ask instructors the question, "Why do we need to study and learn this or that topic?" For instructors, the best way to turn this around is to motivate the students to research why a certain concept/topic is a must-learn? This then opens the discussion for the whole class. This easy to implement teaching practice is quite useful on improving student engagement. For the case study presented here, the author created an online assignment requiring each student to submit a paragraph rationalizing why a certain topic, e.g., finding the least amount of fencing material to cover a specified area, is important and describes a specific experience they can share to personalize the reason. The response level via online submission from students was decent. It was during the synchronous Zoom meeting discussion that students' faces lit up, i.e., the big "AHA" moment for students in the class which every instructor love to experience. The inclusive and culturally responsive approach made this possible. Students from different racial, ethnic, cultural, and economic backgrounds could truly understand why it is necessary to learn how to find the least amount of material to fence off a certain area. The second task of personalization of experience required as part of the assignment is an important aspect of ensuring equity has been embedded in the activity.

Data Collection and Analysis

Student Learning outcome (SLO #4:) *Upon successful completion of the course, students will be able to apply knowledge of derivatives and antiderivatives to real-world problems.*

For brevity, the learning objective stated above and emphasized in this research paper has been assessed in a uniform fashion every semester. Five of the twenty multiple-choice questions of the comprehensive final exam have been classified to measure the students' end-of semester differential and integral Calculus knowledge and its applications. A special scantron sheet is provided per student for uniformity and easy data collection. Two of these five problems are shown in Figures 1 and 2 as examples. Figure 1 shows a multiple-choice question that assesses the students' knowledge of translating word problems to equations and applying their differentiation skills to answer the question, in this case, rate of change of the depth of the water. Figure 2 is a multiple-choice question dealing with integration to find the area bounded by the curves or lines. These two questions measure the two main competencies students must acquire as Calculus 1 students. For this study, the data included in the research are Fall 2016-Spring 2023 highlighting the three years of pre-OER implementation (Fall 2016-Fall 2019) and four years of post-OER transition/implementation (Spring 2020-Spring 2023).

5. A conical tank (with vertex down) is 12 feet across the top and 18 feet deep. If the water is flowing into the tank at a rate of 18 cubic feet per minute, find the rate of change of the depth of the water when the water is 10 feet deep.

(a) $\frac{9}{40\pi}$ ft/min
(b) $\frac{9}{100\pi}$ ft/min
(c) $\frac{81}{20\pi}$ ft/min
(d) $\frac{81}{50\pi}$ ft/min

Figure 1. Testing Students' Skills on Applying of Differentiation Knowledge

16. Find the area of the region bounded by the graphs of the equations

$$y = x^3 + x, \quad x = 4, \quad y = 0.$$

Round your answer to the nearest whole number.

(a) 96
(b) 84
(c) 72
(d) 64

Figure 2. Testing Students' Skills on Applying of Integration Knowledge

Calculus 1 is considered as a core course for STEM majors. One way to truly assess students' knowledge on the two important topics, differentiation, and integration, is to be able to see students' step-by-step detailed answers. To measure this, in addition to these five multiple choice questions, two exam questions (word problems) classified as "essay or short response" questions where students are required to write down their detailed

answers were administered. The special scantron sheet has ample space for students to write their answers to the two questions. Refer to Figure 3. The first short answer question centers on assessing students' skills on optimization which is an application of differential calculus. The second question measures students' skills integral calculus. The students are supposed to sketch the graph and see the application of integration as the technique to find the area represented by the definite integral.

CALCULUS 1 **TEST FORM: A**

FINAL EXAM – SHORT ANSWER Portion **Total Points: 20**

INSTRUCTIONS: You must show all of your work to receive full credit. Write LEGIBLY.

1. A rectangular page is to contain 28 square inches of print. The margins on each side are $1\frac{1}{4}$ inches. Find the dimensions of the page such that the least amount of paper is used.

2. Evaluate the definite integral.

$$\int_5^9 3|x^2 - 36|\, dx.$$

Figure 3. Calculus 1 Final Exam Short Answer Portion

Trend Analysis Results

Navarra-Madsen and Ingram (2024) studied the effectiveness of OER. Figure 4 is a histogram taken from their paper showing the performance rates of students in Calculus 1 per semester. To explain further the equity-mindedness aspect related to OER implementation emphasized in this paper, Figure 4 shows that the students' performance were not tremendously affected by COVID-19. Spring 2020 and Fall 2020 SLO #4 rates were not that different from the rates before OER implementation.

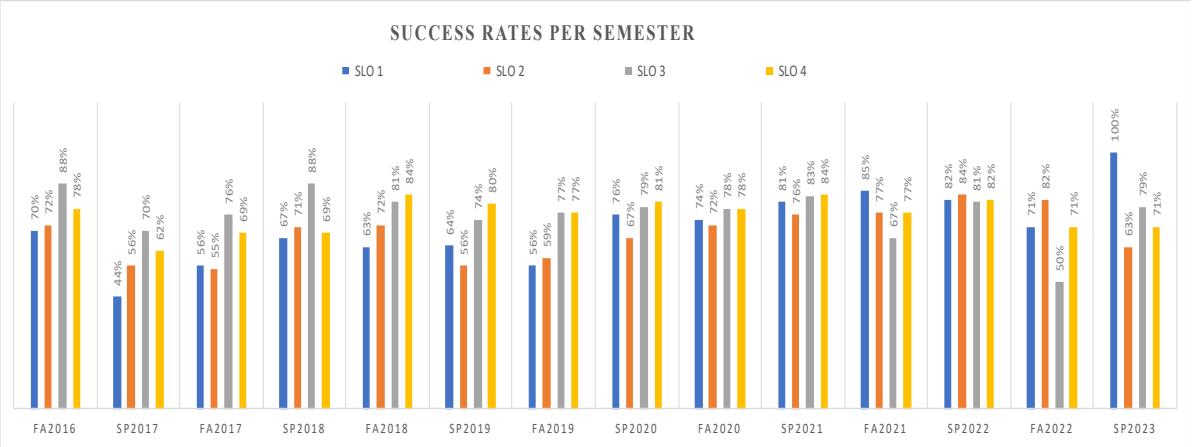

Figure 4. Rates Per SLO Per Semester (Fall 2016-SP2023) (From "OER and Calculus: Pre- and Post-Pandemic", by Navarra-Madsen & Ingram, April 2024, https://www.2024.ihses.net/)

Navarra-Madsen and Ingram (2024) included a table showing the pre-OER and post-OER students' performance.

Table 1. Success Rates in Four SLOs per Group (OER)

Groups	**SLO 1**	**SLO 2**	**SLO 3**	**SLO 4**
Pre-OER	60%	63%	79%	74%
Post-OER	78%	73%	74%	78%

Discussion

The Method Section describes a set of equity-minded practices, classified under OEP done during the implementation of OER. Aside from the use of two forms, OpenStax Calculus 1 free textbook and MyOpenMath HW platform, instructors were made aware of ensuring that students were provided clear and uniform instructions on day 1 of each semester. Zooming in and examining closely the OER effect on SLO #4, the pre-OER rate was 74% while the post-OER rate is 78%. The 4% increase in SLO #4 performance does not provide the full story of the equity-minded teaching practices done. Given that the first formal implementation of OER and OEP was amid the pandemic, one positive result is that the students' performance did not suffer much in the Spring 2020 and Fall 2020.

This small study presented here was done at the largest university focused on women, 90% women of 15664 students as of 2023 data collection. This research article provided a small study of what could be done by other higher educational institutions serving mainly women and minorities where 65% are people of color, i.e., non-white. In this study some equity-minded practices have been done in Calculus 1 classes in implementing OER and OEP. Why study Calculus 1? Given that this course is the gateway to success of STEM majors, there is a need for more institutions to create institutional changes to ensure that Calculus is not a barrier but a crucial steppingstone to STEM degree completion. Another important part of this study is that the institution where this study was done is also classified as Hispanic-Serving Institution (HSI) in North Texas. A small study like this can be a model for HSIs with STEM degree program offerings.

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Stock Price Trend Prediction Using Machine Learning and Sentiment Analysis

Arian Azmoudeh
University of Oregon, United States, https://orcid.org/0009-0005-4065-8223

Dr. Suman Saha
Pennsylvania State University, United States, https://orcid.org/0009-0005-9440-6785

Abstract: Assessing a company's value in financial markets heavily relies on stock prices, a critical metric for investors, analysts, and researchers. Predicting stock prices has become a cross-disciplinary interest involving finance, economics, and computer science. The challenge stems from intricate factors like company performance, economic conditions, industry trends, and market sentiment, making stock price movements dynamic and unpredictable. Understanding these interconnected dynamics is crucial for accurate predictions in the evolving stock market. Previous studies suggest a link between tweets and stock price fluctuations. Combining fundamental and technical analyses provides a comprehensive view for investors. This paper explores machine learning techniques, including sentiment analysis and deep learning, to predict stock prices. Results indicate market sentiment and breaking news significantly influence stock and cryptocurrency prices, causing sharp fluctuations. The paper emphasizes the combined use of sentiment analysis and machine learning models, assessing the effectiveness of models like Prophet and LSTM. It reviews recent research on the subject and outlines potential directions for future work, highlighting the importance of sentiment analysis in predicting stock trends in the complex financial landscape.

Keywords: Stock Price Prediction, Machine Learning in Finance, Algorithmic Trading, Time Series Forecasting, Deep Learning in Finance, Natural Language Processing, Sentiment Analysis, Prophet and LSTM, Predictive Analytics, AI in Investment Analysis, Financial Market Prediction, Financial Risk Management, Investment Strategies

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Introduction

Worldwide investors face a considerable obstacle when investing in the stock market due to its highly profitable but extremely unstable nature. However, the latest advancements in machine learning have proven to be immensely beneficial in enhancing investment decisions and risk management in financial markets (Yenkikar &

Babu, 2023). With the ability to analyze vast amounts of complex data, machine learning can identify concealed patterns and predict stock price trends based on historical data, leading to superior investment decisions (Patel Vraj et al., 2023). Additionally, machine learning algorithms can offer early warning signals to detect potential risks and prevent financial losses. By harnessing this technology, financial institutions can gain a competitive edge in the market, minimize human errors, and enhance overall performance (Kumar et al., 2023).

Studies have shown that the vast array of digital information available on the internet, including news articles from reputable news sources and social media platforms like Twitter, can impact investors' perspectives. Furthermore, news regarding individual companies has a significant influence on stock prices. As a result, investors must stay informed about the latest developments and announcements from specific companies to adjust their investment strategies accordingly. This study emphasizes the significance of keeping up to date with company news and its potential impact on the stock market (Kim et al., 2023).

Machine learning has become increasingly influential within the realm of trading philosophies. It plays a crucial role in both fundamental and technical analysis. Fundamental analysis examines economic factors, supply and demand dynamics, and financial metrics impacting stock price movements. Conversely, technical analysis entails the examination of chart patterns and market behavior (Alshara, 2022).

Incorporating machine learning advancements has led to improved market analyses. For instance, sentiment analysis models assess news and social media to ascertain market sentiment. Likewise, algorithmic trading strategies utilize past data to recognize patterns and execute trades autonomously. This integration of machine learning has introduced novel approaches to comprehending and predicting market trends (Gunturu et al., 2023). It is interesting to note that various research studies have been conducted in Machine Learning to predict stock prices. One of the popular approaches is to develop an artificial neural network and feed in historical asset data as a feature to create predictions. This technique has shown promising results in the past and continues to be an area of active research. Two of the most prominent models used for this purpose are Long Short-Term Memory networks and Prophet (Gunturu et al., 2023). LSTM, a form of recurrent neural network tailored for managing time series data, is a suitable option for predicting stock prices (Chaudhary et al., 2023). It is trained in historical stock price data with a defined window size representing the number of past days considered for prediction. LSTM models are effective at modeling sequential data and can learn complex relationships within the data (Patel Vraj et al., 2023). On the other hand, the Prophet Model, developed by Facebook, is a versatile time series forecasting tool that has gained popularity in stock market prediction. Although it may not capture intricate patterns as effectively as LSTM can, its simplicity and robustness make it a valuable tool for identifying overall trends and making informed decisions in the stock market (Kumar et al., 2023).

However, analyzing only the historical price series is not sufficient, as there are many other factors that influence asset prices. To create a well-rounded portfolio, it is crucial to consider multiple factors in the analysis. Even during the COVID-19 pandemic, sentiment analysis of news articles has shown positive results despite the global economic instability. The COVID-19 pandemic has brought about a change in people's

viewpoints on diverse subjects, including their approach to stock market investments. With easy access to financial information and investment tools, more retail investors have become interested in the stock market (Kim et al., 2023). Many fintech companies charge high fees for portfolio management services, making it difficult for small investors to take advantage of their offerings. As a result, more and more researchers and investors are creating their investment strategies, relying less on fintech and banks (Varaprasad et al., 2022). Innovative researchers now use natural language processing techniques to predict stock prices. They analyze opinions from diverse sources like social media, news articles, customer feedback, and corporate communication. This approach has numerous marketing applications, and sentiment analysis is essential for effective human communication (Yenkikar & Babu, 2023).

Sentiment analysis has become increasingly popular due to its potential applications, particularly in mining and evaluating public opinions expressed in text or speech. The method involves analyzing the sentiment or opinion expressed, the target object or topic, the time of expression, the person expressing the opinion, the reason for the expression, the opinion qualifier, and the opinion types (Kim et al., 2023). Different levels of sentiment analysis can be applied, such as document, sentence, entity, and aspect, and can be implemented in a supervised, unsupervised, or semi-supervised approach.

Twitter is frequently utilized to obtain sentiment data within crypto-communities, forex, and other stock markets. Performing sentiment analysis can be a demanding undertaking, with numerous obstacles to overcome, such as marketing-oriented tweet replication and the existence of automated bot tweets. Focusing on a specific influencer who significantly impacts the market is highly beneficial. This is because their tweets are considered more reliable and accurately reflect the sentiment of a larger portion of the market. Furthermore, extraneous elements present in tweets, including hashtags, profile mentions, and URLs, can adversely affect the precision of sentiment analysis (Yenkikar & Babu, 2023). Therefore, it is essential to pre-process tweets prior to analysis to reduce the likelihood of interference, especially when dealing with sarcasm (Chaudhary et al., 2023).

Relying solely on sentiment analysis or machine learning predictions for stock market forecasting may need to be revised, particularly given the inherent volatility of financial markets (Srivastava et al., 2022). Researchers have discovered that a new approach combining the power of machine learning with sentiment analysis holds the key to more accurate stock price trend predictions. This innovative strategy recognizes the dynamic nature of financial markets, where sentiment-driven fluctuations often occur rapidly and unpredictably. By synergizing these two methodologies, researchers are better equipped to capture the intricate interplay between market sentiment and quantitative data, leading to more robust and reliable stock price forecasts. This innovative approach signifies a fundamental shift in the field, demonstrating its potential to enhance the precision of stock market predictions – a critical development in the face of ever-changing market conditions (Shah et al., 2022).

Our research delved deep into stock market prediction, utilizing cutting-edge machine-learning techniques to uncover valuable insights. Our findings shed light on the vast potential of combining sentiment analysis with machine learning algorithms. Our study's remarkable discovery is the incredible effectiveness of merging news

sentiments with machine learning models. This innovative approach has allowed us to achieve unparalleled accuracy and reliability in our stock price trend predictions, especially in buoyant sentiment markets, where our prediction accuracy is more than 80 percent. By harnessing this dynamic synergy, we have significantly enhanced the precision and dependability of our stock price forecasts.

The structure of the document continues as follows. A summary of previous studies in this area is provided in the subsequent section. Section four provides insights into stock market forecasting and sentiment analysis. The fifth section explains the proposed model and methodology for implementation. The results and discussion are presented in the sixth section, and finally, the study concludes with the seventh section, which covers limitations, conclusions, and potential avenues for future research.

Related Work

Yenkikar (Yenkikar & Babu, 2023) paper examines using Machine Learning and sentiment analysis to predict stock prices. They mention the difficulty of predicting stock prices due to the complexity of financial markets. The authors compare 13 different models, including Linear Regression, Naive Bayes, and LSTM, on five datasets of financial news. The results indicate the potential of combining machine learning techniques with sentiment analysis to aid in stock price prediction. Patel, Kumar, and Varaprasad discuss in their research (Patel Vraj et al., 2023) (Kumar et al., 2023) (Varaprasad et al., 2022) the potential of using LSTM to predict stock prices. LSTM stands out as a potent machine learning technique capable of capturing long-term dependencies in time series data. The study compares the performance of LSTM to traditional methods and highlights the potential of machine learning to improve prediction accuracy and facilitate profitable trades in the stock market. Kim (Kim et al., 2023), in their paper, offers insights into how COVID-19 and the RU War have affected the stock market. The study mentions that sentiment analysis can help investors make informed decisions during high-volatility periods, providing a more accurate picture of market sentiment and potential future trends. Gunturu (Gunturu et al., 2023) and Mehtab (Mehtab & Sen, 2020) compared various Machine Learning and Deep Learning techniques to identify profitable stocks. This research had three main goals. Firstly, to assess and compare different prediction models. Secondly, to create a new hybrid model that can predict stock market trends better than existing models. Finally, use historical stock data from various industries to test and evaluate the performance of these models. The models are tested on a historical dataset of different industrial sectors' stocks and assessed based on various performance metrics.

Chaudhary (Chaudhary et al., 2023), Srivastava (Srivastava et al., 2022), and Shah (Shah et al., 2022) believe that predicting stock prices in unstable financial markets is a challenging task, and it is crucial to consider people's emotions while conducting research. They proposed a two-part model that employs LSTM to analyze stock patterns and forecast prices. In addition, they integrated sentiment analysis to predict the direction of stock movements based on news sentiment. Their findings indicated that the model outperformed conventional statistical methods in terms of accuracy. The combination of sentiment analysis and machine learning holds

immense potential for improving stock market prediction. Bharti (Bharti et al., 2022) studied how sentiment data from news headlines can be used with daily stock data to predict stock market trends and prices. They suggest using XGBoost for trend prediction and LSTM for price prediction. Their research shows that combining both datasets using ensemble techniques and time series models improves prediction accuracy compared to traditional methods.

Behera (Behera & Chinmay, 2022), Kavinnila (K et al., 2021), and Jiang (Jiang, 2021) recognize the intrinsic challenge of forecasting stock market patterns and emphasize the increasing adoption of deep learning methods to tackle this issue. Their research delves into the LSTM model as a viable solution for predicting stock market prices. The ultimate aim of their study is to equip investors with accurate insights to support their investment decisions. Alshara (Alshara, 2022) explains that predicting stock prices in an uncertain market is difficult, but machine learning methods can help. These methods include technical analysis, fundamental analysis, time series analysis, and statistical analysis. The paper focuses on using Prophet and LSTM models to forecast stock prices and compares their accuracy and performance. The results show that LSTM models are better at predicting future stock prices than the Prophet algorithm. Sonkiya (Sonkiya et al., 2021) explores a combination of technical analysis involving technical indicators and sentiment analysis of news headlines using BERT. They employ a Generative Adversarial Network (GAN) to predict stock prices for Apple Inc. The proposed model, S-GAN, outperforms traditional time series forecasting models such as GAN, GRU, LSTM, and ARIMA. The paper discusses the model's ability to predict trends in stock market data and emphasizes its practical applications in daily stock market investments, inter-day trading, and real-time stock market prediction for intraday trading.

Mehta (Mehta et al., 2021) used sentiment analysis on Twitter data to predict stock market trends and discovered that the ARIMA model provides the best accuracy for stock price prediction Vijh (Vijh et al., 2020) studies predicting stock market returns using ANN and Random Forest techniques. The study aims to predict the next day's closing price for stocks from various sectors. Low values of RMSE and MAPE indicate that the models are efficient in predicting stock closing prices. ANN outperforms RF in predicting stock prices, as evidenced by RMSE (0.42), MAPE (0.77), and MBE (0.013) values. Shahi (Shahi et al., 2020) studied two deep-learning methods, LSTM and GRU, for predicting stock market performance. They compared the two methods and evaluated how adding financial news sentiment impacted the accuracy of the predictions. The study found that adding financial news sentiment improved the accuracy of both LSTM and GRU models. Both LSTM and GRU models perform better when financial news sentiments are included. The LSTM-News model had a lower MAE than the GRU-News model, indicating better predictive accuracy. However, there was no significant difference in the coefficient of determination between the two models, meaning that the direct correlation between actual and predicted prices is similar for both.

Our approach distinguishes us from others in two significant ways. Firstly, we concentrate on gathering data from Twitter's social media influencers, who tend to yield greater response rates to their tweets. Secondly, we go beyond relying solely on machine learning models and instead utilize a weighted average approach that assigns

importance to each model. We also place greater emphasis on sentiment analysis to accurately predict stock trends.

Theoretical Background

Forecasting stock prices is a challenging task due to the many variables and factors that can influence them. These factors are broadly categorized into two categories: microeconomic and macroeconomic variables. Microeconomic factors include variables associated with individual firms or entities, such as financial performance, management decisions, and industry-specific conditions. On the contrary, macroeconomic variables encompass more extensive economic factors, including inflation rates, interest rates, GDP growth rates, and geopolitical events like wars and natural disasters. These factors can indirectly impact the stock prices of individual companies by influencing the overall market sentiment.

When it comes to forecasting trends in financial markets, investors and traders have historically relied on two types of prediction methods: fundamental analysis and technical analysis. However, a significant advancement in recent years has been the integration of machine learning techniques into the prediction landscape. These cutting-edge methods are proving to be powerful tools for predicting stock market behavior, utilizing algorithms and data-driven insights to make predictions based on historical and real-time data. This exciting development is opening new horizons in the realm of financial market forecasting.

Technical Analysis

Technical analysis involves examining and analyzing historical prices of securities, commodities, or currencies to forecast future price movements. Technical analysis aims to recognize patterns in past data to predict market movements. Technical analysis involves recognizing trends, support and resistance levels, as well as chart patterns such as head and shoulders, double tops, and triangles. These patterns are believed to repeat over time, and technical analysts use them to predict future price movements. Ultimately, the success of technical analysis relies on the trader's proficiency and experience in interpreting charts and recognizing patterns.

Fundamental Analysis

Fundamental analysis is a systematic approach to assessing a given stock's inherent value by examining its underlying economic and financial factors. Fundamental analysis is based on the idea that the value of a company is determined by its underlying economic and financial factors. This analysis includes examining a company's financial statements, management team, industry trends, and macroeconomic indicators to assess whether the stock is overvalued or undervalued. One of the primary financial statements used in fundamental analysis is the income statement, which outlines a company's revenue, expenses, and net income over a specific period. By collecting and processing information before it affects the market, investors can decide to sell stocks

about to decrease in value or buy stocks about to increase. Unlike technical analysis, fundamental analysis includes news as a primary data source. However, automating the interpretation of news can be a very complex task. This is where sentiment analysis comes in.

Machine Learning Techniques

The advent of machine learning marks a new chapter in stock price prediction, providing an extensive range of models and methods. This empowers investors and analysts to leverage the potency of time series prediction and sentiment analysis for better-informed choices. We will explore each of these components and highlight some of the most commonly employed models and techniques.

Time Series Prediction

Time series prediction is an essential technique for identifying trends and patterns in market movements. It involves using past data to predict future stock prices. To accomplish this, sophisticated machine learning models are utilized, which incorporate techniques such as statistical analysis, regression, and algorithms to analyze historical stock prices and make predictions regarding future movements. The precision of these models is heavily reliant on the quantity and quality of historical data accessible for analysis. Some prominent machine learning models in time series prediction are

- Recurrent Neural Networks (RNNs): The efficacy of Recurrent Neural Networks in modeling sequential data has been well-established, attributed to their capacity to capture intricate dependencies over time. Among RNNs, Long Short-Term Memory networks have emerged as a popular choice for modeling and predicting stock price time series data. Utilizing their distinctive architecture comprising memory cells and gates, LSTMs can effectively grasp long-term dependencies in the data, leading to more precise and dependable predictions. Consequently, LSTMs have emerged as a preferred tool for financial analysts and traders seeking insights to make well-informed decisions in the stock market.

- Autoregressive Integrated Moving Average (ARIMA): Models based on ARIMA are a widely accepted and esteemed approach for predicting time series data. One of their key strengths is their ability to break down a time series into its constituent parts, such as trend, seasonality, and noise. This provides a rigorous and systematic approach to analyzing and predicting patterns within the data, enabling more accurate forecasts of future trends. By uncovering underlying patterns and identifying anomalies, ARIMA models provide a robust tool for businesses and organizations aiming to make informed decisions through dependable predictions of future trends.

- Prophet: Prophet is a time-series forecasting tool developed by Facebook that is specifically designed for analyzing daily observations that exhibit patterns on different time scales. It is a highly useful tool for investors who need to analyze stocks that experience frequent fluctuations. With its advanced algorithms, Prophet can

effectively model a wide range of seasonal and non-seasonal patterns, making it a valuable asset for anyone looking to make informed decisions based on data-driven insights.

Sentiment Analysis

Sentiment analysis is the process of analyzing news and other forms of communication to determine the emotional tone of the message. This task can be accomplished through the application of natural language processing and machine learning algorithms, which have the capability to swiftly analyze extensive datasets and categorize the sentiment of individual pieces of content. One way to predict market movements is through sentiment analysis, which involves analyzing the emotional tone of news articles and social media posts. By monitoring the amount of positive or negative news surrounding a specific company or industry, We can predict whether the stock price will increase or decrease. The goal of sentiment analysis is to provide insights into investor attitudes and emotions towards a particular stock, which can be used to make informed investment decisions.

Methodology

This study proposes an innovative approach to predicting stock price trends, which involves three stages, namely sentiment analysis, Machine Learning price prediction, and trend prediction, as illustrated in Figure 1.

Figure 1. Methodology

Each stage has different requirements and approaches to provide accurate predictions. The final stage focuses on trend prediction by using the outcomes of the previous two stages to forecast the future trend of the stock. Our research methodology was distinct as we focused on social media influencers within our targeted stock market instead of collecting all recent tweets from the Twitter API. These influential individuals are regarded as having a more significant impact on the market, and their tweets are considered more reliable. Furthermore, we adopt a weighted approach methodology that combines LSTM, Prophet, and market sentiment. Unlike traditional studies that rely on a single model, our holistic strategy considers the results of each model and technique individually, allowing for easy integration of additional models and opportunities for growth. We allocate weights to each of these factors based on their respective significance and impact on market dynamics. The

market prediction is then determined by interpreting and combining all of our Market Weight values, which represent the overall market outlook. Positive values suggest a bullish trend, negative values indicate a bearish trend, whereas a value of 0 implies a Sideways market.

Database Descriptions

In order to conduct a comprehensive analysis of stock prices, it was imperative to have access to a significant amount of historical data. After careful consideration, we opted to leverage the Yahoo Finance platform due to its reliability and wealth of information on the long-term performance of various financial data. As depicted in Figure 2, the data furnished by Yahoo Finance was both precise and dependable. Furthermore, aside from stocks, the platform also offered access to historical data pertaining to an array of financial instruments such as ETFs, mutual funds, and currencies.

In addition to historical data, we also required up-to-date news and information on market conditions. With more than 300 million monthly active users, Twitter is an excellent source for current news on global events, including stock-specific news. While it's difficult to estimate the daily tweet count due to various factors, such as the day of the week and time of year, it's generally believed that over 500 million tweets are sent per day. To access this valuable information, we utilized the Twitter developer API to retrieve news based on hashtags or recent posts from specific users, as shown in Figure 3. To optimize the use of this resource, it's best to focus on social media influencers within our targeted stock market, as their tweets have a more significant impact on the market and are considered more reliable, along with specific hashtags like BTC, rather than collecting all recent tweets from Twitter.

Figure 2. Historical Bitcoin data

There are two main criteria to consider when identifying someone as an influencer in a specific stock. Firstly, they should have considerable followers, often exceeding 100,000, and keep their page active. Secondly, their tweets should consistently receive a significant amount of attention through retweets and likes, and you can access this data using the Twitter API. This approach provided us with a dataset of sentences from influencers and tweets containing the specific word we sought. To avoid duplication, we narrowed down the news corpus to only unique news articles.

```
bitcoin last high before dump this is not financial advice

bitcoin is growing smarter faster and stronger behind wall of encrypted energy
```

Figure 3. Sentences in Twitter Posts

Sentiment Analysis

Twitter Sentiment Analysis is a process that involves several steps to extract meaningful information from tweets. The first step in this process is pre-processing the tweets, including several sub-steps such as data cleaning, stop word elimination, speech tagging, stemming, and tokenization. Data cleaning involves removing any unwanted characters, symbols, or URLs from the tweet text. Stop word elimination involves removing common words such as "the", "and", and "is" from the tweet text as they do not add any value to the sentiment analysis. Parts of speech tagging involve identifying the parts of speech of the words in the tweet text, such as nouns, verbs, and adjectives. Stemming involves reducing the words to their root form to capture their essence. Tokenization is the process of breaking down the tweet text into individual words. Finally, after completing these steps, the text is converted to lowercase characters to make it uniform. This pre-processing step is essential in preparing the input data for the sentiment classifier as it ensures that the text is clean, consistent, and meaningful.

To complete the sentiment analysis of tweets, a sentiment classification model is necessary. However, building such a model from scratch requires significant effort, including creating a labeled dataset and training the model to recognize various sentiment types. Fortunately, there are simpler and more reliable options available, such as using fine-tuned models like hugging-face RoBERTa (Wolf et al., 2019) to achieve accurate analysis of English-language text and generate sentiment predictions for each instance.

Another popular tool for sentiment analysis is the TextBlob library (Loria, 2018), which includes a polarity function that measures sentiment on a scale of -1 to 1. By tallying the occurrences of positive, negative, and neutral emotions in recent tweets, we can assess the overall polarity of the sentences. A score of 0 indicates neutral sentiment, a score less than 0 suggests negativity, and a score greater than 0 implies positivity, as illustrated in Figure 4. Both methods are excellent and produce consistent results.

	Tweet	Polarity
6304	test resistance. too mani crack in the system ...	0.025
7816	rt @rovercrc: bitcoin go parabolic! 🔥 👇	0.000
928	@documentingbtc wrong wrong wrong western unio...	-0.220

Figure 4. Polarity of Tweets

Time-Series Prediction Models

The third phase involves utilizing historical data of assets and feeding it into the time series prediction models. There are multiple machine learning models available, but this paper will only discuss two of them.

LSTM Model

The initial model, referred to as Long Short-Term Memory (LSTM), is a type of recurrent neural network explicitly crafted for managing time series data. LSTM can identify long-term dependencies in the data as long as the training data is properly segmented into sub-sequences with a well-defined beginning and end. The size of these subsets must be defined by the researcher, as a window that is too small can inhibit the model's memorization capacity, while a window that is too large will cause an execution bottleneck during model training. An ordinary LSTM model typically consists of three layers: an input layer, an LSTM layer with a size of 'n', and an output layer. The output layer is responsible for consolidating the input received from the LSTM layer into a final prediction value.

The model presented in this paper introduces an extra pre-processing step for the input data, formatted according to a single parameter, specifically, the window size. This parameter specifies the number of days to be considered 'dependent' for stock price prediction. For instance, with a window size of 't = 30', the model incorporates information from the preceding 30 days leading up to the prediction day 'd'. A larger window size provides the model with a more extensive historical context, but it also increases the computational cost.

In contrast to the random data splitting commonly applied in artificial neural networks, the separation between training and validation data in this work is not random. Since the data represents a historical time series, the values are interconnected with their predecessors. For example, the price on day 'd' is directly influenced by the prices on the preceding days 'd - 1', 'd - 2', and so on. Therefore, the data splitting is conducted based on the price dates. Specifically, an 80% training and 20% validation split is employed, where data from the years 2021 to 2022 is used for training, and data from the year 2023 is allocated for validation.

Evaluation Metrics: The metric used to assess the accuracy of the model is the Root Mean Squared Error, which represents the square root of the mean squared error. RMSE is a commonly employed evaluation metric in regression tasks, and it provides a measure of how closely the model's predictions align with the actual values. Lower RMSE values indicate better predictive performance, as they signify smaller prediction errors.

Prophet Model

Prophet is a powerful forecasting library developed by Facebook specifically for time series data. Its non-parametric model can easily predict a wide range of data, including stock prices, and can easily handle missing data, outliers, and multiple seasonality patterns. The popularity of its user-friendly interface makes it a favored

option for forecasting trends in the stock market. Getting started with Prophet is easy: simply rename your columns to "ds" for the date column and "y" for the target value column. From there, you can create a new Prophet object and pass your historical data to its fit method. This process trains the model on your historical data, setting the stage for future predictions. When you're ready to make predictions, the model assigns a predicted value labeled as "yhat" to each future date. These predictions are organized into a forecast object, which includes the "yhat" column for forecasted values, as well as additional columns providing insights into the different components of the forecast and information about the uncertainty associated with the predictions.

Trend Prediction

To accurately forecast market trends, it is crucial to harness the capabilities of multiple models. We have compiled data on the prevailing market sentiment and the predictive results produced by the LSTM and Prophet models. For a comprehensive grasp of the market trend, it is essential to amalgamate the insights derived from these models.

A weighted average is a mathematical computation that determines the average of a group of numbers by allotting varied weights or degrees of importance to each value in the set. This indicates that specific values impact the final average more than others. Weighted averages are widely utilized in various industries, including finance, statistics, and data analysis, as they emphasize specific data points based on their relative significance. We thoughtfully allocate weights to the LSTM and Prophet models' predictions through the Predictive Process, considering their past performance and the current market situation. These weight assignments are customizable to reflect different confidence levels in each model, making it versatile for various market scenarios, from tumultuous to calm conditions. Furthermore, this method's inherent flexibility allows for effortless integration of additional models, when necessary, as illustrated in Figure 5.

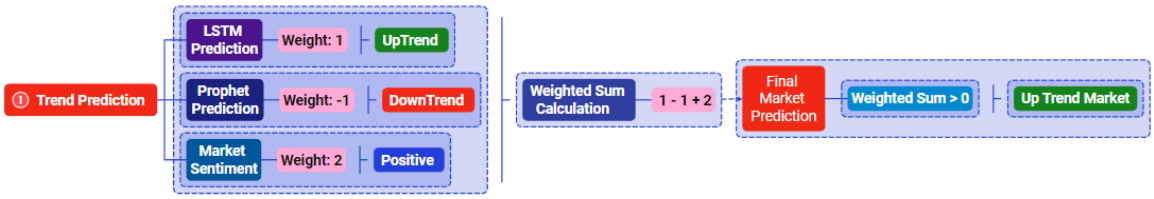

Figure 5. Trend Prediction

This approach boasts impressive versatility, allowing you to balance the weighting between LSTM and Prophet models. To facilitate trend analysis, we attribute a weight of 1 to LSTM and Prophet models for 'UpTrend' and a weight of -1 for 'DownTrend'. Nevertheless, the true potential of this method shines when you strategically allocate higher weights to models that have a proven track record of historical accuracy.

Incorporated into our predictive approach is sentiment analysis, providing an additional layer of precision to the

process. A sentiment labeled as 'Neutral' is given a weight of 0, indicating a neutral impact on the market. However, a sentiment labeled as 'Positive' is assigned a weight of 2, amplifying its positive influence. Conversely, a sentiment labeled as 'Negative' is given a weight of -2, intensifying its negative effect on the final prediction. By taking market sentiment into account, we can more accurately predict market dynamics by recognizing the psychological factors that drive them.

The reason for assigning higher weights to 'Positive' and 'Negative' sentiment is rooted in the distinctive responsiveness of financial markets to market sentiment, particularly those tied to cryptocurrencies. Favorable news has the potential to lead to a surge in prices, whereas unfavorable news can result in a significant decline. Our approach acknowledges the exceptional sensitivity of the market to significant news events, resulting in more accurate predictions.

The final outcome is determined by calculating a weighted sum that considers the impact of the LSTM and Prophet models, as well as market sentiment. This approach provides a comprehensive assessment of all the factors involved in the analysis. When the weighted sum exceeds 0, it signals an optimistic future with an 'UpTrend Market'. Conversely, if the sum falls below 0, it predicts a pessimistic outlook with a 'DownTrend Market'. When the weighted sum reaches 0, the market is deemed directionless, resulting in a 'Sideways Market' that hints at a stable or ranging market.

It's worth emphasizing that customizing and refining these models according to your own stock data and desired level of confidence is essential. Predicting stock prices is a challenging undertaking, and even the most advanced models cannot ensure perfect precision. Nonetheless, adopting an integrated approach like this can provide more reliable guidance for informed decision-making in the stock market. Ultimately, the optimal combination method will vary depending on your unique stocks and objectives. It may require some experimentation to identify the most effective approach for your forecasting requirements.

Results and Discussion

Comparing our findings to previous studies by other authors is a challenge due to variations in datasets, news sources, sentiment analysis methods, model architecture, and implementation. Our examination consistently reveals that the LSTM model exhibits superior accuracy compared to the Prophet model. However, it is critical to emphasize the importance of meticulous fine-tuning for all selected models to optimize their predictive performance. Our methodology involves utilizing a dataset sourced from Yahoo Finance, which is meticulously detailed in Table 1. This dataset includes a comprehensive array of financial variables, such as open price, close, high, low, adjusted close price, and trading volume. To fully understand the intricacies embedded within this dataset, we leverage a correlation heatmap, which is visually represented in Figure 6. The heatmap serves as a powerful tool, illuminating the nuanced interrelationships among various variables. Notably, the presence of a dominant dark maroon region in the heatmap signifies highly correlated features, providing insightful cues into

the complex dynamics within the financial dataset.

Table 1. Data obtained from Yahoo Finance for BTC

Date	Open	High	Low	Close	Adj Close	Volume
2021-01-01	28994.009766	29600.626953	28803.585938	29374.152344	29374.152344	40730301359
2021-01-02	29376.455078	33155.117188	29091.181641	32127.267578	32127.267578	67865420765
2021-01-03	32129.408203	34608.558594	32052.316406	32782.023438	32782.023438	78665235202
2021-01-04	32810.949219	33440.218750	28722.755859	31971.914062	31971.914062	81163475344
2021-01-05	31977.041016	34437.589844	30221.187500	33992.429688	33992.429688	67547324782

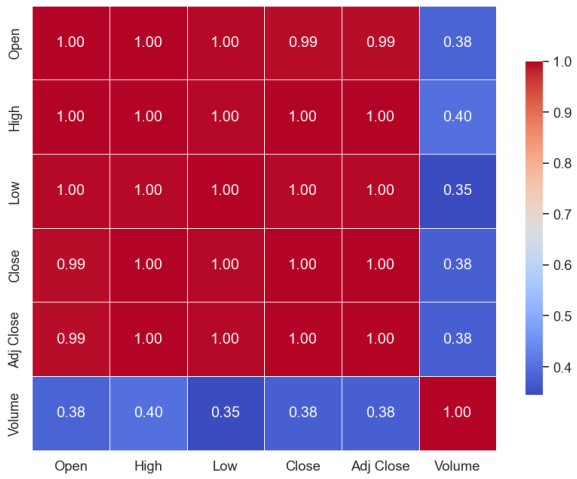

Figure 6. Correlation Heatmap for BTC

The visual representation in Figure 7 clearly demonstrates the impressive accuracy of LSTM models in predicting stock prices. The model's ability to accurately forecast prices, especially during times of high volatility and critical turning points, highlights its effectiveness in capturing complex market dynamics. Additionally, the LSTM model proves to be adaptable to various time intervals, making it a versatile tool for handling both short-term fluctuations and long-term trends.

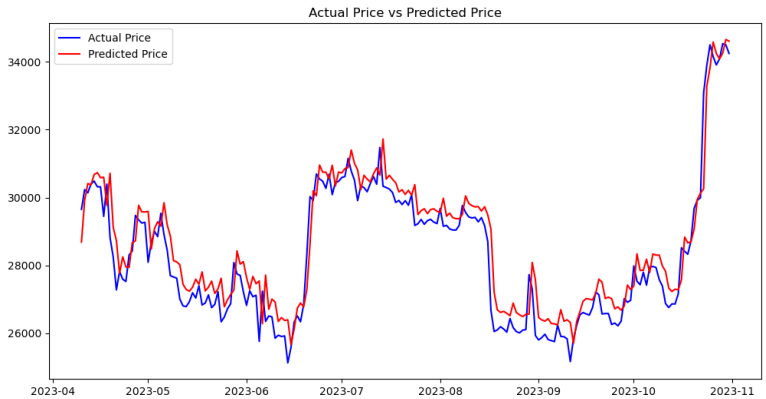

Figure 7. Bitcoin Prediction Using LSTM

During our model evaluation, we determined that training it for 50 epochs would enable continuous learning and parameter adjustment. However, we made a significant observation that after the first 10 epochs, there was no substantial improvement. This finding suggests the need for more efficient training methods, such as incorporating early stopping mechanisms, to cease training when progress becomes marginal.

Figure 8 clearly showcases the impressive predictive abilities of LSTM models when it comes to forecasting future stock trends. By meticulously analyzing extensive historical data, these models are able to effectively decode the intricate patterns and relationships that govern stock price movements. To achieve this, we configure an LSTM architecture using the Keras Sequential API and train it for 50 epochs using the Adam optimizer and mean absolute error loss. Once trained, the model is deployed to make predictions across the entire historical data timeline and generate a 30-day forecast. The output of the model includes the last day's predicted price, actual closing price, and identified market trends. To provide a comprehensive view, this information is presented alongside a graphical representation that compares historical data, prior predictions, and the envisioned 30-day forecast.

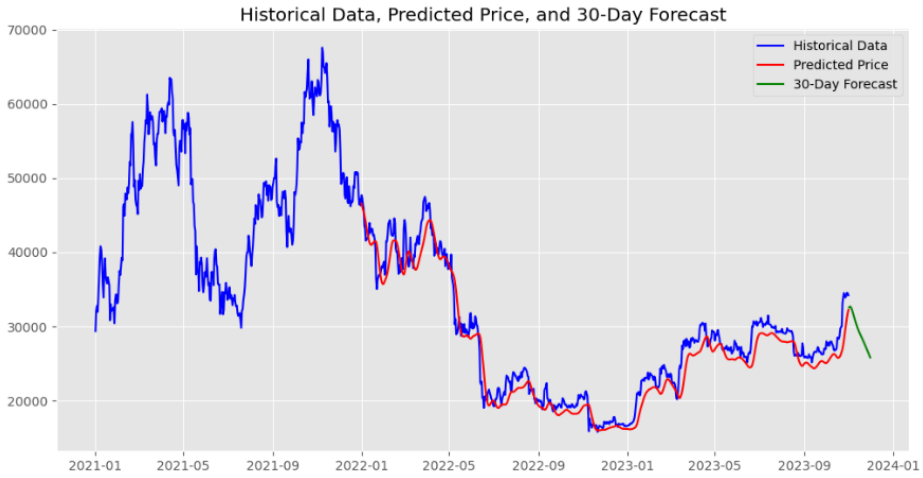

Figure 8. Bitcoin Forecasted Using LSTM

In Table 2, you'll find a thorough breakdown of the evaluation metrics used to measure the effectiveness of LSTM, a highly advanced predictive model designed specifically for forecasting time-series data with a particular focus on stock prices. The Mean Absolute Error (MAE) for the LSTM model is precisely documented as 520.89. These metric gauges the average absolute differences between the model's predictions and the observed actual values. The fact that the MAE is relatively low is a clear indicator of the model's exceptional ability to predict and capture the complex patterns inherent in Bitcoin stock prices. This quantitative assessment goes beyond mere numbers, confirming LSTM's remarkable reliability as a robust tool for forecasting time-series data in the stock market. Thanks to its consistent and precise predictive performance, as demonstrated by the evaluation metrics, LSTM is a dependable resource for stakeholders navigating the intricate dynamics of stock investments.

Table 2. LSTM Evaluation Metrics Result

Evaluation	Result
Mean Absolute Error	520.89
Mean Squared Error	441111.52
R-squared Score	0.92

Based on the analysis depicted in Figure 9, it is evident that the Prophet model excels in producing precise forecasts for the stock market. The graphical representation highlights the concordance between actual and predicted prices and accentuates the model's ability to deliver precise predictions. While the predicted prices may not be as closely aligned as those generated by LSTM, the results are still impressive. Furthermore, the rapidity with which the Prophet model provides predictions within just 5 seconds adds an extra dimension of efficiency to the model's commendable forecasting capabilities. This feature can be particularly useful in time-sensitive trading scenarios where quick and accurate predictions are essential.

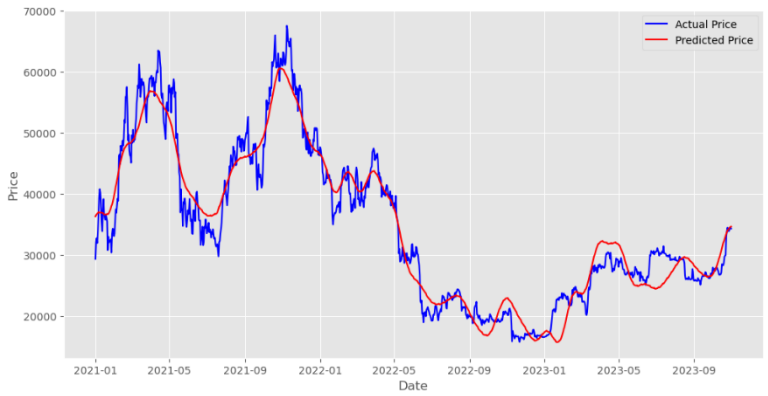

Figure 9. Bitcoin Prediction Using Prophet

Figure 10 showcases the forecasting outcomes produced by the Prophet model, which is renowned for its ability to generate predictions for an extended future timeframe, thanks to its daily seasonality suppression feature. The forecasted data is meticulously evaluated, providing crucial metrics such as Mean Absolute Error. By comparing the last prediction with the actual closing price, the model can discern the market trend and store the trend direction for future reference. The resulting visual representations offer valuable insights into the model's predictive capabilities, including both historical and forecasted data, as well as trend and seasonal components. Notably, the Prophet model predicts a potential Down Trend in the upcoming period, similar to the LSTM model.

Prophet's plot_components function generates three important visualizations, which are the trend, yearly seasonality, and weekly seasonality plots, as depicted in Figure 11. The trend plot showcases the time series' overall direction, highlighting long-term patterns. The yearly seasonality plot reveals annual cycles, while the weekly seasonality plot captures short-term fluctuations occurring weekly. These visualizations offer a comprehensive understanding of how different temporal patterns contribute to the forecast, assisting users in

model interpretation, refinement, and informed decision-making in various domains.

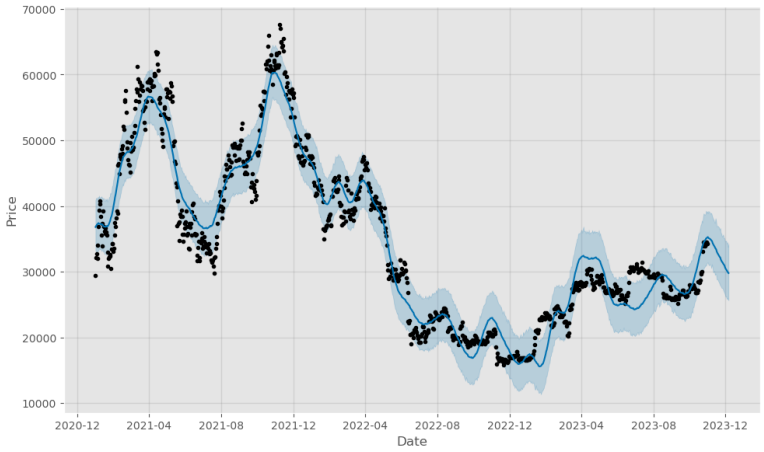

Figure 10. Bitcoin Forecasted Using Prophet

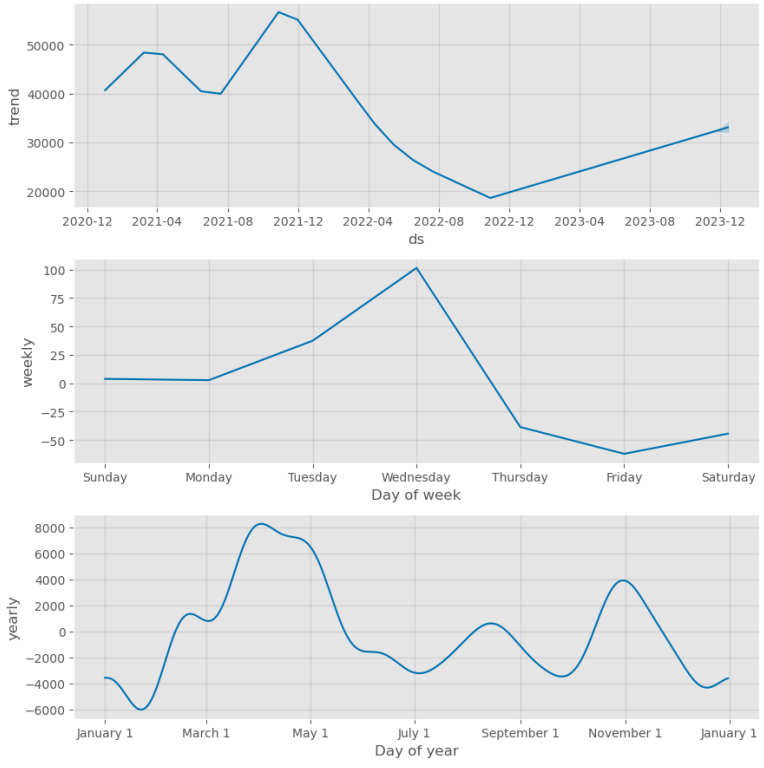

Figure 11. Prophet Seasonal Components

Prophet's model generates a comprehensive set of information for time series forecasting, as shown in Table 3. The "ds" column contains timestamps or dates for predictions, while the "trend" column estimates the overall direction of the time series. The "yhat_lower" and "yhat_upper" columns provide lower and upper bounds, indicating the likely range within which the actual data points will fall. The "additive term" includes additional components like holidays or external influences. The "weekly" and "yearly" components capture periodic

fluctuations on a weekly and yearly basis, respectively. Lastly, the "y_hat" column represents the model's forecasted values, combining the trend, additive components, and seasonal components.

Table 3. Prophet forecast components

	ds	trend	yhat_lower	yhat_upper	additive_terms	weekly	yearly	yhat
0	2021-01-01	39967.332873	32407.166941	39775.435238	-3726.035141	-61.039596	-3664.995545	36241.297732
1	2021-01-02	40110.364903	32536.354041	40285.824392	-3687.620852	-43.624434	-3643.996419	36422.744051
2	2021-01-03	40253.396933	32550.979946	40644.788035	-3640.532027	4.386639	-3644.918665	36612.864907
3	2021-01-04	40396.428964	32548.651471	40769.888356	-3666.109201	3.212052	-3669.321253	36730.319763
4	2021-01-05	40539.460994	32965.583027	40706.765524	-3680.204014	37.931747	-3718.135761	36859.256980
...	...	...	...	...	...	...	...	...
1073	2023-12-10	32517.511479	24576.450161	32811.164617	-3753.485524	4.386639	-3757.872163	28764.025955
1074	2023-12-11	32550.644133	24486.931791	32838.715129	-3918.101657	3.212052	-3921.313709	28632.542476
1075	2023-12-12	32583.776787	24205.402182	32825.322738	-4031.992701	37.931747	-4069.924448	28551.784087
1076	2023-12-13	32616.909441	24419.242908	32669.803929	-4099.747023	102.119479	-4201.866502	28517.162419
1077	2023-12-14	32650.042095	24026.853826	32512.981690	-4358.503038	-42.985888	-4315.517150	28291.539058

Based on the assessment metrics outlined in Table 4, the Prophet model demonstrated outstanding performance. Notably, the R-squared score stood at an impressive 0.90, indicating a robust predictive capability of the model. Additionally, the low MAE score highlights the model's accuracy in making predictions. Overall, these metrics serve as a testament to the Prophet model's efficacy in capturing and forecasting the patterns inherent in the time series data.

Table 4. Prophet Evaluation Metrics Result

Evaluation	Result
Mean Absolute Error	2525.69
Mean Squared Error	10468888.56
R-squared Score	0.90

After conducting a thorough analysis, it is clear that the LSTM model outperforms the Prophet model in terms of forecasting accuracy. This is demonstrated by the LSTM model's ability to generate predictions that closely align with actual values, resulting in significantly lower prediction errors compared to the Prophet model. The LSTM model's exceptional precision in forecasting can be attributed to its aptitude for capturing intricate temporal dependencies and nuanced patterns within the historical cryptocurrency price data.

Additionally, when examining specific metrics such as MAE and R-squared, the LSTM model exhibits superior performance. Its robust predictive capabilities not only align with historical trends but also provide a more detailed understanding of market dynamics. Interestingly, both models anticipate a downward trend in the market, indicating a shared perspective on the likelihood of a confident descent. This convergence reinforces the coherence and reliability of the forecasted trends generated by both models, adding further depth to the comparative evaluation of their forecasting prowess.

In Table 5, all the results of the sentiment analysis process are presented in a detailed manner. This includes important metrics like the polarity score, subjectivity score, and the corresponding sentiments that are associated

with the analyzed text. The polarity score reflects whether the text is positive or negative, providing a deeper understanding of the sentiment's emotional tone. The subjectivity score measures the degree of personal opinion or objectivity expressed in the text. In addition to the tabulated data, Figure 12 provides a scatter plot visualization that helps to enhance the visual understanding of sentiment analysis. By examining this graphical representation, it is possible to explore the relationships and patterns inherent in the sentiment scores in a more nuanced way.

Table 5. Sentiment Analysis Result

	Tweet	reTweet_Count	Polarity	Subjectivity	Sentiment
3270	rt atcherguru: just in: 19,000 bitcoin	295.0	0.0	0.000	Neutral
8131	rt @corechaincrypto: commun question guys? be ...	275.0	0.7	0.825	Positive
4457	rt @btc_archive: bitcoin just broke $19,000 😎	109.0	0.0	0.000	Neutral
5019	rt @saylor: bitcoin is grow smarter, faster, a...	625.0	-0.4	0.700	Negative
2605	rt @bitcoinmagazine: miss el salvador wear bit...	723.0	0.0	0.000	Neutral

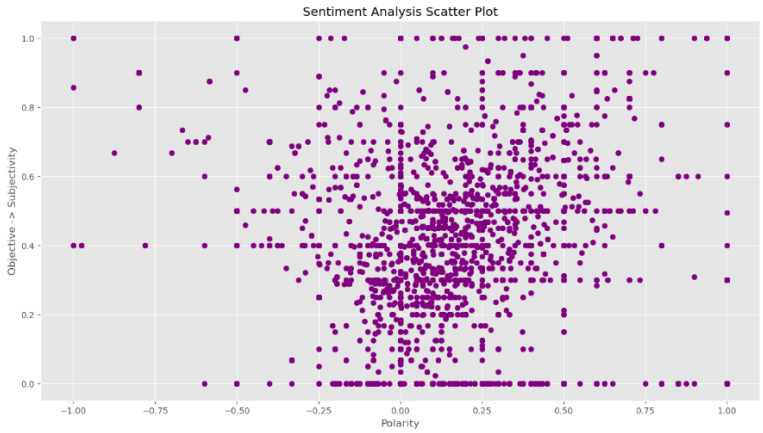

Figure 12. Scatter Plot of Sentiment

The sentiment distribution illustrated in Figure 13 reflects a snapshot of one day, which can fluctuate based on the news published on your targeted pages. In addition, Figures 14, 15, and 16 provide a more thorough analysis of the language used during specific market conditions. These figures highlight the most commonly used words in both positive and negative situations. These lexical insights not only help to gauge prevailing sentiment but also aid in understanding the linguistic subtleties inherent in discussions surrounding varying market sentiments. Our findings suggest that market sentiment plays a crucial role in accurate predictions. Positive market conditions tend to result in more precise predictions, with an accuracy rate exceeding 80 percent. Moreover, incorporating additional models like ARIMA and expanding the system to include more than three models significantly improves the chances of achieving accurate predictions. It has been observed that credible news releases, such as those from the Federal Reserve, can trigger changes in the market as they can influence investor expectations and confidence, ultimately affecting buying and selling behavior. Consequently, numerous investors and traders carefully track these news releases, considering them a pivotal factor in their decision-making process. Our strategy considers the results of each model and technique individually, allowing for easy

integration of additional models and opportunities for growth. When the tone of credible news is positive and our machine learning models forecast a surge in prices, it presents an excellent opportunity for potential profits in the market, as highlighted in Table 6.

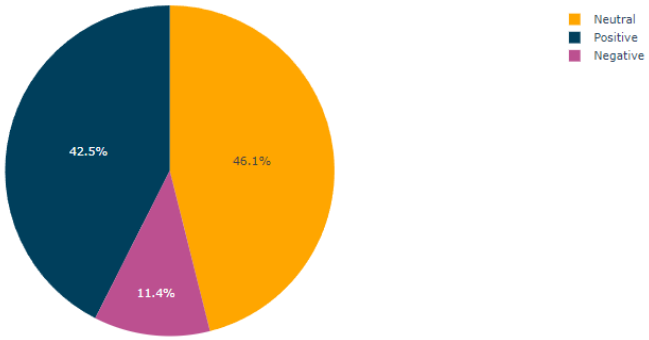

Figure 13. Distribution of Sentiments

Figure 14. Most Frequent Words in Tweets

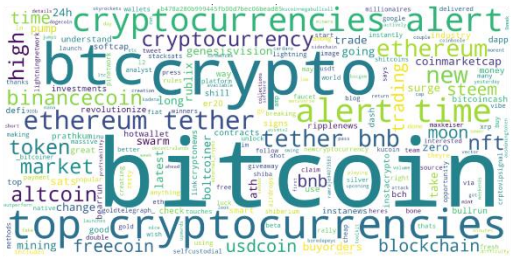

Figure 15. Most Frequent Words in Positive Tweets

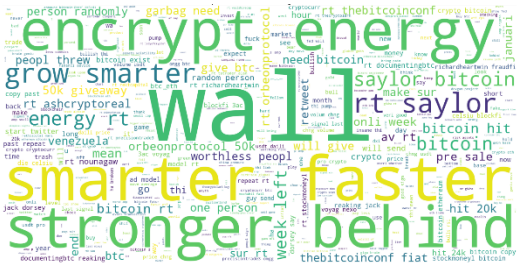

Figure 16. Most Frequent Words in Negative Tweets

In order to make accurate predictions about stock prices using LSTM and Prophet models, it's crucial to consider how the level of detail in the input data impacts their precision. The choice of temporal resolution - whether daily, weekly, or another interval - presents unique advantages and challenges. Daily resolution offers a highly detailed view of a stock's performance and trends, providing more nuanced insights. However, it requires more computational resources due to the larger dataset. Weekly resolution sacrifices some of these details but may be more manageable for users with resource constraints. Achieving an equilibrium between these factors is crucial for accurate stock price predictions. By carefully evaluating the data resolution, analysts can fine-tune the forecasting accuracy of LSTM and Prophet models to meet specific analytical requirements.

Table 6: Trend Prediction Results

Date	LSTM	Prophet	Sentiment	Trend Forecast
2023/10/01	Downtrend	Downtrend	Negative	Downtrend
2023/10/10	Downtrend	Uptrend	Negative	Downtrend
2023/10/20	Uptrend	Downtrend	Neutral	Sideway
2023/11/01	Uptrend	Uptrend	Positive	Uptrend
2023/11/10	Downtrend	Downtrend	Positive	Sideway

Conclusion and Future Work

Stock price trend prediction is a very ambitious and complicated task, mostly because of the many different factors that affect a stock price. In the world of finance, relying on time series prediction models to predict stock prices without taking into account the sentiment of the market is not enough to provide accurate predictions. This is because the stock market is highly sensitive to news and events that can either drive the market up or down. Therefore, it is important to consider various factors such as market sentiment, economic indicators, and news events to make informed predictions about the stock market.

We proposed the stock price trend prediction method, which uses Twitter data to conduct sentiment analysis and incorporates historical asset data into time series prediction models. Using a weighted approach, we combine the results of sentiment analysis and price prediction stages to generate a precise prediction regarding the future trend of the stock.

This research has practical implications for investors and financial analysts alike. Our model can be used by investors to complement their analyses and gain valuable insights into market trends. Additionally, financial analysts can improve their stock valuation models with the insights provided by our research. Additionally, this paper establishes a foundation for future research, delving into sophisticated algorithms and leveraging social media data to augment the precision of stock price prediction. These efforts will contribute to both academic research and practical applications in the financial sector.

For future endeavors, an automated algorithmic prediction system can be established that employs sentiment analytics, time series forecasting, and technical analysis in concert to enhance the accuracy of stock price predictions. Moreover, I plan to extensively examine machine learning and deep learning techniques specifically for sentiment analysis.

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Displacement-Energy and Enthalpy as Forms of Energy: An Upgrade

Sebastiaan H. Mannaerts

Wageningen NL, https://orcid.org/0000-0003-3596-1541

Abstract: In order to formulate proper energy balances and uphold the law of conservation of energy, there is a need to account for all forms of energy for any system. A survey of thermodynamic engineering literature reveals little consensus about the energy forms to be taken into account. This paper intends to advance the case for formal and explicit recognition of 'displacement energy' as a form of energy that is either missing from textbooks, implied by some unspecified potential energy, hiding inside enthalpy, or incorrectly designated as 'flow work' or 'pV-work' as work is not a form of energy. An important implication is that contrary to prevailing views, enthalpy can also be deemed a form of energy, thereby justifying its presence in many energy balances, and thus rendering Hess' law into an energy balance as well. The paper specifies 23 conclusions and recommendations.

Keywords: fluid-mechanics, chemistry, thermodynamics, energy balance, forms of energy, displacement, displacement energy, enthalpy, Archimedes principle, Stevin's law of hydrostatics, gravity, potential energy, pressure work, volume work, flow work, vacuum.

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Introduction

Quote: *Conservation of energy can be understood only if we have the formula for all of its forms* (Feynman, 1964, vol I, 4-2). This statement implies that *we* should have identified all forms of energy ('E-forms' in the following), and how they are quantified. The verification of the *conservation of energy* implies an energy-balance equation with an understanding of whether E -forms overlap and when their change can be neglected. It would not be too exacting to have unique names and symbols assigned to all E-forms, preferably across the sciences. The following intends to show a few prevailing shortcomings and an attempt to fix some of them.

The survey of the literature in Section 2 addresses the issue of what E-forms have been identified (see table 1), with an emphasis on engineering thermodynamics and a special interest in the intersection between thermodynamics and fluid mechanics. The E-form hereinafter referred to as 'displacement energy' resides in that intersection. Section 3 is preparation for Section 4, specifying the notation used (3a, Appendix A) and tackling five related issues. Those issues are: The meaning of 'displacement' (3b), the need to make 'ambient parameters' explicit (3c), and its spin-off for work terms (3d). Section 3e addresses the problem of sign conventions, and the

energy-balance equation is addressed in Section 3f. In the review of Section 4, 'displacement energy' is properly introduced and it is shown how it fits the prevailing formulations. This includes implications for enthalpy. Conclusions and recommendations are collected in Section 5(a/w).

The word 'body' is taken here to have the same meaning as 'system'. This paper assumes macroscopic systems and bodies without relativistic effects.

Forms of Energy (E-forms) in Engineering Thermodynamics

Formulating a proper energy balance with implied conservation of energy requires all forms of energy to be accounted for. For those E-forms that are "not considered" in the process at hand, i.e. E-forms that are not entered in the energy balance, it must be explicitly or implicitly assumed that their change is zero or negligible, or that they are included in one of the forms specified. The energy balance cannot specify quantities that are not E-forms (it must be energy only) and the forms specified cannot share any components: all intersections should be void, i.e. the E-forms should be disjointed. The case can also be made that every E-form must have a unique name and symbol: without a symbol, the quantity cannot be entered into an equation and for physical quantities, quantification is a must, especially for the one that are considered to be conserved.

Having said that, it may come as a surprise that there is no agreement among textbooks (and presumably scientists) about a definitive list of E-forms. Table 1 shows what are considered to be E-forms in the literature selected: It lists 15 E-forms as encountered in 37 references, sorted by year of publication (1948-2023).

Literature Selected

The 37 references can be classified mainly as texts on engineering and/or thermodynamics, with a few physics texts and a few internet sources (including chatgpt). The selection is based on an interest in those parts of applied science where energy balance equations are most common. In addition, the accessibility of the text itself (English only) was a factor.

E-forms Listed

The table lists 15 E-forms, with symbols used as specified in Appendix A. Some E-forms are not included in the table itself, but listed at the bottom of the table, most of them encountered only once or twice. The emphasis is on the more common quantities, notably those that might be encountered in general energy balances. It must be emphasized that the table quotes the E-forms as given, but the assumed exact meaning has not been checked and can differ between the references. This is notably true for 'heat' (see 2e). Nothing is assumed or specified in the table about the mutual independence of the E-forms mentioned, i.e. whether they are disjointed or not. For example, mechanical energy is commonly defined as the sum of kinetic energy and potential energy, so it overlaps with both. To arrange the E-forms, they have been classified as mechanical energy (to the left of

enthalpy) or internal energy (to the right). The three quantities at the extreme right (radiation, heat and work) have been included simply because they are mentioned as E-forms (see 2e). The 'displacement energy', to be defined and demarcated in Section 4, appears centrally in the table, in anticipation of its position in the spectrum of E-forms. Note that internal energy (hence enthalpy) encompasses the unquantified E-forms chemical energy and thermal energy.

Relative Occurrences of E-forms

The literature is quite diverse in terms of the E-forms listed: The number of E-forms mentioned by each reference ranges from 3 to 9 out of the 15, with an average of 6.3. Only 3 out of the 15 E-forms occur 25 times or more: kinetic energy (32|37), electrical energy (27|37), and potential energy (25|37). Two of the listed E-forms occur 6 times or fewer: flow-/pressure energy (6|37) and enthalpy (1|37). Interestingly internal energy is only mentioned by 43% in this survey, gravitational energy by only 38%.

Potential Energy

When Rankine introduced the concept of 'potential energy' (Rankine,1853) he also proposed designating kinetic energy as an 'actual energy'. So Rankine defines potential energy as the collection of all non-kinetic energies. Today there is little 'potential' about potential energy (Roche, 2003), but it still encompasses a large number of different E-forms. Trefil (Trefil & Hazen, 2000, p67) specifies: gravitational-, chemical-, elastic- and electromagnetic energy. Lumping these E-forms together does not seem to be helpful. Sometimes potential energy is indicated as the 'energy of position' or 'energy of configuration', which could include spring energy (elastic energy). Others define it as 'energy of position in an external field', which could include electric energy. In thermodynamics, potential energy commonly means gravitational energy when applied in the energy balance and does not include chemical energy, the latter being included in enthalpy. From the above, it is inferred that it would be helpful to abandon potential energy altogether and replace it with the intended, more precise E-forms. In most cases, potential energy is simply gravitational energy.

Heat and Work

In 1948 Steiner is clear and writes: *In thermodynamics, heat and work are not considered forms of energy*. Romer (2001) deems it necessary to write: *Heat is not a noun.* In this paper too, heat (Q) and work (W) are not understood as E-forms, but as input variables, the way they are used in energy balance equations. However, Blundell & Blundell (2006, p106) formulate : *Though the idea that heat and work are both forms of energy seems obvious to a modern physicist, the idea took some getting used to. Lavoisier had, in 1789, proposed that heat was a weightless, conserved fluid called caloric.*

This *quote* and Table 1 show that there is still a need for stipulation. However, this being understood, in the following 'flow work' is promoted as 'displacement energy' and 'heat at constant pressure ' as an E-form called 'enthalpy'.

Conclusions from The Survey

There is no consensus about E-forms among the references listed. The nomenclature, ordering and understanding of the E-forms lack clarity. Work and heat are still listed as E-forms, while 'flow energy' and 'enthalpy' are scarcely recognized as such. Thermal energy and chemical energy are not quantified and do not belong in the list and (in all practical circumstances), both are taken care of as enthalpy. The replacement of potential energy by more specific E-forms is to be recommended. The position of 'displacement energy' and enthalpy needs to be more closely considered, as done in Section 4.

Table 1. Forms of Energy (E-forms) Listed as such in The Literature of Science and Engineering 1948-2023*)

	energy forms (E-forms)	electrical energy	magnetic energy	mechanical energy	kinetic energy (motion)	potential energy	gravitational energy	flow, pressure energy	enthalpy (heat content)	internal energy	spring & strain energy	chemical energy	thermal energy	radiation, light	heat	work	**totals**
		e-m energy						enthalpy						*not E-form but input*			
				mechanical energy						internal energy							
	symbols	-	-	Em	Ek	Ep	Eg	Ed	H	U	Ey	?	?	Q	Q	W	**15**
year	***author*** *page*																
1948	Steiner p24	x		x	x	x						x	x	x			**7**
1948	Faires p22	x			x	x		x		x		x			x	x	**8**
1961	Schaum&al p49,126	x	x		x	x								x	x		**6**
1964	Feynman ch4	x			x		x					x		x	x		**6**
1966	Joel p59				x	x		x							x	x	**5**
1972	Abbott&al p10				x	x				x							**3**
1976	James p62	x		x	x	x						x	x		x		**7**
1979	Simms p211	x		x	x	x	x	x			x	x			x		**9**
1980	Alonso&Finn p241			x	x		x			x		x		x			**6**
1991	deNevers p95	x	x		x	x	x			x	x						**7**
1994	Smil p2			x	x		x					x	x	x			**6**
1996	Warn&Peters p11	x		x								x	x	x			**5**
2000	Trefil&Hazen p67	x	x		x	x	x				x	x			x		**8**
2001	Dincer&al p120	x	x		x	x	x			x	x	x	x				**9**
2001	Darby p108			x	x	x	x	x		x			x		x	x	**9**
2003	Earle&Earle p33				x	x		x	?			x			x	x	**7**
2004	Hobson p113	x			x		x				x	x	x	x			**7**
2005	Felder&al p315				x	x				x							**3**
2005	Massoud p3 p96	x		x								x	x	x	x	x	**7**
2006	Cengel&Boles p53	x	x	x	x	x						x	x				**7**
2006	Moran&Shapiro p43				x		x			x							**3**
2007	Rajput p46	x		x	x	x	x			x		x					**7**

2009	BorgnakkeSontag[p130]				x	x				x							**3**
2009	Theodore&al [p65]				x	x				x					x	x	**5**
2010	Holbrow &al [p47]	x	x		x		x	?			x	?			x		**6**
2012	Goldemberg [p8]	x	x	x								x	x				**5**
2013	Koretsky [p37]	x	x		x	x				x							**5**
2014	Potter&al [p11]	x			x	x				x		x					**5**
2015	Winterbone&Turan [p7]	x	x		x	x							x				**5**
2016	Kleidon [p25]	x			x	x		?				x	x	x			**6**
2018	Smith&al [p25]	x	x	x	x	x				x					x	x	**8**
2018	eia.gov/kids/energy	x		x	x	x	x					x	x	x	x		**9**
2019	Jenkins [p6]	x			x							x		x	x		**5**
2019	NajamAcademy	x		x	x	x						x	x	x			**7**
2020	EnglishWiki:	x	x	x			x				x	x	x	x			**8**
2023	ChatGPT-Q1(sci)	x			x	x				x		x	x	x			**7**
2023	ChatGPT-Q2(eng)	x	x	x				x		x		x	x				**7**
	symbols	-	-	Em	Ek	Ep	Eg	Ed	H	U	Ey	?	?	Q	Q	W	
37	**totals**	**27**	**12**	**16**	**32**	**25**	**14**	**6**	**0**	**16**	**7**	**24**	**17**	**14**	**15**	**7**	**233**

* E-forms encountered but not included in this table are: capillary-, centrifugal-, cohesion-, mass-, nuclear-/atomic-, osmotic-, sonic-/sound-, surface- and ionisation-energy.

Preliminaries: Notations, Definitions, Demarcations

Notation

The symbols used, both standard and some new, are listed in appendix A. Symbols of quantities in bold (**V**, **m**, **g, W**) have a meaning slightly different from the regular-font symbols (V, m, g, W). The rest of Section 3 can be seen as a clarification of appendix A. Except for U and H, symbols for E-forms are all of the format 'Ej', e.g. Ek=kinetic energy. All equations are separated from the embedding text by curly brackets: {equation | constraint}, to improve readability and conciseness. In *quotes*, the symbols used in the original have been transcribed to the symbols from appendix A.

Displacement

The word 'displacement' has two meanings in physics. First, in the displacement of a body, it is moved from P to Q: it changed position, i.e. is "displaced". This displacement is a vector, expressed in metres. This kind of displacement is referred to hereinafter as a 'change in position' or movement, expressed as Δx (horizontal) and Δz (vertical).

In this paper, 'displacement' refers to the fluid volume a body will force aside, in the way a ship at sea displaces the water and a balloon displaces the air: displacement by a body. This displacement is a 'displacing volume', a scalar denoted here as **V** (bold). This displacement volume may be slightly different from the volume enclosed in a container (system) and commonly denoted as V. In mechanical engineering, 'displacement' is the volume displaced by a piston (as in a pump or an engine) in a single stroke, a usage compatible with the intended meaning, as the volume change will equal the change in displacement $\{\Delta V=\Delta \mathbf{V}\}$.

Ambient Parameters

Approaching the subject of displacement requires a proper distinction to be made between the system and its surroundings. Properties of the system itself are given without a subscript, or with subscript capital O if warranted. The system and its surroundings are separated by either a piston or other interface: the subscript 'I' (capital i) is used for the interface. In the surroundings, a distinction is made between 'natural surroundings' (subscript A, e.g. p_A=ambient pressure) and 'artificial surroundings' or load (subscript X, p_X= pressure exerted by weight and/or engine). When all the contributions from the surroundings are added, the subscript E is used: $\{p_E=p_A+p_X\}$. When the system pressure (p) is equal to the pressure exerted (p_E), then $\{p=p_E\}$, but such an external equilibrium is not generally present in working systems and is not assumed in this paper except for control volumes.

Volume-Work Versus Shaft-Work

Work is taken to be an energetic interaction between the system and its surroundings. Following Guggenheim (1967, p10) this can be reflected in the use of subscripts with the symbol for work: W_{IO} stands for work done by the interface/piston (I) on the system (O), and W_{OI} stands for work by the system on the interface/piston, with $\{W_{IO}= -W_{OI}\}$. This notation might end most of the enduring confusion with the sign of work terms in energy balances. It also allows for proper distinctions between various work terms.

Most changes in volume involve work done, particularly when a piston is in play. However, it is not always made clear that a moving piston means that at least four forces (and hence four work terms) are involved, and all four classify as volume-work. The first force is the one that the enclosed fluid (system) imposes on the piston, and the related work $\{W_{IO}=-p\Delta V=-W_{OI}\}$. The second force comes from the load exerted (weight, engine) with $\{W_{XI}= -p_X\Delta V\}$. In the more technically oriented literature, this type of work is indicated as shaft work or technical work. For systems with a free interface, this term is zero. The third force arises from the ambient pressure p_A, with related work $\{W_{IA}=p_A\Delta V\}$. The sum of these three forces is the fourth force, which determines the movement of the piston: $\{F_I=\sum(F)\}$ and $\{W_I=W_{OI}+W_{AI}+W_{XI}\}$. The most interesting one here is W_{IX} with $\{W_{IX}= -W_{XI}\}$, as it represents 'useful work', hence the upper limit (maximum) of W_{IX} represents the system's 'capacity to do work' (a.k.a. free energy). Remarkably, its fixed companion (W_{AI}) is not always made explicit. Some wrongly consider work on the surrounding atmosphere as 'lost work' (Mayhew, 2020). Note that in a full cycle, the work W_{AI} is zero, i.e. $\{W_{AI}=0|_{cycle}\}$. The latter condition predicts that W_{AI} is a 'variable of state'. However, with these in mind, it must be remembered that in a chemical reaction $\Delta V=\Delta\mathbf{V}$ (and hence W_{AI}) will often be non-zero and has to be accounted for.

Sign Conventions

In mechanics, the preferred sign convention would be the one implied by the Cartesian system with coordinates (x,y,z). This assumes forces, velocities and accelerations are vectors, where (in 2D) upward (z) and rightward

(x) forces are positive and downward and leftward forces negative. In a homogeneous gravitational field, this convention implies that the gravitational force (F_g) and the acceleration of gravity (g) must always be negative and that a buoyant force (F_b) always positive. To prevent confusion, we distinguish the positive gravity constant {$g=+9.8m/s^2$} from the negative one {$\mathbf{g}= -9.8m/s^2$}, with {$g= -\mathbf{g}$}. Applying Newton's second law gives {$F_g=m\mathbf{g}$}, where F_g is negative as required in the Cartesian convention. However, gravitational work is quantified by {$W_g=|z',z''|\int F_g\cos(\alpha)dz$}, where |z',z"| represents the integration interval and α represents the angle between force and change in position, with {$\alpha=0$} and {$\cos(\alpha)=1$}. The definition of work does not allow for signs to be changed at will. As a consequence, the change in gravitational energy becomes {$\Delta Eg=W_g=m\mathbf{g}(z''-z')$}, which makes W_g negative when the movement is upward, i.e. {z">z'}. The sign convention in thermodynamics is that negative work means that energy is leaving the system, but in mechanics it is established that gravitational energy increases with z. This problem might be overcome by considering gravitational energy as an 'external energy': Raising a body increases its gravitational energy, but that energy is seen as belonging to the body. When the body is in free fall, this external energy is converted into kinetic energy, but no energy is added to the body or removed from it during this process. We will show that 'displacement energy', to be introduced below, might also be considered to be external energy.

Energy Balances

Energy is a conserved extensive quantity. The energy balance equation for a system can be written as {$\Delta E=\sum E_i$"}, where ΔE is the change of the total energy of the system, and ∑E" represents all inputs (E_i">0) and outputs (E_i"<0) without a need to use two separate symbols. The total energy is the sum of all E-forms: {$E=\sum Ei|_{disjoint}$} with the condition that all Ei must be mutually disjoint. Forms that are considered to be constant do not need to be included, but this constancy is then a required constraint (condition).

In thermodynamics, the energy balance is commonly first encountered as the First Law: {$\Delta U=Q+W|_{constraints}$}. There is an implicit requirement that internal energy U is a form of energy (cf. Section 2c), and there are two constraints: internal energy is the only E-form involved, and the system is closed (energy is only exchanged by heat Q and work W). The equation does not exclude any irreversible process. The system boundaries have to be specified to include, or exclude, the walls and/or pistons, which in turn will determine how W and Q are to be specified. Two cases can be distinguished. In the first, more common in engineering, there is an external load and the kinetic energy of the piston is neglected. Here the external load must be specified, otherwise little can be calculated, hence the energy balance is {$\Delta U=Q+ W_{AI}+W_{XI} |_{Ek(piston)\approx 0}$}, with {$W_{AI} = -\int p_A dV$}. As p_A is independent of the state of the system, W_{AI} is independent of the path. If we define ($\mathbf{H}=U+p_AV$} we can write the energy balance equation as {$\Delta\mathbf{H}= \Delta U+W_{IA}=Q+W_{XI} |_{Ek(piston)\approx 0}$} (cf. Section 4g for enthalpy).

The case that is more common in physical chemistry and calorimetry is the one without a load: {$W_{XI}=0$}. As pistons are absent or neglected, the energy balance equation becomes {$\Delta\mathbf{H}=Q|_{no\text{-}load}$}. Again: irreversibility is not excluded. This is important for calorimetric observations. Many of the processes such as chemical reactions

that proceed in the calorimeter are irreversible, and these observations lead to Hess's Law, which is in essence a law of energy conservation.

For an open system with mass transfers Φ(kg), the energy balance is written as {$\Delta E=\sum(\Phi.e)+Q+W$} where e the total energy per unit mass {e=ek+eg+h}. The total specific energy e(J/kg) is taken as the sum of specific kinetic energy (ek), specific gravitational energy (eg), and specific enthalpy (h). For a horizontal steady-state process (reactor), the energy balance simplifies to {$\Delta E=\Delta H=\sum(\varphi.h)+Q+W_{IX}$}, where the maximal (useful) work equals {$W_{IX}<0$} as the work may be taken out as an electric current.

It can be concluded that in the more common energy balances, enthalpy plays a central role. This suggests that enthalpy should be considered to be a form of energy (cf. Section 4g).

Displacement Energy

In the following, the whereabouts of displacement energy is shown for several processes with an indication of the existing approaches to this quantity.

Moving A Solid Across A Pressure Difference

First, define the system as a rigid, solid cylinder of length L, cross-section A, and displacing volume **V**, with {**V**=L.A}. This system is to be moved from an environment with pressure p_L, to one with pressure p_R. (see Figure 1; assume horizontal move from left to right). For this transfer, work W_{XI} needs to be done, with {$W_{XI}=\mathbf{V}(p_R-p_L)$}, to be called 'pressure-work'.

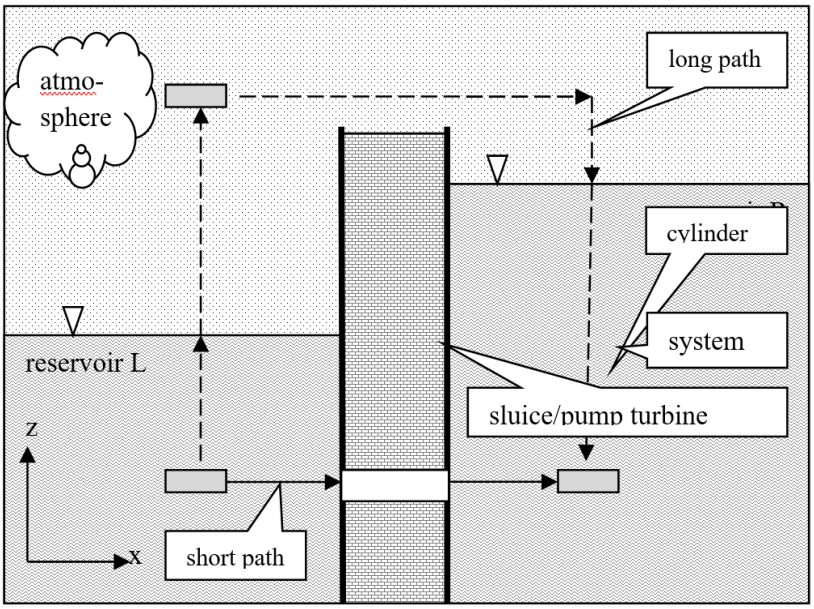

Figure 1. Exchange of a body(system=cylinder) between constant-level reservoirs L and R through either a long path or a short path that together constitute a full cycle

If $\{p_{L>}p_R$, thus $W_{XI}>0$, this work is done on the system and hence is associated with the system, although the system as such (internal energy, gravitational energy) is unaltered if compression can be ignored. We call the energy supplied the 'displacement energy' (Ed) with $\{W_{XI}=\Delta Ed=\mathbf{V}(p_{R-}p_L)\}$. This is consistent with setting $\{Ed_R=\mathbf{V}.p_R\}$ and $\{Ed_L=\mathbf{V}.p_L\}$, or in general: $\{Ed=\mathbf{V}.p_A\}$, where p_A is the ambient pressure, here equal to the hydrostatic pressure. The displacement energy is independent of the path taken: compare the long path in Figure 1, and consider the energy-changes during a full cycle. If $\{p_{R>}p_L\}$ at level z, the system has 'a capacity to do work' as long as the reservoir with pressure p_L is accessible. Turbines make use of this property to generate electricity, where the system is a control volume with a composition identical to the reservoir, commonly water.

Note first that here a distinction is made between the 'pressure-work' ($\mathbf{W}=\mathbf{V}$dp) and the 'volume work' (W=pdV) (cf appendix A). Also note that the displacement energy is completely independent of the composition of the system (parts, chemical make-up, temperature) and hence independent of any inside pressure, i.e. the pressure of an enclosed fluid. If the solid encloses a vacuum (see section **4b** below), this vacuum will contribute to the 'energy of displacement' according to its volume. Also note that if the system stays in place but the pressure of the surroundings changes because the water level in the reservoir has changed, its 'energy of displacement' changes accordingly. The problem with this change is that no work (or heat) is supplied to the system itself: it seems to violate the energy balance for the system. This might be compared to a change of the gravitational energy due to a change in g. Small changes in g occur for example, due to a change of the position of the moon relative to the position of the body under consideration. (These changes are small, but large enough to cause the tides).

The question might arise of whether the displacement energy can be called a state variable. If state variables are defined in such a way that they cannot depend on the state of the environment, then Ed is not a state variable sec, but (following Gibbs) it qualifies as a mixed variable of state, depending on the state of the system (via **V**) and the state of the medium (via p_A). This is not different from the situation for gravitational energy Eg, where g is a property of the environment and not of the body.

Vacuum

Consider the system as a piston-cylinder arrangement (PCA). In this system, a vacuum is created by starting with an initial internal volume V'=0 and final volume V''=V. To do so, we have to do work $\{W_{XA}=p_A(V''-V') = p_AV\}$, where p_A is the ambient pressure. The shaft work needed (W_{XI}) is used to displace the ambient air from the PCA with volume V, i.e. $\{W_{XI}= -W_{AI}\}$. So, the energy input (work) does not end up inside the system but flows into the environment. It might be indicated as 'external energy'. However, this energy is still associated with the volume of the displacement, as is obvious from the fact that the vacuum system has 'a capacity to do work' (a.k.a. free energy) equal to p_AV. Once again, we define $\{Ed=p_AV\}$ and call it the 'displacement energy'. The work involved could be called 'volume work of displacement' and has to be distinguished at all times from 'volume work' done by the system itself. Note that in this case, the vacuum itself does not work at all.

Stevin's Law of Hydrostatics

Stevin's law is generally known as the law of hydrostatics and it describes the static pressure p in a liquid under gravitation as a function of depth, generally formulated as {p=p°+ρgh} (Homer, 2014, p571) where p° is the atmospheric pressure, ρ is the density of the fluid, h is the depth below water level, g=+9.8m/s^2. Note: all quantities in the equation are positive.

Now consider a system (control mass) of **m** kilograms of water {ρ= **m**/**V**} (suspended) in a reservoir with water level z° and its centre of gravity at position z with {h=z°-z}. For this control volume, {p=p_A} so there is no need to distinguish p and p_A. Now the Stevin equation can be written as: {(p-p°)**V**= **m**g(z°-z)} or, if {**g**= −g**}**, {(p-p°)**V**= **mg**(z-z°)} or {Δp**V**= **mg**Δz} and {Δp/Δz=ρ**g**}. The lower z (the deeper), the higher the pressure, or (Δp/dz) should be negative, and it is as required as ρ**g**<0. Where the traditional formulation of the gravitational energy is {Eg=mgz}, it can be written as {Eg=-m**g**z}. This lets us state that in a hydrostatic reservoir, at any depth z the sum of the gravitational energy and the displacement energy is constant, i.e. {d(Eg+Ed)/dz=0} or {d(-m**g**z)/dz+d(p**V**)dz=0}, {-ρ**g**+(dp/dz)=0} and {(dp/dz)=ρ**g**}. This indicates that Stevins' law is a specific formulation of the conservation of energy. A consistent sign convention seems helpful for this conclusion.
It might be possible to claim that the sum of gravitational energy and displacement energy is potential energy, but it is preferable to call this energy the 'Stevin energy' Es: {Es=Eg+Ed}, to distinguish this potential energy from all other potential energies (see 3d). From Cengel &al (2017, p90): *The flow energy at the turbine inlet is equal to the gravitational potential energy at the free surface of the reservoir.* Hence Cengel thinks along the same line. (cf. 4f)

Bernoulli Equation

Now, the sum of the Stevin energy and the kinetic energy Ek, which applies in hydrodynamics, can be called 'Bernoulli energy' Eb: {Eb= Es+Ek}. The Bernoulli equation then also embodies the conservation of energy under specified circumstances (cf. Homer, 2014, p575). Note that both the Stevin energy and the Bernoulli energy can be classified as mechanical energy and that they are both independent of the internal energy of the system. *Without the consideration of any losses, two points on the same streamline satisfy {p/rho.g+vv/g+z=constant} where p/ρ is flow energy, vv/2 is kinetic energy, and gz as potential energy, all per unit mass. The Bernoulli equation can be viewed as an expression of mechanical energy balance.// Therefore, the mechanical energy of a flowing fluid can be expressed on a unit-mass basis as {e(mech)=p/rho+vv/2+gz}, where p/rho is the flow energy, vv/2 is the kinetic energy, and gz is the potential energy of the fluid, all per unit mass.* (quote from: 'Thermo-Fluid Engineering,2nd semester 2013-14, by S Essalaimeh, Philadelphia University).

Archimedes' Principle

Archimedes' principle is one of the oldest laws in physics, literally as old as the road to Rome. According to

Galileo: *A solid heavier than a fluid will, if placed in it, descend to the bottom of the fluid, and the solid will, when weighed in the fluid, be lighter than its true weight by the weight of the fluid displaced*. (Heath, 1897, p258). Note that Galileo measures buoyancy as a correction to weight. Weight and volume (fluid displaced) are the observables. Wikipedia ($^{2020/03/20}$) formulates under the 'Archimedes Principle': *the buoyant force that is exerted on a body immersed in a fluid is equal to the weight of the fluid that the body displaces*. In the 'wiki' entry, the word 'force' occurs 69 times. However, the words 'work' and 'energy' are not encountered at all. Stated differently: after the concepts force, work and energy are introduced, 'buoyant force' has become a household name, but 'buoyant work' and 'buoyant energy' have not. However, it can be seen from the above that for the 'buoyant force' F_b (which at equilibrium balances the force of gravity F_g), the following holds: $\{F_b=dEd/dz\}$. In other words, the buoyant force is the (commonly vertical) gradient in the displacement of energy.

Flow Energy And Flow Work:

From Cengel et al. (2017, p64): *A pressure force acting on a fluid through a distance produces work, called flow work, in the amount of p/rho per unit mass. Flow work is expressed in terms of fluid properties, and it is convenient to view it as part of the energy of a flowing fluid and call it flow energy*. *Therefore, the mechanical energy of a flowing fluid can be expressed on a unit mass basis as {e(mech)=(p/ρ+v^2/2+gz}(eqn 3.10)*. What is called mechanical energy here, is called 'Bernoulli energy' in this paper (Section 4d). Note that mechanical energy is commonly defined as (Ek+Ep).

From Cengel et al. (2017, p188): *Others argue that the product pV represents energy for flowing fluids only and does not represent any form of energy for nonflow (closed) systems. Therefore, it should be treated as work. This controversy is not likely to end, but it is comforting to know that both arguments yield the same result for the energy balance equation.*

The name 'flow energy' suggests that if there is no flow, the flow energy is zero. This is made explicit by Wu (2007, p18): *Flow energy occurs only when there is a mass flow into the system or out from the system.* However, on the next page, Wu writes: *Enthalpy is not a directly measurable property. It is a synthetic combination of the internal energy (U) and the flow energy (pV) exchanged with the surroundings {H=U+pV}*. The problem then arises that the concept of enthalpy is also applied to closed (no-flow) systems. It is shown above that even closed systems have 'displacement energy' and that the name flow energy for the same quantity leads to confusion. In literature, 'work of displacement' is also referred to as 'pV-work', commonly without specifying which pressure is involved. Note that work is not a state variable, but 'displacement energy' is, although it depends on the state of the system (**V**) and the state of the surroundings (p_A).

Enthalpy

In thermodynamics, part of both chemical engineering and thermal physics, enthalpy can be seen as a central concept. Firstly, enthalpy is an important intrinsic property of all substances. Secondly, there are enthalpies

listed for many processes, including atomization, combustion, dissociation, evaporation, formation, hydration, hydrogenation, hydrolysis, isomerization, solution, sublimation, etc. Thirdly, for most systems, enthalpy is a common element of the energy-balance equation, together with kinetic energy and the gravitational energy. Quote: *These equations suggest the usefulness of enthalpy, but its greatest use becomes fully apparent with its appearance in* ***energy balances for flow processes*** *as applied to heat exchangers, chemical and biochemical reactors, distillation columns, pumps, compressors, turbines, engines, etc.*. (Smith *et al.*, 2018, p40, this author's emphasis).

The collection of enthalpy data started with the invention of the calorimeter and made much progress with the formulation of Hess' law (law of constant heat summation) in 1840. However, the word 'enthalpy' was only introduced in 1922, to replace *what is usually known in England as 'total heat' or 'heat content'. I submit that these names are not satisfactory.* (Porter, 1922). The problem at hand was (is?) that the state variable 'total heat' (U+pV) was not well distinguished from the input-variable 'heat' (Q). This ambiguity is exemplified by the use, even today, by 'heat of evaporation ' and 'enthalpy of evaporation ' for the same quantity and reinforced by the equation $\{\Delta H=Q|_{constraints}\}$, where the equality can be mistaken for an identity because the constraints are not always properly specified. These constraints are twofold: no other work than work against ambient pressure, $W_{IX}=0\}$, and constant pressure, i.e. $\{p=p_A=constant\}$. Gibbs (1961, p92) calls enthalpy 'heat function for constant pressure '. An historical review can be found in (Howard, 2002).

If a system is under isobaric conditions, this means mathematically $\{dp=0|_{isobaric}\}$ hence $\{pdV=d(pV)|_{isobaric}\}$, but physically (experimentally) it means that system pressure follows the constant ambient pressure closely, hence $\{p\approx p_A\ |_{constant}\}$, where ≈ can be understood as quasi-equal. In equations that apply to isobaric systems and processes, p could (and should) be eliminated by substituting it with p_A, but in prevailing equilibrium thermodynamics, the ambient pressure is seldom made explicit, with the tacit assumption $\{p=p_A\ |_{equilibrium}\}$. The convention of writing p instead of p_A with $(p=p_A)$, leads to confusion and obstructs the conceptualisation of 'enthalpy'. This becomes evident as $\{dH/dT=C|_p\}$where $C|_p$ is the 'heat capacity at constant pressure'. If the derivative (dH/dT) has a constraint (constant p) attached, so must the original function (H). Note that before 1922, enthalpy was called 'heat at constant pressure' and the importance of $\{dH/dT=C|_p\}$ is obvious from the experimental point of view (calorimetry).

For solids, 'pressure' is neither a state variable nor an observable property: the only pressure around is the ambient pressure p_A. This pressure does cause stress in the solid, but the related 'strain energy' is not mentioned in most thermodynamic textbooks and is (tacitly) included in the internal energy. If enthalpy is defined as {H≡U+pV} and enthalpy is an intrinsic property of every solid, then this definition raises the questions of what p in 'U+pV' stands for. That problem is solved when $\{H\equiv U+p_AV\}$.

This paper proposes to understand p in the definition of enthalpy {H=U+pV) as the ambient pressure, hence $(H=U+p_AV)$. This is not something new. Brodkey (1988, p287) formulates: *The* [specific] *enthalpy h is related to u by the defining relation: {h=u+p/rho} (7.36)*, where adjustments are made in the transcription to conform to

specific quantities. This is a straightforward definition of enthalpy as the sum of internal energy and displacement energy. Brodkey is backed by MIT: *In an open flow system, enthalpy is the amount of energy that is transferred across a system boundary by a moving flow, composed of the internal energy (u) and the flow work (pv) associated with pushing the mass of fluid across the system boundary*. (MIT›thermo6,[2020/06/21]).

To these testimonies we can add those of Schroeder (physics) and Fletcher (chemistry): Schroeder (2000,p33): *To create a rabbit out of nothing and place it on the table the magician must summon up the energy U off the rabbit, and some additional energy, equal to pV, to push the atmosphere out of the way. The total energy required is the enthalpy, H=U+pV.* Fletcher (2012,p68): *Enthalpy: This measures the total energy of a physical system, including the internal energy and the energy needed to accommodate the system by displacement of the surrounding environment* . Fletcher (2012) forgets about (macroscopic) kinetic and potential energy and assumes ($p=p_A$). Elsewhere, support is gathered for the position that enthalpy can be considered a form of energy for the case of the throttling process (Mannaerts, 2010).

Most textbooks define enthalpy not as a form of energy, but as {H≡U+pV}, without any physical explanation except that H must be a state variable because U, p and V are. This assessment may be comforting, but leaves everybody, including students, in the dark. The mystery is further enhanced when it is assumed that enthalpy is to be understood as the Legendre transform of the internal energy (Alberty, 2001) and (Mander, 2014).

Once enthalpy is accepted as a form of energy, the specific total energy of a system e can be defined as {e=h+ek+eg). This is not new, as Urieli writes: *The* (total) *specific energy e can include kinetic and potential energy, however, will always include the combination of internal energy and flow work (pv), thus we conveniently combine these properties in terms of the property enthalpy: {e=u+pv+ek+ep} or {e=h+ek+ep}*. (Urieli, 2010).

This position is endorsed by Cengel & Boles (2006, p824): *When analyzing control volumes, we find it very convenient to combine internal energy and flow energy of a fluid into one term, enthalpy, defined per unit mass as {h=u+pv}. Whenever Ek and Ep of the fluid are negligible, H represents the total energy of a fluid.*

The defence rests its case.

Conclusions and Recommendations

Conclusions and Recommendations from the Survey on E-Forms (Section 2)

a. There is no consensus in the specified literature on a proper list of E-forms (Table 1).
b. There is a persistent tendency to include heat (Q) and work (W) as E-forms, while these are energy inputs, and they are not state-variables as required (Table 1).
c. Flow energy/pressure energy is not seen as a form of energy by most references.

d. Enthalpy is essentially not mentioned as a form of energy, internal energy only by a minority.

e. The concept of potential energy can be abandoned: while there is very little 'potential' about it, it is a collection of unconnected 'non-kinetic' forms of energy that can be specified separately. In thermodynamics and fluid mechanics, gravitational energy is intended anyway.

f. Solids do not have a property 'pressure' as a state variable, but they can be under 'stress', and this stress is always imposed from the outside. Stress $\sigma(N/m^2)$ is expressed as a strain (change in length) or as a change in volume. In thermodynamics, it is silently assumed that strained energy is a (small) part of internal energy. This silent assumption might need further corroboration.

g. While 'mechanical energy' can be defined in outer space as the sum of kinetic and gravitational energy, in the anthroposphere, the mechanical energy balance is disturbed by pressurized surroundings, most commonly the atmosphere but also the hydrosphere. This aspect can be handled by displacement energy.

Conclusions and Recommendations from the Preliminaries (Section 3)

h. It is useful and necessary at all times to distinguish the pressure of the surroundings from the pressure of the system. In the surroundings, the ambient (natural) pressure (commonly the atmospheric pressure) can be distinguished from the auxiliary (artificial) pressure due to loads, commonly weights or engines hooked up to a piston.

i. Every pressure relates to a force through the surface area, and every force relates to work through the movement of the piston or interface. It is to be recommended that the notation for different work terms should follow the Guggenheim convention, with an implied sign convention.

j. The energy balance is a *sine qua non* for the check on the conservation of energy.

k. The constraints on the validity of the First Law as $\{\Delta U=Q+W\}$ are not always properly explained in thermodynamics, notably that E-forms other then U are constant. The First Law can equally be formulated as $\{\Delta H=Q+W_{XI}\}$ with the constraint that E-forms other then H are constant.

l. The most common formulation of the specific total energy of a system is: $\{e=ek+ep+h\}$.

m. In most energy balances, enthalpy plays a central role, strongly suggesting that enthalpy should be considered to be a form of energy.

Conclusions and Recommendations Concerning Displacement Energy (Section 4)

n. Currently (in texts on engineering thermodynamics), the displacement energy is covered by a list of quantities like 'flow work', 'flow energy', pV-work, pV energy, pressure energy, volume energy, 'pV work energy' and 'energy of displacement'.

o. The displacement energy (Ed) can be defined as $\{Ed\equiv p_A.\mathbf{V}\}$ where p_A is the ambient pressure and **V** is the displaced volume. In a natural environment, p_A will be a function of vertical position (z). For systems at constant pressure: $\{p=p_A|_{isobaric}\}$ hence $\{Ed=p.\mathbf{V}|_{isobaric}\}$.

p. The displacement energy is an extensive quantity, i.e. an additive quantity. (Mannaerts, 2014) It is also a state variable, i.e. independent of the path. (cf. Figure 1).

q. Each and every system or body, even a vacuum, that displaces a volume **V** in a pressurized environment with pressure p_A can be assigned a displacement energy (Ed) with {Ed≡p_A.**V**}.

r. The displacement energy of can change in three different ways: 1) A system at constant (external) pressure changes its volume for whatever reason: {ΔEd=p_E(Δ**V**)}; 2) A system of constant volume moves from an environment at pressure p_L to one with p_R: {ΔEd=**V**(p_L-p_R)}; 3) Any system for which the pressure of the environment changes around a system of constant displacement **V** from p_A' to p_A", with {ΔEd=**V**(p_A"-p_A')}. Note that this change in Ed does not involve any work related to the system. A common change of this kind is a change in hydrostatic pressure due to the tides, or a change in barometric pressure.

s. A system moving upward in a fluid gains gravitational energy (dz>0) but loses displacement energy (dp_A<0).

t. Enthalpy can be defined as an E-form, as the sum of internal energy and displacement energy.

u. This definition as {**H**=U+p_AV} is in accordance with the expression 'heat at constant pressure' that was used for the quantity enthalpy before 1922, as constant pressure is attained by setting inside pressure equal to ambient pressure.

v. Granting enthalpy the status of an E-form makes its presence in energy balances self-evident.

w. The first law of thermodynamics can equally be formulated as {ΔH=Q+W_{XI}}.

This sets {H=Q$|_{\text{no tech work}}$} i.e. with the condition that no technical work is done, which includes electrical work. This aspect is very useful in science education to explain Hess' law.

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Appendix A: Symbols for quantities and their relationships (grey: new or deviating quantities).

symbol	units (SI)	name	relationship	notes
superscripts & Greek				
y°	m	y at reservoir-level		used for p, z_L and z_R
y',y''	~	initial, final values of y	$\Delta y=y''-y'$	interval of integration |y',y''|
α	°	angle between force & path	$W=\int F.\cos(\alpha)dx$	nb cos(90°)=0, cos(180°)=-1
ρ	kg/m^3	density (ambient fluid)	$\rho=\mathbf{m}/\mathbf{V}$	hence $\mathbf{V}=\mathbf{m}\rho$
Φ	kg	mass transfer (cf. E‟)	$\varphi=d\Phi/dt$	applies to open systems
Latin symbols				
A	m^2	area (cross-sectional, piston)	see **V** and p	L(m): length, stroke length
E	J	total energy (system)	E = U+Eb=H+Em	sum of all E-forms
E‟	J	any energy input or output	$\sum E'=W+Q+\Phi.e$	energy balance eqn: $\Delta E=\sum E'$
e	J/kg	specific total energy	e= E/m	
Eb	J	Bernoulli energy	Eb= Ed+Eg+Ek	Bernoulli-eqn: dEb=0
eb	J/kg	specific mechanical energy	eb= Eb/m	(cf. Cengel &al, 2017, p64)
Ed	J	displacement energy	$Ed\equiv p_A\mathbf{V}$	
ed	J/kg	specific flow energy	$ed= p/\rho=Ed/m$	(cf. Cengel &al, 2017, p64)
Eg	J	gravitational energy	$Eg= mgz= -m\mathbf{g}z$	$dEg/dz=F_g=m\mathbf{g}=-mg$
Ek	J	kinetic energy	$Ek= ½mv^2$	(here: macroscopic only)
Em	J	mechanical energy	Em=Ek+Eg	(compare to Eb)
Ep	J	potential energy	∑(non-kinetic E)	Ep commonly used for Eg
Es	J	Stevin energy (external E)	Es= Eg+Ed	embodies law of hydrostatics
Ey	J	strain & spring energy	part of U or Em	y for T. Young (1773-1829)
F	N	force (vector)	$F= m(dv/dt)$	v=velocity
F_g	N	force of gravity	$F_g= m\mathbf{g}= -mg$	definite negative
F_b	N	buoyancy	$F_b= dEd/dz$	$F_b=\mathbf{V}dp_A/dz=\mathbf{V}.\rho\mathbf{g}$

g	m/s^2	gravity (acceleration of)	g = +9.81= −**g**	**g**<0: Cartesian convention
H	J	enthalpy (useful function)	H=U+pV	applies at constant pressure
H	J	enthalpy (E-form)	**H**=U+Ed	if $p=p_A$: Ed=p**V**, hence **H**=H.
h	m	depth *below* water level	h=z°−z, dh= −dz	nb: height=z in this paper
m	kg	mass (body/system)		
m	kg	mass of displaced fluid	Archimedes law	see ρ and **V**
p	Pa	pressure (system)	p=F/A	$(p-p_A)$= gauge pressure
p_A	Pa	ambient pressure	$(dp_A/dz)=\rho\mathbf{g}$	Stevin's law of hydrostatics
p_E	Pa	imposed (external) pressure	$p_E=p_A+p_X$	at equilibrium ($p=p_E$)
p_X	Pa	load-pressure (auxiliary p)	$p_X=F_X/A$	imposed by load/engine
Q	J	heat (transfer)		q=dQ/dt=heat-power (watt)
T	K	temperature (system)	(nb: t=time)	(T_A : ambient temperature)
U	J	internal energy		f(T,composition)
V	m^3	volume (available, enclosed)		nb: volume under piston
V	m^3	volume of displaced fluid	**V**>V, but Δ**V**=ΔV	for cylinder: **V**=A(m^2).L(m)
W	J	work (general)	$W=\int F.\cos(\alpha)dx$	w=dW/dt=work-power (W)
W_I	J	work on piston/interface	$W_I=W_{OI}+W_{XI}+W_{AI}$	mech. equilibrium: $W_I=0$
$\mathbf{W_{IA}}$	J	(p) work of displacement	$\mathbf{W_{IA}}=\mathbf{V}dp_A$	flow-work, pressure-work
W_{IA}	J	(V) work of displacement	$W_{IA}=p_A d\mathbf{V}$	expansion-, volume-work
W_{IO}	J	work on enclosed gas	$W_{IO}=-pdV$	commonly: gas = system
W_{IX}	J	shaft-work	$W_{IX}=\mathbf{V}dp_X$	technical work, useful work
W_g	J	work of gravitation	$W_g=F_g(z''-z')$	
x	m	position in x-direction	(centre of gravity)	
z	m	position in z-direction, height	(centre of gravity)	**z** =position centre buoyancy

Technology Programs Assessment and Continues Improvement Plan

Jay Albayyari
Wright State University, USA

Abstract: Undergraduate programs in Technology are required to have an assessment and continuous improvement plan in place for obtaining accreditation. Recognizing the value of accreditation and also motivated by the University level initiatives, an assessment and continuous improvement plan has been developed for new Technology program at Wright State University. This paper presents a comprehensive assessment and continuous improvement plan for the Technology program at Wright State University. The major goal of the Technology Program is to prepare graduates to understand the applications of concepts and knowledge of structured and analytical techniques of decision making in industry and technology. The Technology students study one technical track in sufficient depth to appreciate its methodologies and fundamental unresolved questions, and acquire a basis for life- long learning. Required courses for the program are established in: 1) Technology core, 2) required technical courses in the track area, 3) elective courses combining breadth of subject matter with specific study in depth, and 4) Projects focused on applied research. Program objectives, learning outcomes, assessment measures, assessment plan and metrics includes both direct and indirect measure will be presented in this paper.

Keywords: technology programs, industrial technology

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Introduction

Undergraduate programs in Technology are required to have an assessment and continuous improvement plan in place for obtaining accreditation[1-3]. Recognizing the value of accreditation and also motivated by the University level initiatives, an assessment and continuous improvement plan has been developed for new Technology program at Wright State University. This paper presents a comprehensive assessment and continuous improvement plan for the Associate of Applied Science in Mechatronics Engineering Technology program.

The major goal of the Technology Program is to prepare graduates to understand the applications of concepts and knowledge of structured and analytical techniques of decision making in industry and technology. Technology students' study one technical track in sufficient depth to appreciate its methodologies and fundamental unresolved questions and acquire a basis for life- long learning. Required courses for the program are established in: 1) Technology core, 2) required technical courses in the track area, 3) elective courses

combining breadth of subject matter with specific study in depth, and 4) Projects focused on applied research. Program objectives, learning outcomes, assessment measures, assessment plan and metrics include both direct and indirect measure will be presented in this paper.

Program Objectives and Outcomes

The objective is to offer an Associate of Applied Science in Mechatronics Engineering Technology program that meets the needs of regional manufacturing and service industries, research and development organizations, government, and not-for-profit organizations to prepare successful industry leaders and technical managers**.** The program provides the knowledge and skills required for its graduates to function effectively in a technical environment and to accept increasing responsibility in technical leadership positions. It is intended that graduates of the Associate of Applied Science in Mechatronics Engineering Technology program will demonstrate:

1. Students will demonstrate effective written, oral, and digital communication skills.
2. Students will demonstrate an applied knowledge of materials, structures and mechanical design and analysis.
3. Students will demonstrate an applied knowledge of circuit design and analysis and programmable logic controlling.
4. Students will apply knowledge of math and science in engineering design and analysis.
5. Students will understand industrial engineering and project management.
6. Students will apply proper lab techniques while performing experiments and research in engineering labs.
7. Students will utilize innovations and technology in planning, experimenting and evaluating professional engineering assignments.

Program Assessment and Continuous Improvement Tools

Table 1 summarizes the assessment methods used to measure the program outcomes outlined in the earlier section. The assessment tools consist of course syllabi, student cafeteria evaluation, student's performances in the course, Corse projects, exit and alumni survey and employer survey. It also clearly outlines the functional responsibilities of the instructors including the actions needed towards the continuous improvement of the program.

Table 1. Summary of Assessment Tools Their Purpose and Measurement Frequency

Program Outcomes	Tool	Purpose	Frequency
1-7	Course Syllabus	Course schedule, prerequisites, learning objectives	Each time course is offered
1-7		to learn student's evaluation	Each time course is

	Student cafeteria evaluation	of course & change the course accordingly	offered
1-7	Student performance assessments (exams, quizzes, homework, projects, presentations	to evaluate if program/course outcomes are fulfilled	Each time course is offered
5-7	Directed Projects	To evaluate if program outcomes are fulfilled	Each time project is presented
1-7	student exit interview (Questionnaire)	student's reflections on program	upon graduation
1-7	Alumni survey (Questionnaire)	Alumni perception of achievement of program goals	Every 2 years
1-4,6,7	Employer survey (Questionnaire)	Employer perception of achievement of program goals.	Every 2 years

The analysis of each course assessment (cafeteria evaluation) is reviewed by the instructor and the corresponding chair of academic department offering the course. The review information is included in the annual assessment report.

Assessment Measures

The graduation plan strategy (Table 2) shows the program courses. Table 1 has illustrated a broad plan, and tools used in measuring the program/course outcomes. Both direct and indirect measures are used to assess the level of accomplishment of program outcomes.

Direct Measures

The Directed Projects provides the first direct measure of the overall level of program outcomes achieved by the graduates of the program. Several courses have team projects with real life companies/organizations embedded in the course work. A formal assessment of course embedded team projects by the corresponding industry using a standardized questionnaire is the second direct measure.

Indirect Measures

The indirect measures include alumni surveys and student exit surveys. These surveys include a wide range of attributes related to alumni and student satisfaction. The employer survey also provides yet another indirect measure for assessment of program outcomes. Cafeteria evaluation is the indirect measure of the individual

course outcomes.

Table 2. Graduation Plan Strategy

Time period	Curriculum component	Time period	Curriculum component
Year 1 *Fall Semester*	Courses/Activities	*Year 1* *Spring Semester*	Courses/Activities
	ENG1100: Academic Writing and reading		MTH2300: Calculus I
	ME 1040: Engineering Design & Solid Modeling		PHY2400/2400L: General Physics I
	EGR 1010: Intro. Mathematics for Engineering Appl.		ISE 2211: Statistics for Engineers
	CHM 1210/1210L: General Chemistry I		ME 1020: Engineering Programming with MATLAB
Time period	Curriculum component	Time period	Curriculum component
Year 2 *Fall Semester*	Courses/Activities	*Year 2* *Spring Semester*	Courses/Activities
	PHY2410/2410L: General Physics II		EGR3350: Tech. Comm. For Engr. & Sci.
	ME 2120: Statics		ISE 1110/1110L: Intro. To EGR SCI APP for All
	ME 2700: Structure and Properties of Materials I		EE2010/2010L: Analog Circuit Theory and Lab
	MTH 2310: Calculus II		ME4121/4121L: Industrial Controls and Automation with Lab
	Social Science/Art		

Measuring Student Success

The Unit director, program faculty, academic advisors and career services advisor will be responsible for directing assessment efforts.

The measurements include:

1. Exams (measurement within a course)
2. Essays (measurement within a course)

3. Presentations (measurement within a course)
4. Projects (measurement within a course)
5. Lab reports (measurement within a course)
6. Student grades (measurement within the program)
7. GPA (measurement within the program)
8. Feedback from program faculty (measurement within the program)

Data labeled as 'measurement within a course will be collected every semester. For all other measurements, data will be collected every year to assess the students' success. At the end of every academic year, the data such as GPA progress, grades and feedback from program faculty will be summarized to inform the student. The Following initiatives will be used to track student success after program completion and will be administered by career services advisor and development and community relations coordinator:

1. Exit interview
2. Surveys of job placement upon graduation
3. Employer surveys on program graduates

Conclusion

While accreditation for undergraduate programs are sort of becoming "requirements" for all undergraduate programs, its important for every program to have an assessment plan that is clear, organized and executed on a timely matter to ensure the students success. This paper has presented a comprehensive assessment and continuous improvement plan for the Associate of Applied Science in Mechatronics Engineering Technology program. Included were program objectives, learning outcomes, and assessment measures. A clearly defined continuous improvement process and implementation timeline were also presented.

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Trends of The Studies Gamification in Education Between 2019 and 2023: A Thematic Content Analysis Study

Gönül Yazar
Süleyman Demirel University, Türkiye, https://orcid.org/0009-0005-2283-3497

Vural Tünkler
Süleyman Demirel University, Türkiye, https://orcid.org/0000-0002-3536-968X

Veysel Demirer
Süleyman Demirel University, Türkiye, https://orcid.org/0000-0002-3264-9424

Abstract: The aim of this study is to determine tendencies through bringing a cumulative perspective to research on gamification in terms of education. A total of 72 fulltext studies were filtered according to the purpose of the study and they were analyzed through thematic content analysis according to the along with their years of publication, research issue, department and course, research groups, methods used, data collection tools, data analysis techniques and independent variables. Research findings display that the the studies on gamification in education have increased over the years, and although there are various research issues, they focus on the effects of gamification on student motivation, academic achievement, and course attendance. It was determined that the most frequently studied department was the faculty of education, and the applied course was the mathematics course, sample level/study group consisted mostly of undergraduate students and middle school 5th grade students, quantitative methods were mostly preferred in the studies, mostly survey were used as data collection tools, and t-test and ANOVA were used in data analysis. On the other hand, it was seen that the dependent variables such as academic achievement, attitude, course attendance, perception and performance, especially motivation, were frequently examined. Although studies on gamification in education generally focus on students, there is a need for more studies to reveal the gamification competencies of teachers and their perceptions and opinions about gamification.

Keywords: Education, Gamification, Thematic Content Analysis

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Introduction

Innovations and developments in the field of technology are progressing at a dizzying pace today compared to the past. Especially mobile technologies have become an indispensable part of our daily lives and individuals have had the opportunity to quickly obtain many of their requests regardless of time and place with the convenience provided by technology (Güler, 2015). It is very difficult to think of the generations born in this period of rapid development of technology as independent from digitalisation and the internet because these generations use social networks very frequently and are constantly online (Bozkurt, & Genç-Kumtepe, 2014). With the developing technology, education and training activities have also been digitalised and different methods and techniques have been needed (Sarı, & Altun, 2016). As a result of technological developments, the understanding of education in which the teacher is at the centre has been replaced by a system in which the learner is at the centre, and with this system, it is aimed to raise individuals who think creatively, question, research and work in cooperation (Arslan, Bozan, & Ayar, 2023). Educational games, which are one of the promising strategies frequently used by educators, help not only to teach knowledge but also to reinforce important skills such as problem solving, cooperation and communication skills (Dicheva et al., 2015). Games, which are an indispensable part of human life, have also taken their share from technological changes and transformations, especially the time children spend on the street to play games has been replaced by digital screens, so children and games have also turned their faces to digitalisation (Şahin, & Samur, 2017).

The game is the oldest form of social interaction and is one of the most protected cultural heritage areas of society that have been integrated into every culture throughout history. (Berber, 2018) In gamification, it is aimed to solve real problems by using the positive aspects of games (Lee, & Hammer, 2011). "Gamification" method, which is used to keep learner motivation high in the teaching phase, to increase the interest and participation in the lesson, is a digital method used to make teaching more efficient (Sarı, & Altun 2016). Due to these effects, with the use of gamification in education, it is aimed to find a solution to the indifference in learning requests, which is one of the most important problems experienced by students in today's education system, with the idea of games that students love very much (Alagöz Hamzaj, 2023). The aim of gamification is not to design a new environment and take people there as in the game universe, but to bring the game elements to life and make them feel similar feelings without breaking away from reality (Arkün Kocadere, & Samur, 2016).

Although game logic has been used in education for a long time, the term "gamification" was first used by Nick Pelling in 2003, and although game designers talked about the strong effects of gamification in the following years, it took until 2010 to be adopted by the masses (Werbach, & Hunter, 2012). Although the definition of gamification varies according to the context in which it is used (Bozkurt, & Genç-Kumtepe, 2014), Deterding et al. (2011) defined gamification as the transfer of game components outside the game. Zichermann and Cunningham (2011) defined gamification as the use of game mechanics and game ideas to solve problems and stated that this definition offers a flexible space and can be applied to overcome the problems encountered in the

process of changing participant motivation and behaviour. The common point of the definitions of gamification is to use game components in contexts that normally do not contain any game elements and to provide a "game-like" experience (Sezgin et al., 2018). The most important feature that makes gamification different from the game is that there is no game (Arkün Kocadere, & Samur, 2016). Werbach and Hunter (2012), in their work "For the Win", grouped the basic elements of gamification into three categories and emphasised the importance of using these elements according to the requirements of the designed gamification project and stated that a successful gamification can be achieved in this way. Game elements are the basic elements that players interact with and shape the game world; game designers create balanced and immersive games using these elements (Berber, 2018). Dynamics, mechanics and components can be defined as follows (Werbach, & Hunter, 2015):

- *Dynamics:* The elements that provide motivation are included in this category. Dynamics are felt by users, but direct interaction cannot be provided. Story and emotions are examples of dynamics.
- *Mechanics:* Elements that enable player engagement. By activating mechanics, player behaviour is expected to emerge with the formation of player engagement. Each mechanic may depend on one or more dynamics. Examples of mechanics are luck, co-operation and challenges.
- *Components:* They contain more specific elements than dynamics and mechanics that players can easily see. Each component can be linked to one or more mechanics, as in the next level up. Examples of components are avatars, levels and badges.

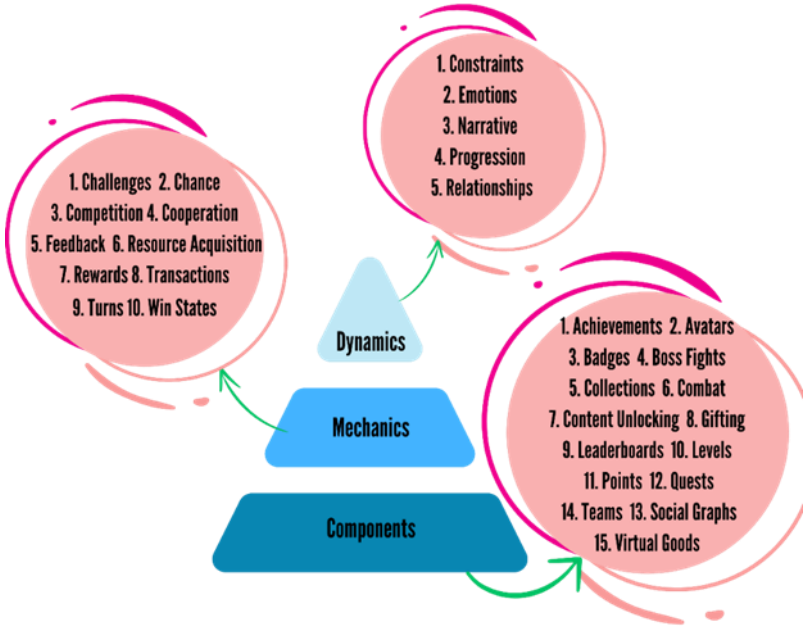

Figure 1. Gamification Pramid (adapted from Werbach, & Hunter, 2012, pp. 78-82)

The game design process starts with the selection of the basic dynamics suitable for the need and then proceeds by determining the mechanisms and components suitable for these dynamics; it is not obligatory to use every element here, the main thing is to choose the right elements for the purpose and need of the designed game (Bozkurt, & Genç-Kumtepe, 2014). Werbach and Hunter (2015) stated that one of the most common mistakes

made by designers is to skip details such as the high goals of the designed gamification, the desired behaviours to be gained and the characteristics of the addressed audience, and to focus more on which reward will be given to which action. Werbach and Hunter (2012), therefore, prepared a design checklist called the D6 model for designers to create an effective product. The model was initially designed for business processes, but over time it has been used for various situations and goals (Köse, & Çilingir Ük, 2019).

Figure 2. D6 Gamification Design Model (adapted from Werbach & Hunter, 2012, pp. 86)

According to this gamification design model (Werbach, & Hunter, 2012, pp. 87-101);

1. *DEFINE busines objectives:* For an effective gamification, gamification objectives should be defined and understood very well.

2. *DELINEATE target behaviours:* After defining the gamification objectives, it is necessary to determine how we want the players to behave and how we will measure these behaviours and to think about these two steps together. The target behaviours of the players should support the gamification goals.

3. *DESCRIBE your players:* It is very important to define who the players who will use the system are, how they are motivated, and design a game within this framework. If the target audience and their characteristics are not understood well enough, a successful product may not emerge.

4. *DEVISE activity cycles:* The process between the start and end of the games works through a series of cycles. These cycles are divided into two;

- Interaction loops: Defines at a simple level what players do and why they do it, and how the game system reacts to player actions; motivated actions are rewarded with system feedback, which is provided through components such as badges, points, leaderboards, etc.
- Progression ladders: Indicates that the level of the players increases as they progress, there should be different levels of difficulty and challenges should be offered to the players. The player's interest should be kept alive by adding various unexpected rewards.

5. *DON'T forget the fun:* While designers are interested in different aspects of gamification, they often overlook the fun. If players find the system fun, they will want to come back again. It should be determined what kind of

fun will be provided according to the context of the design and this step should not be ignored.

6. *DEPLOY the appropriate:* In the last phase, the implementation phase, it is necessary to select and code the right dynamics, mechanics and components and incorporate them into the system.

7.

In general, gamification provides significant benefits in education systems in the light of the reflections of technological developments on education both today and in the coming years (Ar, & Akgün, 2014). Due to the contributions of gamification to education and training, it is seen that many studies on gamification have been carried out, as well as studies that examine these studies. In this research, it is aimed to examine the studies on gamification in education from various perspectives. In line with the aim of the research, answers to the following questions were sought:

1. *Do the studies on gamification differ according to years?*
2. *Which topics were investigated in the studies on gamification?*
3. *Do the studies on gamification differ according to the departments applied?*
4. *Do the studies on gamification differ according to the courses applied?*
5. *Do the studies on gamification differ according to sample levels?*
6. *Do the studies on gamification differ according to the target group?*
7. *Which methods are commonly used in studies on gamification?*
8. *Which data collection tools were preferred in studies on gamification?*
9. *Which analysis methods were commonly used in studies on gamification?*
10. *Do the dependent variables examined in studies on gamification differ?*
11. *What are the findings obtained in studies on gamification?*

Method

In this study, studies on gamification in education were examined, and content analysis method, one of the qualitative analysis methods, was preferred to explain the data collected by using document analysis method, which is one of the qualitative research designs in the research. With content analysis management, it is aimed to examine all qualitative and quantitative studies published on the specified subject and to determine the research trends on the subject (Ültay, Akyurt, & Ültay, 2021). In this section, the scope of the research, data collection process and data analysis procedures are described in detail.

Scope of the Study

The scope of the research consists of national and international article studies on the gamification method in education in the last 5 years (between 2019-2023). In this context, the research covers domestic and foreign article studies. Studies outside the field of education and paid or inaccessible studies were excluded from the scope of the research.

Data Collection Process

In order to determine the studies to be examined within the scope of the research, Web of Science, Scopus and ULAKBIM databases were searched using the keywords "gamification and education", "gamification" and "gamification in education". As a result of the search, 128 article studies were reached and 72 articles were included in the study within the scope of the inclusion criteria.

Data Analyses

As a result of the literature review, 72 studies on gamification in education were examined in terms of publication year, research topic, departments and courses in which gamification was examined, sample level, target group, methods used, data collection tools, analysis methods, dependent variables examined, and findings obtained. The data obtained as a result of content analysis were analysed with descriptive statistical methods to answer the research questions. The data obtained were organised, grouped and quantified and presented in tables, and the tables were interpreted.

Findings

In this section, the year of publication, research topic, departments and courses in which gamification is examined, sample level, target group, methods used, data collection tools, data analysis methods, dependent variables examined, and findings of the studies related to gamification in education are given. In order to indicate the distribution of studies on gamification according to years, the statistics for each year are presented in Table 1.

Studies on Gamification in Education According to Research Years

Table 1. Distribution of Studies on Gamification According to Years

Years	2019	2020	2021	2022	2023	**Total**
Article	8	17	10	15	22	72

Looking at the descriptive statistics of the distribution of studies on gamification in education by years, it is seen that the number of studies on gamification increased with the transition to online education during the pandemic process, and although there was a decrease in the number of studies in 2021, there was an increase in the number of studies in the following years. Looking at this increase over the years, it can be said that the tendency towards gamification in education has increased.

Studies on Gamification in Education According to Research Topics

Studies on gamification in education were analysed according to research topics. Descriptive statistics of research topics are presented in Table 2.

Table 2. Distribution of Studies on Gamification According to Subjects

Research Subject	***f***	**%**
Use of gamification during courses, lectures etc.	21	29.16
Scale development studies	1	1.40
Revealing experiences and opinions on gamification	8	11.11
A model proposal for gamified course design	5	6.94
The relationship between gamification and various dependet variables such as motivation, academic achievement, etc.	29	40.27
Combined use of gamification and flipped classroom model	2	2.77
Gamification studies in different subject areas	6	8.33
Total	72	100

When Table 2 is examined, it is seen that the most researched topic in the studies on gamification in education is the relationship between gamification and dependent variables such as motivation, academic achievement, etc. (f=29). It is seen that the use of gamification during courses, lectures, etc. (f=21), revealing experiences and opinions about gamification (f=8), model suggestion for gamified course design (f=5) were investigated more than the studies on the use of gamification and flipped classroom model together and gamification studies on different subjects, while the use of gamification and flipped classroom model together (f=2) and gamification studies on different subject areas (f=6) were conducted less.

Studies on Gamification in Education According to the Applied Departments

The studies on gamification in education were analysed according to the departments in which they were applied. Statistical information about the departments in which the studies on gamification in education were applied is given in Table 3.

Table 3. Distribution of Studies on Gamification According to the Department of Study

Department	***f***	**%**
Faculty of Medicine	4	5.55
Faculty of Education	17	23.61
Faculty of Engineering	5	6.94
Economy	1	1.38
Public Administration	1	1.38
Tourism	1	1.38
Social Sciences	2	2.77

Biology	1	1.38
Unspecified	40	55.55
Total	72	100

When Table 3 is examined, it is seen that the studies on gamification in education differ according to the departments in which they are applied, and the most studied department is the Faculty of Education (f=17). It was determined that the studies conducted in the Faculty of Engineering (f=5), Faculty of Medicine (f=4), and Social Sciences (f=2) departments were more than the studies conducted in the departments of Economics (f=1), Public Administration (f=1), Tourism (f=1) and Biology (f=1). It is seen that there are quite a lot of articles that do not specify in which department the gamification study was conducted (f=40).

Studies on Gamification in Education According to the Applied Courses

Statistical information on the courses in which the studies on gamification in education were applied is presented in Table 4.

Table 4. Distribution of Studies on Gamification According to the Courses in which They Are Applied

Lessons	***f***	**%**
English	7	9.72
Maths	10	13.88
Science and Technology	2	2.77
Social Studies	1	1.38
Chemistry	2	2.77
Developmental Disorders	1	1.38
History	1	1.38
Social Sciences and Didactics 1	1	1.38
Coding	1	1.38
Calcula	1	1.38
Visual Programming	1	1.38
Introduction to Education	1	1.38
Cyber Security	1	1.38
Physical Education Course	3	4.16
Environmental Education	1	1.38
Life Science	1	1.38
Music	1	1.38
Introduction to Hotel Management	1	1.38
Technology Applications in Education	2	2.77
Laboratory Techniques	1	1.38

Computer 1 Course	1	1.38
Education in Virtual Worlds	1	1.38
Programming	1	1.38
Scientific Communication	1	1.38
Spanish	1	1.38
Unspecified	27	37.49
Total	72	100

When Table 4 is examined, when the distribution of the studies related to gamification in education is examined according to the course in which they are applied, it is seen that most studies are in Mathematics (f=10) course. English (f=7), Physical Education (f=3), Science and Technology (f=2), Chemistry (f=2) and Technology Applications in Education (f=2); Social Studies (f=1), Developmental Disorders (f=1), History (f=1), Social Sciences and Didactics 1 (f=1), Coding (f=1), Calculus (f=1), Visual Programming (f=1), Introduction to Education (f=1), Cyber Security (f=1), Environmental Education (f=1), Life Science (f=1), Music (f=1), Introduction to Hotel Management (f=1), Laboratory Techniques (f=1), Computer 1 Course (f=1), Education in Virtual Worlds (f=1), Programming (f=1), Scientific Communication (f=1) and Spanish (f=1).

Studies on Gamification According to Sample Levels and Target Audience

The studies on gamification in education were examined according to the sample level and target group, and descriptive statistics on the target group and sample levels of the studies on gamification are given in Table 5.

Table 5. Sample Level & Target Audience

Sample Level	***f***	**%**	**Target Audience**	***f***	**%**
Teacher	5	6.94	Preschool students	3	4.05
Academician	2	2.77	Primary school 1st grade students	1	1.35
Preschool Student	3	4.16	Primary school 2nd grade students	4	5.40
Primary School Student	10	13.88	Primary school 3rd grade students	4	5.40
Secondary School Student	7	9.72	Primary school 4th grade students	3	4.05
High School Student	2	2.77	Secondary school 5th grade students	5	6.75
Undergraduate Student	35	48.61	Secondary school 7th grade students	1	1.35
Graduate Student	3	4.16	Secondary school 8th grade students	1	1.35
Unspecified	5	6.94	High school 9th grade students	2	2.70
			1st year undergraduate students	3	4.05
			2nd year undergraduate students	3	4.05
			3rd year undergraduate students	2	2.70
			4th year undergraduate students	2	2.70
			Master's degree students	3	4.05

			Working teacher	5	6.75
			Academician	2	2.70
			Unspecified	30	40.54
Total	72	100		74	100

When Table 5 is examined, the studies on gamification in education were analysed according to the sample level. It is seen that the studies on gamification differ according to the sample level; most of the studies examine undergraduate students (f=35). It is seen that studies examining primary school students (f=10), secondary school students (f=7) and teachers (f=5) are more than studies examining kindergarten students (f=3), graduate students (f=3), academicians (f=2) and high school students (f=2).

When Table 5 was examined, the studies on gamification in education were analysed according to the target audience. The reason why the total frequency value of the target audience is 74 is related to the selection of more than one target audience in some studies. When the gamification studies are examined, it is seen that they differ according to their target audience; it is seen that most of the studies were conducted with secondary school 5th grade students (f=5) and working teachers (f=5). It is seen that the studies in which primary school 2nd grade (f=4), primary school 3rd grade (f=4), kindergarten (f=3), primary school 4th grade (f=3), undergraduate 1st grade (f=3), undergraduate 2nd grade (f=3) and graduate students (f=3) were examined; primary school 1st grade (f=1), middle school 7th grade (f=1), middle school 8th grade (f=1), high school 9th grade (f=2), undergraduate 3rd grade (f=2), undergraduate 4th grade students (f=2) and academicians (f=2).

Methods Used in Studies on Gamification

The studies on gamification in education were examined according to the methods used, and the method of the studies using quantitative and qualitative methods together was specified as mixed. Descriptive statistics showing the change in the methods used in studies on gamification according to years are presented in Table 6.

Table 6. Distribution of Methods Used According to Years

	2019	**2020**	**2021**	**2022**	**2023**	**Total**
Mixed	3	4	2	5	6	20
Quantitative	4	9	5	6	15	39
Qualitative	1	4	3	4	1	13
Total	8	17	10	15	22	72

When Table 6 is examined, it is seen that quantitative methods (f=39) are used more than other methods, mixed methods (f=20) and qualitative methods (f=13) are used more in the studies on gamification. When we look at the distribution of the studies according to the years, it is seen that qualitative methods were one of the least preferred methods in all years and started to be preferred less and less, while mixed and especially quantitative

methods were preferred more and more over the years.

Data Collection Tools Used in Studies on Gamification

The studies on gamification in education were analysed according to the distribution of data collection tools. The reason why the total frequency is 88 is that more than one data collection tool was used in some studies. The statistics of the data collection tools are given in Table 7.

Table 7. Distribution of Data Collection Tools Used

Data Collection Tool	***f***	**%**
Survey	44	49.99
Test	5	5.68
Interview	14	15.90
Observation	8	9.09
Document	12	13.63
Scale	5	5.68
Total	88	100

When Table 7 is examined, it is seen that the use of survey (f=44) is mostly preferred as a data collection tool in studies on gamification in education. It is seen that the use of interviews (f=14), documents (f=12) and observations (f=8) in the studies is higher than the use of tests (f=5) and scales (f=5).

Data Analysis Methods Used in Studies on Gamification

The studies on gamification in education were analysed in terms of data analysis methods. The reason why the total frequency of data analysis methods was 93 was that more than one data analysis method was used in some studies. The statistics of the data analysis methods used in the studies are given in Table 8.

Table 8. Distribution of Data Analysis Methods Used

Analysis Method	***f***	**%**
ANOVA	14	15.05
T-test	14	15.05
Content Analysis	12	12.90
Thematic Analysis	2	2.15
Descriptive Analysis	9	9.67
Document Analysis	8	8.60
SEM	1	1.07

Kolmogorov- Smirnov testi	4	4.30
Wilcoxon signed-rank test	3	3.22
Mann Whitney U Test	7	7.52
Kruskal –Wallis Test	2	2.15
Variance Accounted for	1	1.07
Exploratory Factor Analysis	2	2.15
Confirmatory Factor Analysis	1	1.07
Shopiro Wilk Test	3	3.22
Freidman Test	1	1.07
Chi Square Test	1	1.07
MANOVA	2	2.15
Correlation analysis	4	4.30
Cronbach Alfa	2	2.15
Total	93	100

When Table 8 is examined, it is seen that the most preferred data analysis methods in the studies on gamification in education are ANOVA (f=14) and T-test (f=14). Content analysis (f=12), descriptive analysis (f=9), document analysis (f=8) and Mann Whitney U test (f=7) methods were used; Kolmogorov-Smirnov test (f=4), Correlation analysis (f=4), Wilcoxon signed-ranks test (f=3), Shopiro Wilk test (f=3), Thematic Analysis (f=2), Kruskal-Wallis test (f=2), Exploratory Factor Analysis (f=2), MONOVA (f=2), Cronbach's Alpha (f=2), SEM (f=1), Variance Accounted for (f=1), Confirmatory Factor Analysis (f=1), Friedman's Test (f=1) and Chi Square Test (f=1) data analysis methods.

Dependent Variables Analysed in Studies on Gamification

The studies on gamification in education were analysed according to their dependent variables. The reason why the total frequency of dependent variables was 107 was that more than one dependent variable was examined in some studies. The dependent variables examined in the studies on gamification are given in Table 9.

Table 9. Distribution of Dependent Variables Analysed

Variables	***f***	**%**
Academic Success	17	15.88
Attitude	13	12.14
Motivation	29	27.10
Class Participation	14	13.08
Satisfaction	2	1.86
Attention	6	5.60
Interest	2	1.86

Perception	11	10.28
Performance	7	6.54
Skill	3	2.80
Self-confidence	1	0.93
Emotion	2	1.86
Total	107	100

According to the data in Table 9, it is seen that the most examined dependent variable in the studies on gamification in education is motivation (f=29). It is seen that the studies in which dependent variables such as academic achievement (f=17), attitude (f=13), class participation (f=14), perception (f=11), attention (f=6) and performance (f=7) are examined are more than the studies in which independent variables such as skill (f=3), satisfaction (f=2), interest (f=2), self-confidence (f=1) and emotion (f=2) are examined.

Findings from Studies on Gamification

The general findings of studies on gamification in education support the positive effects of gamification on education. According to the results obtained from the examined articles, gamification has increased participant motivation, engagement in the course, interest, academic achievement, and cooperation among individuals. Participants' attitudes towards the course changed positively, undesirable behaviors were replaced by desirable ones, and a study observed a decrease in internet addiction among male adolescents. Participants' anxiety towards exams and courses decreased, and their willingness to learn increased. The use of gamification during the course process and active participation of participants in the course enhanced interaction within the course and provided effective teaching. Increases in problem-solving and creative thinking skills were observed among participants, and they indicated that their views on gamification were positive.

Conclusion and Discussion

In this study, research on gamification in education was examined based on publication year, the topic investigated, the department applied, the course applied, sample level, target audience, data collection tool, data analysis method, the dependent variable examined, and the findings obtained. The findings from the research show that studies on gamification in education have increased over the years, with most studies conducted in 2023. The studies differ in terms of the topics investigated, and although studies have been conducted in many different departments, it is observed that most studies have been carried out by faculties of education.

Although gamification studies in education have been applied to many different courses, it has been determined that the most frequently applied courses are mathematics and English. The studies on gamification in education encompass various sample levels, ranging from preschool to active professionals such as educators and healthcare workers, but the most preferred sample level has been identified as undergraduate students. As for the

target audience, it is seen that most studies have been directed towards teachers and 5th-grade middle school students.

When we look at the studies on gamification in education in terms of the research methods used, it is seen that quantitative methods are used more frequently than qualitative and mixed methods, and the number of quantitative studies has increased over the years. Many data collection tools have been used in the studies, but it has been determined that the most preferred data collection tool is the survey. It has been concluded that the most frequently used methods for analyzing the data obtained in the studies are ANOVA and t-test, and content analysis, descriptive analysis, and document analysis methods are also frequently preferred. The most examined dependent variable in gamification studies in education is motivation, along with other frequently addressed variables such as academic achievement, attitude, perception, performance, and course participation.

Finally, when looking at the findings of the studies, they support the positive effects of gamification on education. According to the findings of the studies, gamification has increased participants' motivation, interest, academic achievement, participation, collaboration, creativity, and problem-solving skills, contributed to the display of positive attitudes and behaviors, and reduced anxiety towards exams and courses. Participants also indicated that their views on gamification were positive.

Recommendations

- Increasing the number of mixed and qualitative studies will contribute to the development of literature.
- Gamification studies should be increased in other courses as well, just as they have been in mathematics.
- The sample level and target audience should be broader, and class levels that have not been included in studies on gamification should be incorporated.
- Although studies on gamification focus on students, more research should be conducted to reveal the competencies, perceptions, and views of practicing teachers regarding gamification

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Review of Studies on Digital Storytelling in Education Between 2019 and 2023

Fatma Ülkü Bacak
Suleyman Demirel University, Türkiye, https://orcid.org/0009-0008-9092-7729

Vural Tünkler
Suleyman Demirel University, Türkiye, https://orcid.org/0000-0002-3536-968X

Veysel Demirer
Suleyman Demirel University, Türkiye, https://orcid.org/0000-0002-3264-9424

Abstract: The purpose of this study is to analyze studies on digital storytelling carried out between 2019 and 2023. Content analysis was selected as the method of this study. In this respect, certain studies were reviewed in Web of Science, ERIC, EBSCO, Google Scholar and the Council of Higher Education (CoHE) national thesis center database. 19 theses and 80 articles are included to the study. In this study, studies on digital storytelling between 2019 and 2023 were examined according to publication year, publication type, research issue, research methods, research designs, study group, data collection tools and data analysis. In the research, it was determined that the studies based on digital storytelling were mostly in the form of articles and master's theses and increased from year to year, and that studies were conducted in all designs, mostly qualitative research design and case study design. It was seen that the most studies were conducted with students at different levels, most of the studies included students at undergraduate and secondary school levels, and most of the studies focused on science and technology, English and Turkish courses. Another finding was the use of various data collection tools such as scales, tests, interviews and especially semi-structured interview forms. Besides, it was determined that concluded that data analysis methods such as descriptive analysis, t-test, content analysis were used. In the studies examined, there are findings that digital storytelling positively affects academic achievement, motivation, interest in the course, positive attitude and learning performance, and contributes to the development of technology literacy, media literacy, writing and language skills. The recommendations found in the studies are mostly related to the utilization of digital stories during teaching in different disciplines and providing training to educators on digital storytelling.

Keywords: Education, Digital Storytelling, Content Analysis

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Introduction

We are living in an "age of storytelling" in which narrative and the mastery of this narrative are recognized as popular culture in separate subjects such as popular culture, marketing, politics, and social justice (Blei, 2018). Given the dominance of print and electronic media in the past and present world, it is an inevitable fact that our sense of reality is increasingly structured by narrative (Küngerü, 2016). The story first manifested itself in the drawings people made on cave walls to express themselves (Kutlucan, Çakır, & Ünal, 2018). And storytelling, which started with the paintings on cave walls, has played a critical role in transferring elements such as knowledge, culture, traditions and customs from generation to generation, has found its place in various fields such as print media and the silver screen over time, and has turned into a tool realized with technology today (Dereli, 2023; Lantz, Myers, & Wilson, 2020; Smeda, Dakich, & Sharda, 2014). Csikar and Stefaniak (2018) stated that storytelling is nowadays used as a known and effective way to share information, ideas, and emotions through digital technology such as books, movies, and internet channels. Scroggie (2009) defines storytelling as "a traditional art that all societies and cultures known to all humanity have practiced for thousands of years". Willis and Sawyer (2011) emphasized that in storytelling, individuals tell what they want to tell by using an unusual style. Behmer (2005) defines storytelling as the transfer of ideas and meanings that people form about their own or others' lives through words, while McDrury and Alterio (2003) define it as a unique experience that allows us to share our own or others' real or fictional worlds through the language of words. In this direction, a story, regardless of whether it is real or fictional, helps to attract the attention of its target audience, the listeners, and to engage their minds with various emotions such as surprise and excitement (Dunne, 2006), and encourages communication by mobilizing individuals (Hill, & Grinnel, 2014).

With all these benefits, storytelling has found its place in the field of education and has emerged as a simple yet effective method to help students make sense of their complex world of experience through a plot (Van Gils, 2005). Storytelling can also be called the oldest form of education (Trawick-Smith, 2003, as cited in Wang, & Zhan, 2010). Storytelling, which is seen as a learning tool, encourages students to explore themselves and increases their ability to communicate their feelings and thoughts in an understandable way (Mokhtar, Halim, & Kamarulzaman, 2011). In addition, Wang and Zhan (2010) stated the effects of storytelling in educational settings as follows: (1) it can be used as a learning tool in different fields, (2) teachers can help students learn new subjects by explaining existing knowledge to them, (3) students can increase their knowledge and skills such as writing and language through creating stories. Today, with the rapid developments in technology, storytelling has emerged with a new adaptation and a new dimension (Xu, Park, & Baek, 2011). Meadows (2003) stated that although storytelling is not new, digital storytelling is. Hu et al. (2020), on the other hand, state that the use of both traditional storytelling and digital storytelling in learning and teaching processes is not a new concept, but it is not as comprehensive as other contemporary approaches. These statements reveal how popular digital storytelling has become in a relatively short period of time and how quickly it has been adopted by educators with the positive effect of developing technology, while taking into account that storytelling has been used for centuries, and on the other hand, it points to the need for more use of the digital storytelling

method. Accordingly, Ulu (2021) points out that the importance of digital storytelling will increase as time passes due to the increase in studies on digital storytelling. This is because digital storytelling is an increasingly prominent teaching technique in various environments, including formal and non-formal education and virtual classrooms enriched by technology (Özpınar, 2017). Lambert (2002) pioneered the creation of digital stories by transferring stories to digital environments. The term digital storytelling was first used by Dana Atchley (Kajder, Bull, & Albaugh, 2005; McLellan, 2007). In 1994, Dana Atchley came together with Joe Lambert, Nina Mullen, media artists, theater workers and storytellers to establish the San Francisco Digital Center, which was renamed the "Center for Digital Storytelling" in 1988 (Aldemir Engin, 2022; Garcia, & Rossiter, 2010).

Since the emergence and use of digital storytelling, there have been many definitions made by researchers. These definitions have been expressed in various ways. Meadows (2003) defines digital storytelling as multimedia elements that are short and personal, told from the heart. It is stated by many researchers that the digital story emerges by combining the traditional art of storytelling with multimedia tools and components of these tools (Davis, 2004; Jakes, & Brennan, 2005; Norman, 2011; Ohler, 2013; Robin, 2006). In addition, Lambert (2006) stated that this integration makes the existing learning and teaching tool more powerful.

Digital storytelling differs from traditional storytelling in that it allows learners to get out of the position of a listener and interact by creating stories (Dörner, Grimm, & Abawi, 2002). The fact that technological tools such as computers and software are now more easily accessible in classroom environments enables students to create digital stories more simply and quickly than in the past, and the increase in the use of the internet makes these digital stories more accessible to target audiences (Girasoli, 2016; Robin, 2006). In addition, considering a systematic teaching process and the use of free digital software, digital storytelling is an approach that empowers teachers and increases the motivation of students (Yang, & Wu, 2012). Through the active learning process, students can develop their thinking skills about the text, the storyteller, and the relationships between the two, and they can both better understand the subject matter and interact with others by becoming listeners (Mello, 2001). Digital storytelling activities enable students to create realistic artifacts and transfer their thoughts creatively to these artifacts (Gakhar, & Thompson, 2007), thus playing a role in activating their creativity skills to bring a solution to realistic problem situations (Jenkins, & Lonsdale, 2007). Inceelli's (2005) statement confirming these statements is related to the fact that digital storytelling gives the opportunity to apply the subject in real life situations by giving control to the student. On the other hand, digital storytelling plays a role in helping students develop different roles and skills (Hafner, & Miller, 2011) and supports in-depth thinking skills, for example, by helping students create and keep together individual digital stories (Psomos, & Kordaki, 2015). Since 21st century skills, in other words, learning environments should be enriched with digital tools and opportunities in order to provide students with higher-order thinking skills (Kaya, 2019), digital storytelling, as a method that has these opportunities, is an important tool used in teaching basic skills such as grammar and history, as well as a method that helps the development of 21st century skills such as cooperation and technology use (McLellan, 2007). Tunç and Karadağ (2013) also supported these statements by stating that the digital storytelling technique is suitable for the age we are in in gaining important behaviors. In addition, in the process of creating digital stories, students' willingness to experiences related to language use skills

increases and they make adjustments in their language use when needed (Hull, & Katz, 2006). Since students actively participate in the learning processes during the activities, they make sense of their learning (Kocaman Karoğlu, 2015), and through digital storytelling, they come up with new ideas by obtaining information and organizing their knowledge, which means that they better assimilate the subject (Burmark, 2004).

Robin (2006) categorizes digital stories under three headings: "personal stories", which are stories that individuals consider important, "historical stories", which help to make sense of the past, and "educational stories", which aim to inform the audience.

The digital storytelling method consists of 7 elements. As shown in Figure 1, these are point of view, interesting question, emotional content, good voice-over, power of music, economy and pacing (Bull, & Kajder, 2004; Jakes, & Brennan, 2005; Lambert, 2010; Robin, 2006).

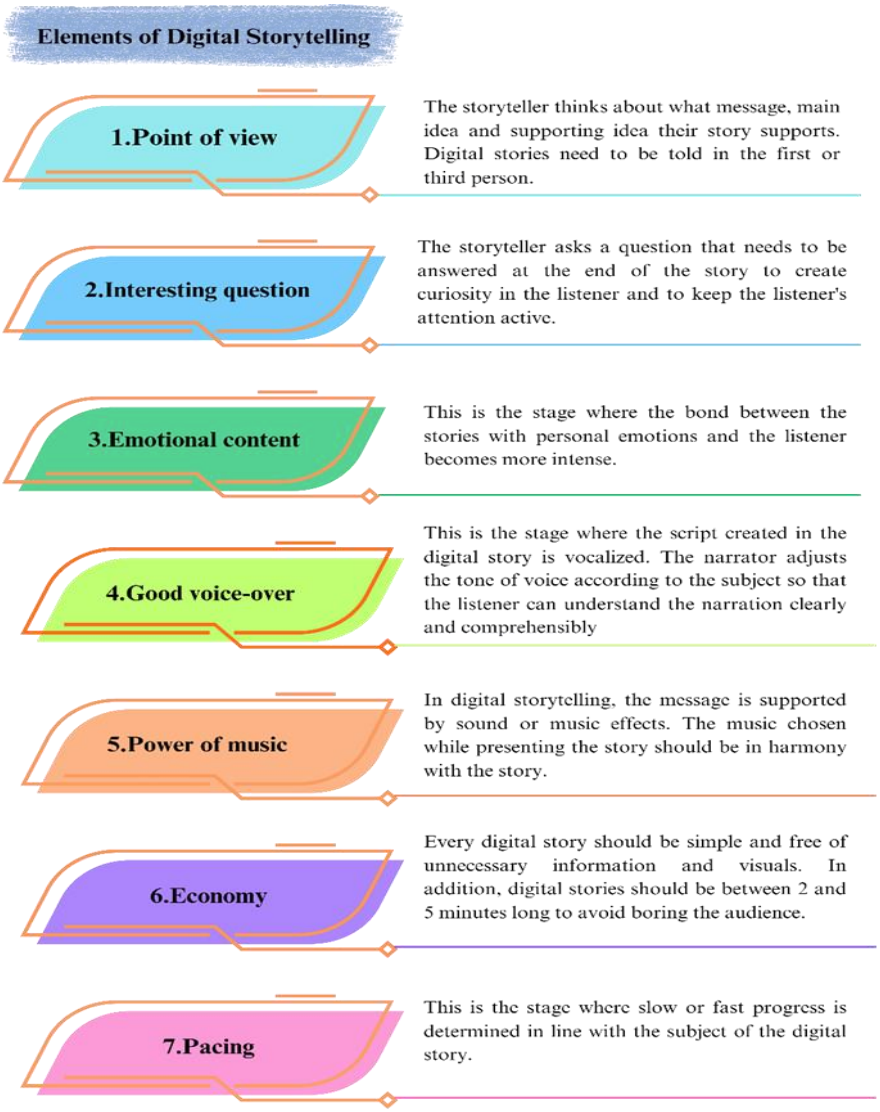

Figure 1. Elements of Digital Storytelling (adapted from Bull, & Kajder, 2004, p. 2)

The fact that the use of technology in learning and teaching environments has become important in the current era has led to the popularization of the use of digital stories, one of the technological tools, day by day (Wu, & Chen, 2020). In line with this situation, scientific studies and studies on the examination of these studies are also increasing. In the literature, there are content analysis studies on digital storytelling at national or international level (Sarar Kuzu, & Yalçınalp, 2023; Talan, 2019; Ulu, 2021). Sarar Kuzu and Yalçınalp (2023) examined the studies on the use of digital stories in language teaching in Türkiye between 2016 and 2019 using the keywords "digital story in language teaching", "digital story in language teaching", "digital story in language teaching" and "digital story in language teaching" and included 17 studies in their research.

Talan (2019) examined the national and international studies on digital storytelling between 2012 and 2019 using the keywords "digital storytelling" and "digital story", and included 78 studies in his research. Ulu (2021) examined the articles published in international foreign journals in SSCI and ERIC with the keywords "digital story" and "digital storytelling" between 2011 and 2020, journals published in the field of education in Türkiye and journals published by faculties of education, and included 70 studies in her research. Although there is one study that examined the year 2023, it is seen that this study examined only the studies covering language education from the field of education, and the other studies examined the last studies in 2021, but only the studies in Türkiye. In this study, national and international studies conducted between 2019 and 2023 were examined.

Purpose of the Study

The aim of this study is to classify and comprehensively examine the studies on the use of digital storytelling method in education in the last 5 years (2019 and 2023). In line with the aim of the study, the following research questions were sought to be answered. The studies on the use of digital storytelling method in education;

- What is the distribution of publications by type and year?
- What is the distribution according to research methods?
- What is the distribution according to research designs?
- What is the distribution according to research issues?
- What is the distribution according to study group and level?
- What is the distribution according to data collection tools?
- What is the distribution according to data analysis methods?

Method

Research Model

Content analysis method, one of the qualitative research methods, was used in this study. With the content analysis method, studies with certain criteria are examined in depth and systematically. Similar data are interpreted under specified themes (Karataş, 2015; Yıldırım, & Şimşek, 2021).

Sample

The aim of the study is to determine the characteristics of national and international studies on digital storytelling within the determined criteria. The results obtained from the study are expected to reveal the status of the studies conducted in the field of digital storytelling. The inclusion criteria determined in the study were taken into consideration and purposive sampling method was used. Purposive sampling enables the selection and in-depth investigation of rich information situations based on the purpose of the study (Büyüköztürk et al. 2016). Within the scope of the literature review, master's and doctoral theses published in the National Thesis Center in the field of digital storytelling in Türkiye and internationally; research articles accessed from Web of Science, ERIC, EBSCO electronic databases and Google Scholar database were examined. The points taken into consideration in order to include the appropriate studies in the research are as follows:

- Master's and doctoral theses published in the National Thesis Center of the Council of Higher Education (CoHE) were examined.
- Web of Science, ERIC, EBSCO electronic databases and Google Scholar database were analyzed.
- It was ensured that the theses and articles included in the study were published in the last 5 years (2019 and 2023).
- Studies conducted outside the field of education (health, economy, etc.) were not included in the study.
- Studies that were closed to access were not included in the study.

Data Collection Process

The stages followed in collecting the data and determining the studies are as follows:

- Determination of the study topic
- Identification of keywords
- Searching the relevant databases
- Selection of studies to be included in the study according to inclusion criteria

Within the scope of the research, firstly, existing master's and doctoral theses on digital storytelling were scanned in the National Thesis Center of the Council of Higher Education. The research stages are shown in Figure 2.

As seen in Figure 2, 36 master's and doctoral thesis studies were listed with the relevant keyword. Considering the studies in the field of education and training and the studies conducted in the last 5 years, 19 master's and doctoral theses were included in the study. Then, articles in Google Scholar database and ERIC, EBSCO, Web of Science electronic databases were analyzed. The research stages are shown in Figure 3.

As seen in Figure 3, 573 research articles were listed with the relevant keywords. Among these studies, first the articles, then the articles in the field of education and training, and finally the articles in the last 5 years were

examined and 80 research articles were included in the study.

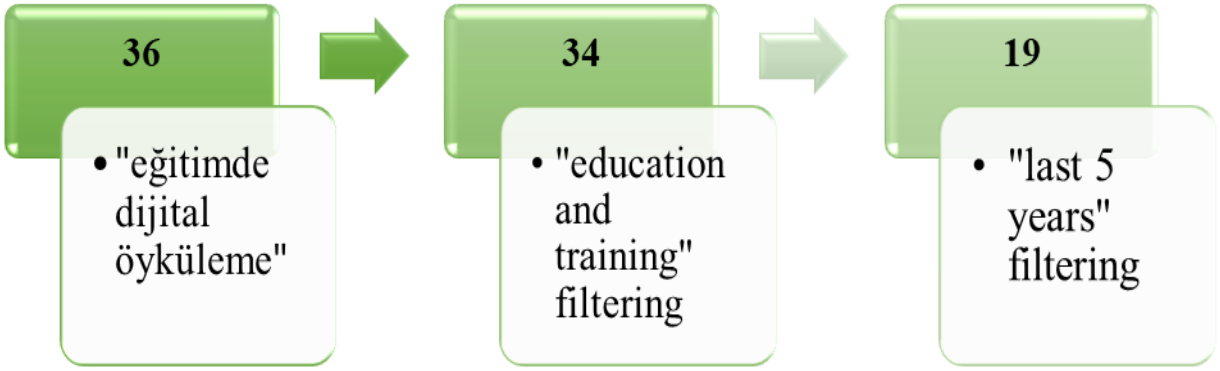

Figure 2. Stages of Accessing Thesis Studies on Digital Storytelling

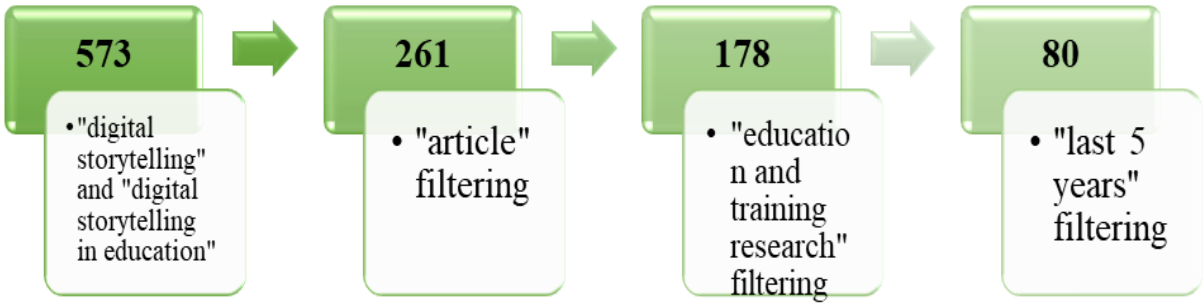

Figure 3. Stages of Accessing Research Articles on Digital Storytelling

Data Analysis

As a result of the literature review, 99 studies on digital storytelling in the field of education were examined in terms of publication year, publication type, research methods, research designs, study group and level, application areas, data collection tools and data analysis methods. The data obtained as a result of the content analysis conducted during the research process were expressed with frequency of use according to the themes determined by the researchers to answer the research questions. The obtained data were arranged numerically and shown in tables. Finally, the findings are presented with their comments.

Results

In this section, findings related to publication year, publication type, research method, research design, study group, application areas (course), data collection tools and data analysis methods related to the studies on digital storytelling are given.

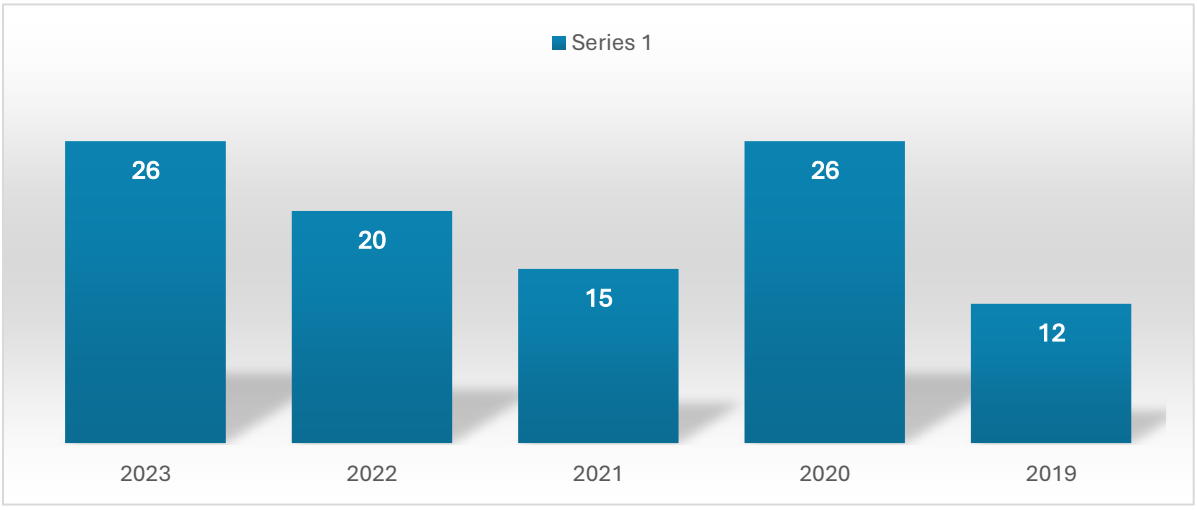

Figure 4. Distribution of Studies on Digital Storytelling by Years

Looking at the statistics of the distribution of studies on digital storytelling according to years, it is seen that the most studies were conducted in 2023 (f=26) and 2020 (f=26). This is followed by 2022 (f=20) and 2021 (f=15), respectively. The least study was conducted in 2019 (f=12). According to the results, it is seen that there is a regular increase in the studies conducted over the years.

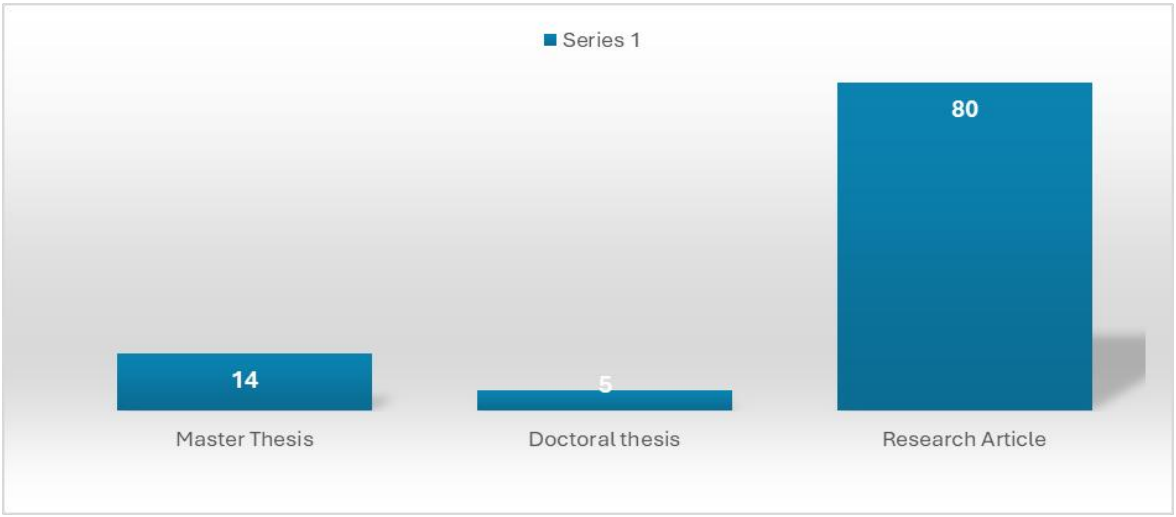

Figure 5. Distribution of Studies on Digital Storytelling According to Research Types

When the statistics of the distribution of studies on digital storytelling according to research types are examined, it is seen that the most studies are in the research article type (f=80). This is followed by master's thesis (f=14) and doctoral thesis (f=5) respectively.

When the statistics of the distribution of studies on digital storytelling according to research methods are examined, it is seen that qualitative research method (f=41) is used the most. This is followed by quantitative research method (f=30) and the least used research method is mixed method (f=28).

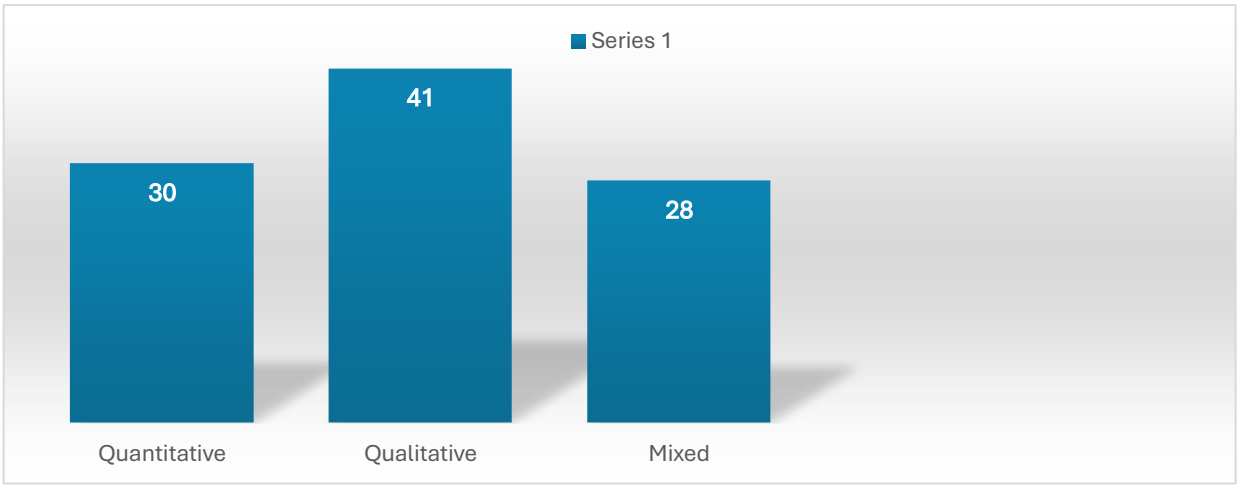

Figure 6. Distribution of Studies on Digital Storytelling According to Research Methods

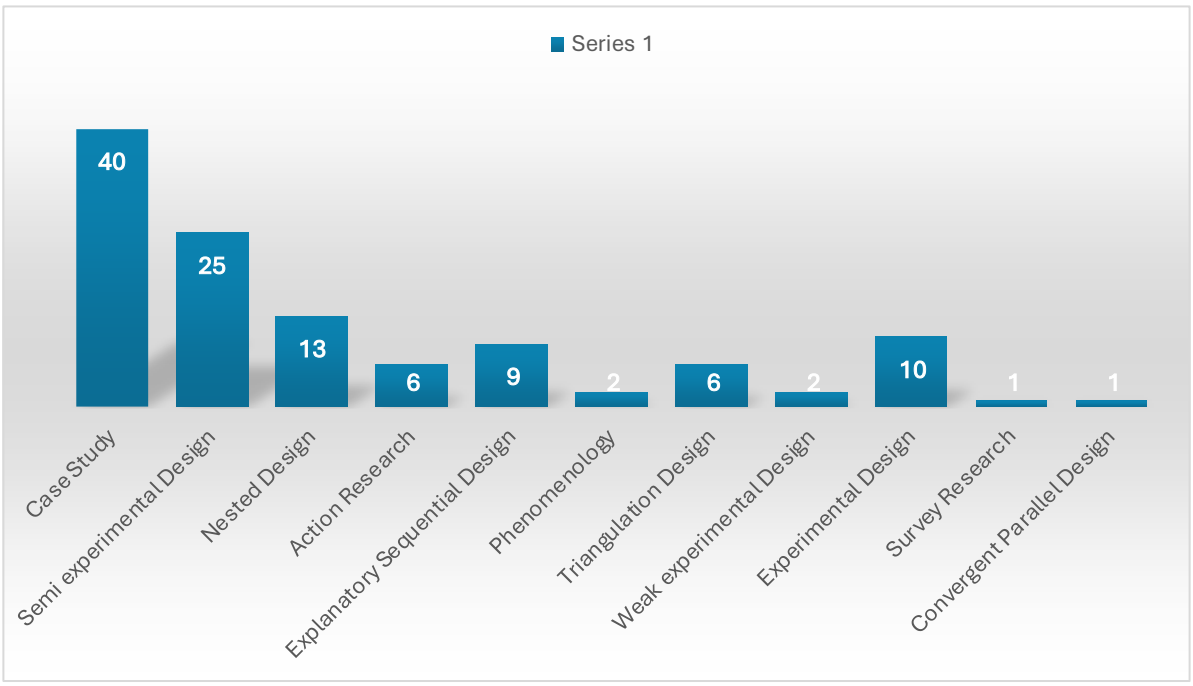

Figure 7. Distribution of Studies on Digital Storytelling According to Research Designs

First of all, it should be noted that more than one research design was used in some studies. When the distribution statistics of the studies on digital storytelling according to research designs are examined, it is seen that the studies were designed in different designs. It is seen that the most studies were conducted in case study design (f=40) from qualitative research methods. Then, it is seen that semi-experimental design (f=25) from quantitative research methods and nested (embedded) design (f=13) from mixed research methods were used. The least used research designs are survey research (f=1) from quantitative research methods and convergent parallel design (f=1) from mixed research methods. Other research designs are experimental design (f=10), explanatory sequential design (f=9), action research (f=6), triangulation design (f=6), weak experimental design (f=2) and phenomenology (f=2).

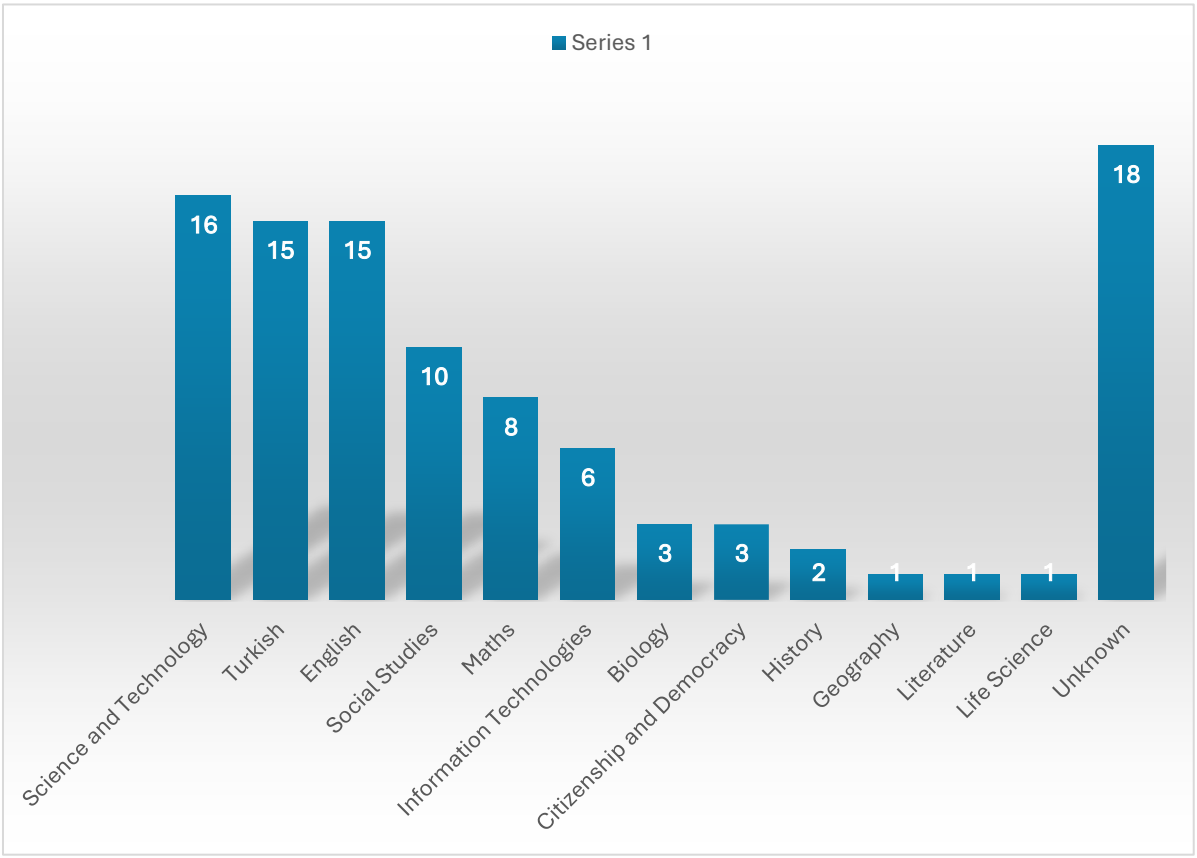

Figure 8. Distribution of Studies on Digital Storytelling According to Research Subjects

Looking at the statistics of the distribution of the studies on digital storytelling according to the research subjects, it was determined that the most studies on digital storytelling in educational environments were conducted in the Science and Technology course (f=16). This is followed by Turkish (f=15) and English (f=15) courses respectively. It was concluded that the least studies on digital storytelling in educational environments were conducted in Geography (f=1), Literature (f=1) and Life Science (f=1) courses. Other research subjects are Social studies (f=10), Maths (f=8), Information Technologies (f=6), Biology (f=3), Citizenship and democracy (f=3), History (f=2). In some of the studies (f=18), the research topic was not specified.

When the statistics of the distribution of the studies on digital storytelling according to the study group and level are examined, it is seen that the most studies were conducted with secondary school students (f=35) and undergraduate students (f=29). The least studies were conducted with preschool students (f=4) and graduate students (f=2). It was concluded that one study was conducted with gifted students.

Looking at the statistics of the distribution of the studies on digital storytelling according to data collection tools, it was found that the most used data collection tools in the studies were semi-structured interview forms (f=50) and scales (f=34). The least used data collection tools were field notes (f=3) and student journals (f=9). In one of the studies, it was determined that storytelling software (f=1) was used. Other data collection tools are test (f=20), form (f=14), survey (f=14), interview (f=16), observation (f=8), document (f=8), rubric (f=11).

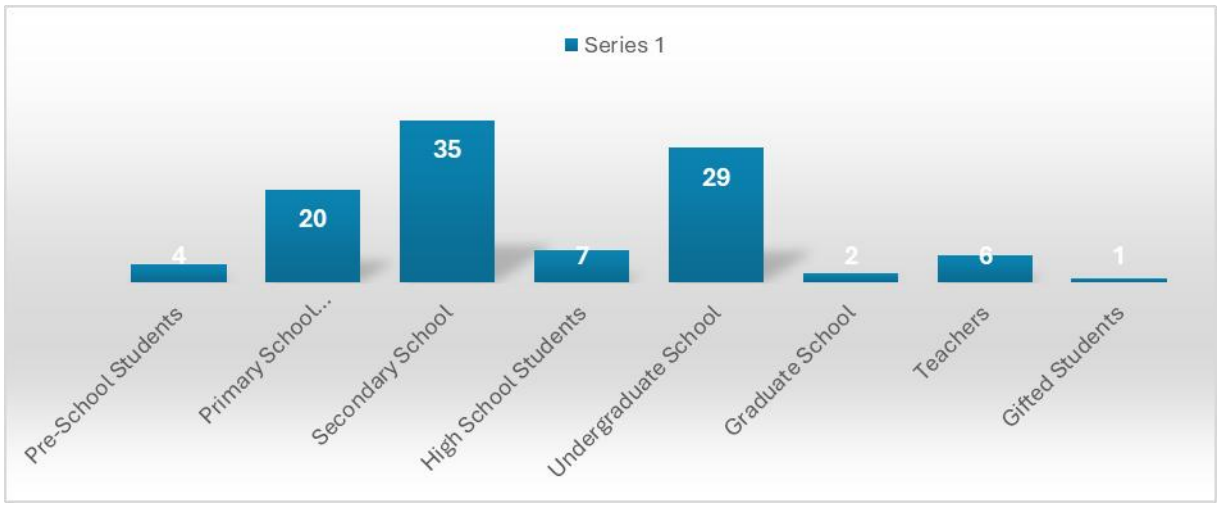

Figure 9. Distribution of Studies on Digital Storytelling According to Study Group and Level

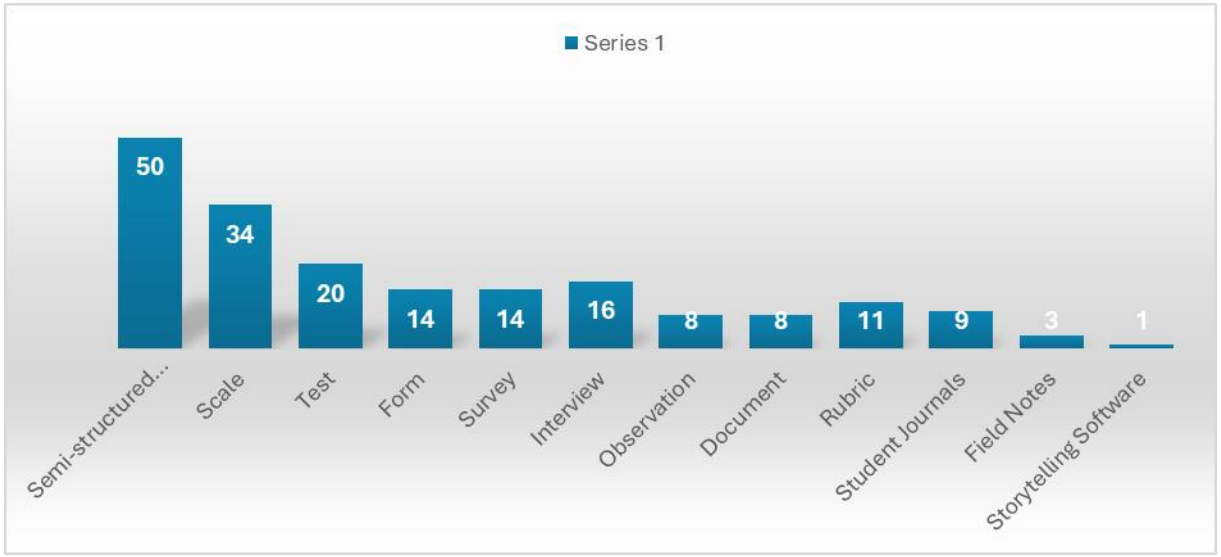

Figure 10. Distribution of Studies on Digital Storytelling According to Data Collection Tools

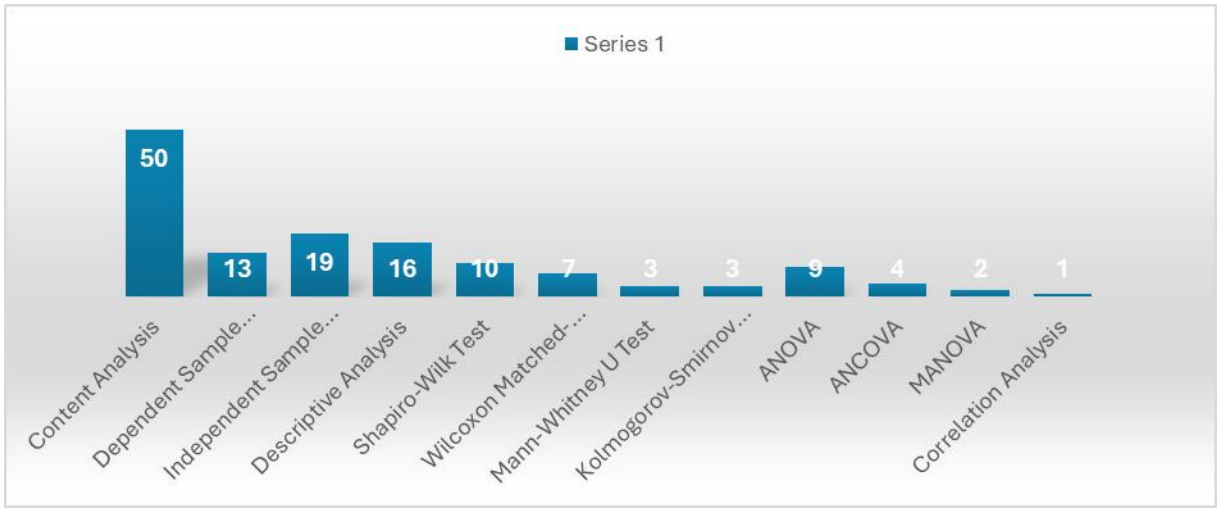

Figure 11. Distribution of Studies on Digital Storytelling According to Data Analysis Methods

Looking at the statistics of the distribution of the studies on digital storytelling according to data analysis methods, it was concluded that the most commonly used data analysis methods in the studies were content analysis (f=50) and independent sample t-test (f=19). The least used data analysis methods in the studies were MANOVA (f=2) and correlation analysis (f=1). Other data analysis methods are dependent sample t-test (f=13), descriptive analysis (f=16), Shapiro-wilk test (f=10), Wilcoxon matched- pairs test (f=7), Mann-Whitney u test (f=3), Kolmogorov-Smirnov test (f=3), ANOVA (f=9) and ANCOVA (f=4).

Discussion and Conclusion

In this study, national and international studies on digital storytelling in the field of education between 2019 and 2023 were examined according to publication year, publication type, research method, research design, research issue (course), study group and level, data collection tools and data analysis methods.

The findings obtained from the research show that the studies on digital storytelling have increased regularly over the years, and the years in which the most studies were conducted were 2020 and 2023. It was determined that studies were conducted in the form of master's thesis, doctoral thesis and research article and the most common type of study was research article.

It was concluded that studies were conducted in all methods, including quantitative research method, qualitative research method and mixed method, and the most frequently used research method was qualitative research method. After qualitative research method, quantitative research method was used the most and mixed research method was used the least. In some of the studies, more than one research design was used. Case study design, one of the qualitative research method designs, was used the most in the studies. Then, it was determined that the quasi-experimental design was used among the designs belonging to the quantitative research method and the nested (embedded) design was used among the designs belonging to the mixed research method. According to the results of the research, it was determined that phenomenology, convergent parallel design and survey research designs were very rarely encountered.

When the analyzed studies were evaluated according to the research subject, in other words, according to the courses in which the study was conducted, it was concluded that the most studies were conducted in Science and Technology, Turkish and English courses, while the least studies were conducted in Geography, Literature and Life Science courses. It was concluded that studies were conducted at all levels in the analyzed studies. The students at the levels where the most studies were conducted were secondary school students and undergraduate students. The students at the levels where the least number of studies were conducted were pre-school students and graduate students. In one study, it was determined that studies were conducted with gifted students.

When the studies were evaluated according to data collection tools, it was concluded that the most used data collection tools were semi-structured interview forms and scales. The least used data collection tools were field

notes and student diaries. In one study, it was determined that story creation software was used differently from the others. When the distribution of the studies according to data analysis methods was examined, it was found that the most used data analysis methods were content analysis and independent sample t-test, while the least used data analysis methods were Manova and correlation analysis.

Digital stories and digital storytelling pave the way for the further development of individuals' skills in various areas such as effective communication, personal and social responsibility, creativity, and technology use (Minga et al., 2014; Razmi, Pourali, & Nozad, 2014). For example, collaborative work with digital story activities contributes to the development of students' communication skills as well as their collaboration skills (Holotescu, Grosseck, & Danciu, 2014). At the same time, involving students in digital story creation activities accelerates their individual development by contributing to their critical thinking and effective use of technology skills (Karaoğlu, 2016). Demirbaş and Şahin (2020) examined the research on digital storytelling and concluded that the digital story method is beneficial in the development of students' skills such as creative thinking, critical thinking and problem solving. The studies examined within the scope of this research have findings indicating that the digital storytelling method is effective in the development of different skills and values of students. These skills and values include story writing and story construction skills (Ayten, & Polater, 2021; Baki, & Feyzioğlu, 2020; Bilici, 2020; Karademir, 2020; Ulusoy, 2020), critical thinking skills (Barsch, 2020; Bilici, 2021; Karaçelik, 2022; Karademir, 2020; Ünlü, & Yangın, 2020), collaboration skills (Ataman, 2023; Bilici, & Yılmaz, 2023; Jessel, & Dumić, 2022), communication skills (Mohammed Al-Amri, 2020; Özüdoğru, & Çakır, 2020), entrepreneurship skill (Mangal, 2020), inquiry skill (Kansoy, & Çıbık, 2022; Korucu, 2020), responsibility skill (Kanbur Kul, 2023), problem solving skill (Küçükoğlu, & İncikabı, 2020), creative thinking skill (Özen, & Duran, 2021), reflective thinking skill (Çoruk, & Seferoğlu, 2020), listening skill (Akdamar, & Sütçü, 2021; Aydın, 2022; Tanrıkulu, 2020), speaking skills (Demirkol, & Girmen, 2023; Yılmaz, & Özden, 2022), creative writing skills (Baki, 2019; Tetik, 2020), computational thinking skills (Kutlu Yıldırım, 2022), scientific creativity skills (Akgül, & Tanrıseven, 2019), ability to use technology effectively (Selanik Ay, 2020), computer usage skills (Yılmaz, & Çelik, 2020), flexible thinking skills (Schrum, & Bogdewiecz, 2022), cognitive and affective skills (Kayalı, 2019), all communication skills including listening, reading, speaking and writing (Karimova et al., 2023) and patriotic value (Uyar, 2023). Niemi et al. (2014) stated that students acquire many skills called 21st century skills while preparing digital stories. Jakes (2006) states that digital storytelling is an educational technology that has almost all the requirements for students to gain 21st century skills. In the studies examined within the scope of this research, Ciğerci (2020) and Kapucu and Avcı (2020) revealed that the digital storytelling method was effective in the development of students' 21st century skills. Since stories, which are realized through oral transmission of knowledge and values and used as a natural method in the education process (Abiola, 2014), provide memorability, the use of digital stories as an educational tool has become widespread day by day (Ulum, & Ercan Yalman, 2018). Transferring a difficult to understand and complex event through stories mobilizes students' emotions, thereby increasing their motivation and realizing meaningful learning (Turgut, & Kışla, 2015). It has been revealed in many previous studies that the digital story method has a positive effect on academic achievement (Büyükcengiz, 2017; Göçen, 2014; Özerbaş, & Öztürk, 2017). In the studies examined within the scope of this research, it was revealed that digital storytelling had a

positive effect on students' academic achievement and permanent learning (Atatekin, İstanbullu, & Korkmaz, 2023; Balçık, 2023; Bayrakdar, & Şahinkayası, 2021; Kırıkçı, & Ciğerci, 2020; Özdemir, 2023; Özkaya, & Coşkun, 2019; Pala, 2021) and increased their motivation (Chen Hsieh, & Lee, 2023; Saltık Ayhanöz, & Kahraman, 2023). In some of the studies examined, it was also concluded that the digital storytelling method improved students' various literacy and awareness skills. These are digital literacy (Gümüş, 2023; Kasap, & Say, 2023; Kendrick et al. 2022), technology literacy (Chubko et al., 2019), information literacy (Hwang, Zou, & Wu, 2023), media literacy (Kanbur Kul, 2023), interdisciplinary literacy (Chubko et al, 2020) and awareness skills such as social awareness (Qureshi, & Iqbal, 2023), cultural awareness (Karakuş, Turhan Türkkan, & Arslan Namlı, 2020), intercultural awareness (Meletiadou, 2022).

It is also among the findings of the studies (Köseoğlu, 2023; Köşeli, 2022; Tavernise et al. 2019; Ulum, & Ercan Yalman, 2020; Yuliani, & Hartanto, 2022) that the lessons in which teaching is carried out with digital storytelling method become more fun, interesting and enjoyable. Digital storytelling is stated as one of the most effective methods that can be used in foreign language education (Hwang et al., 2016). In the studies examined in this direction, there are results that digital storytelling-based activities are useful for foreign language learning (Okumuş, 2020), effective in developing foreign language writing and speaking skills (Fan, & Chen, 2023; Hava, 2021; Ölmez, 2023), and effective on foreign language vocabulary and grammar learning (Karimova et al., 2023). In studies conducted with pre-service teachers, it was observed that pre-service teachers who performed activities with digital storytelling method increased their technological pedagogical content knowledge (Dereli, 2023; Taşkın Ekici, & Dereli, 2023; Uygun, 2022), improved their personal and professional development (Güven Aktay, 2020), increased their self-efficacy levels (Eskimen, & Erdoğdu, 2021), and increased their experiences with digital storytelling (Uslu, 2022). In the studies examined, it was observed that the researchers conducted studies in different courses and various results were reached by the researchers in these courses. These are that the digital storytelling method is useful in teaching geography course (Ryan, & Aasetre, 2021), makes history lessons more efficient (Özdemir, & Tuna, 2023), increases students' success in social studies course (Abimbade et al., 2023), makes Turkish course more effective and efficient (Eroğlu, & Okur, 2021; Özen, & Duran, 2019), increases students' motivation to learn in English course (Aljaraıdeh, 2020). Other findings include that the digital storytelling method contributes to the teaching process (Kabaran et al., 2019), reduces students' writing anxiety (Aydın, & Ciğerci, 2020; Eroğlu, & Okur, 2022), and provides students with rich senses about the reality of experiences (Bryant, 2023). In addition, in some of the studies examined, it was stated that students found the use of digital stories instructive and had positive opinions and attitudes towards the method (Gökkurt, & Erden, 2023; Özden, & Meydan, 2021).

It was observed that some negative findings were also reported in the studies analyzed. These are that the majority of teachers and pre-service teachers do not have sufficient knowledge and skills about the digital storytelling method and the use of digital tools (Kahtalı, & Gençer, 2021; Öğdür, & Meydan, 2022) and that students experience various difficulties due to spending too much time in front of the screen (Korukluoğlu, & Yücel Toy, 2022).

Recommendations

Some recommendations have been made based on the findings of the research:

- Since the research method with the least number of studies is the mixed research method, the studies on this method can be increased. Additionally, studies using quantitative research methods will also contribute to literature.
- Since the least studied groups are pre-school students and graduate students, more studies need to be done in these groups.
- Since they are the least used data collection tools, tools such as observation, field notes, storytelling and story creation software can be used more.
- Very few studies were found in courses such as Geography, Literature, Life Sciences, History, and no studies were found in courses such as Physics and Chemistry. There is a need for studies to be carried out in these courses.

In the studies examined within the scope of this research, it is seen that recommendations have been developed with particular emphasis. These are;

- Curricula should include practices that will enable digital story development (Eroğlu, & Okur, 2022),
- Teacher training programs should be supported with digital storytelling activities and guidelines (Orhan Göksün, & Gürsoy, 2022),
- The deficiencies in the development and changes of prospective teachers' skills in using technological tools, especially in digital storytelling, should be identified, and education and training plans should be made to overcome these deficiencies (Korucu, 2020),
- Workshops on digital story preparation should be organized for teachers through in-service training and teacher candidates through pre-service training (Selanik Ay, 2020),
- Teachers should be provided with trainings on digital storytelling and their ability to use digital technology should be increased (Rahiem, 2021; Yılmaz, & Çelik, 2020),
- Adequate technological infrastructure should be created in schools to popularize the digital storytelling method (Akgül, & Tanrıseven, 2019) and digital story activities should be carried out in less crowded and technologically equipped classrooms (Kırıkçı, & Ciğerci, 2020),
- The long-term effects of teaching with tools supported by digital stories should be investigated (Ünlü, & Yangın, 2020),
- Curricula should be developed to give students opportunities to make digital story applications (Pala, 2021),
- Students should be encouraged to make use of digital story tools while preparing their homework and projects (Bilici, & Yılmaz, 2023),
- Digital stories prepared by pre-service teachers should be carried to real classroom environments and work with students (Kapucu, & Avcı, 2020),
- Software that will enable the development of digital stories should be developed (Özüdoğru, & Çakır, 2020),
- Digital story studies should be conducted in all courses and units and their effect on students' academic achievement should be investigated (Ulum, & Ercan Yalman, 2020),

- Efforts should be made to develop digital literacy skills at all levels of education (Özden, & Meydan, 2021),
- Emphasis should be placed on digitizing all of the stories to be used in teaching practices (Bayrakdar, & Şahinkayası, 2021),
- Digital stories about the history and development of all courses should be prepared for students to comprehend the course content well (Küçükoğlu, & İncikabı, 2020; Saltık Ayhanöz, & Kahraman, 2023),
- It should be used in abstracting abstract concepts, especially in studies on mother tongue teaching (Atatekin, İstanbullu, & Korkmaz, 2023).

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Advanced Emergency Braking on A Bumpy Road

Hasan Sahin

Eskisehir Technical University, Türkiye, https://orcid.org/0000-0002-7943-1502

Abstract: Advanced Emergency Braking (AEB) systems support drivers in critical situations, and they become one of the most effective systems in autonomous driving. The systems have been adopted to work in changing road friction coefficients, in city environment with varying situations. However, the roughness of the road should be still investigated. The originality of this paper arises from the implementation of AEB systems on a bumpy road. In this study, a Fuzzy Logic Controller (FLC) was used in the implementation of the AEB system. Time to Collision (TTC) may decrease suddenly depending on the road gradient on a bumpy road. Therefore, the FLC has been used to update the TTC by observing pitch velocity of the vehicle. The FLC was designed in MATLAB/Simulink interface with the IPG/CarMaker simulation environment. Simulation environment includes a non-linear vehicle model. The simulation results showed that the updated TTC prevented rear-end collisions successfully on a bumpy road.

Keywords: Advanced Emergency Braking, Fuzzy Logic Control, Autonomous Driving

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Introduction

The bumpy road may corrupt the contact between the tires and road. Therefore, the roughness of the road may decrease the Time to Collision (TTC) in case AEB system is working. The decrease in TTC may result in a sudden rear-end collision. The originality of this study arises from the adaptation of AEB systems to work on a bumpy road.

In this study, the vehicle parameters effected during the full-braking maneuver were investigated to identify the correct observing parameter on a bumpy road (Wong, 2001; Rajamani, 2006). Pitch velocity was selected as an observing parameter which mirrors the surface of the road instantaneously. Although, MPC-based predictive systems have significant effect on longitudinal and lateral vehicle stability (Satzger et al., 2016; Qui et al., 2015; Qu et al., 2018; Shimizu & Racksincharoensak, 2017; Zheng et al., 2018; Gietelink et al., 2006). the controlling method of the FLC enables to include simulation experiments into the controller which provided to confirm the effectiveness of the pitch velocity as an observing parameter.

The FLC controller was designed in MATLAB/Simulink interface. IPG/CarMaker environment, which includes four-wheel vehicle models with Anti-Lock Braking System (ABS) and Advanced Driver Assistance Systems (ADAS), works in cooperation with MATLAB/Simulink interface. The rule-based FLC design was completed by observing the effect of pitch velocity on TTC in real-time simulations of the IPG/CarMaker environment. Pitch velocity, pitch angle, vehicle velocity with distance to obstacle and longitudinal acceleration are the parameters which were observed to discuss the effectiveness of the proposed AEB with FLC on a bumpy road.

Method

Environment and Vehicle Design

A passenger car with a two-axle four-wheel vehicle model was created in IPG/CarMaker simulation environment. Vehicle parameters are illustrated in Table 1. To construct the FLC, several experiments were performed in IPG/CarMaker. Tire characteristics were modeled in IPG/CarMaker with the magic formula including nonlinear properties. In the simulation environment, there are two vehicles such as the host vehicle cruising at a constant speed and the preceding vehicle as an obstacle. The road parameters are presented in Table 2. The total road length is defined as 4 kilometers and the road friction coefficient was defined as same as a dry asphalt. In the first case, the road gradient is zero on total road. In the second case, the longitudinal road gradient is set to positive 3% for 2 meters and negative 3% for 2 meters continuously for 4 kilometers. In the third case, the longitudinal road gradient is set to positive 5% for 2 meters and negative 5% for 2 meters continuously for 4 kilometers. The difference between smooth and bumpy road (correspondingly case 1 and case 3) is illustrated in Figure 1.

In order to construct the FLC, a set of full braking experiments were performed at constant speeds on a dry asphalt. Three suitable cases were chosen after the set of experiments. The corresponding road cases are as presented in Table 2. During the experiments, the autonomous driver model avoided rear-end collisions by using the AEB system in case 1 on the smooth road. However, it could not avoid the rear-end collisions by using the AEB system in cases 2 and 3 on the bumpy roads. Therefore, the minimum required distance to start a full braking maneuver has to be updated depending on the road roughness. By adding vehicle velocity to this calculation, the decrease in the TTC has to be calculated.

Depending on the observations, the pitch velocity of the vehicle represented road roughness identically. Therefore, the pitch velocity was chosen to construct the rule based design of the FLC. By adding the sensitivity option, which changes the distance between vehicles after the full braking maneuver is completely performed, the decrease in the TTC could be calibrated depending on the pitch velocity of the vehicle as presented in Table 3 and Figure 2 (Ma et al., 2018). Z stands for zero value, PB stands for positive big, PS stands for positive small, and PM stands for positive medium values, in the construction of the rule based FLC design as presented in Table 3.

Table 1. Vehicle Parameters in IPG/CarMaker (BMW 5 series)

Mass	Springs (N/m)	Damping Push-Pull (Ns/m)	Stabilizer (N/m)	Tire Model
1564 kg	Front: 25000 Rear: 30000	Front: 2500-5000 Rear: 3000-6000	Front: 15000 Rear: 15000	225 60R 16

Table 2. Roughness Parameters of Road in IPG/CarMSaker (Total Road Length: 4 km)

Case	(+) Gradient	(+) Gradient Distance	(-) Gradient	(-) Gradient Distance
1	0%	Total Road	0%	Total Road
2	3%	2 meters	-3%	2 meters
3	5%	2 meters	-5%	2 meters

Table 3. FLC Decision Making to calculate the decrease in TTC

	Pitch Velocity (0-5 deg/s)			
Sensitivity (1-3)	Z	PS	PM	PB
PS	Z	PM	PM	PB
PM	Z	PS	PM	PM
PB	Z	PS	PS	PM

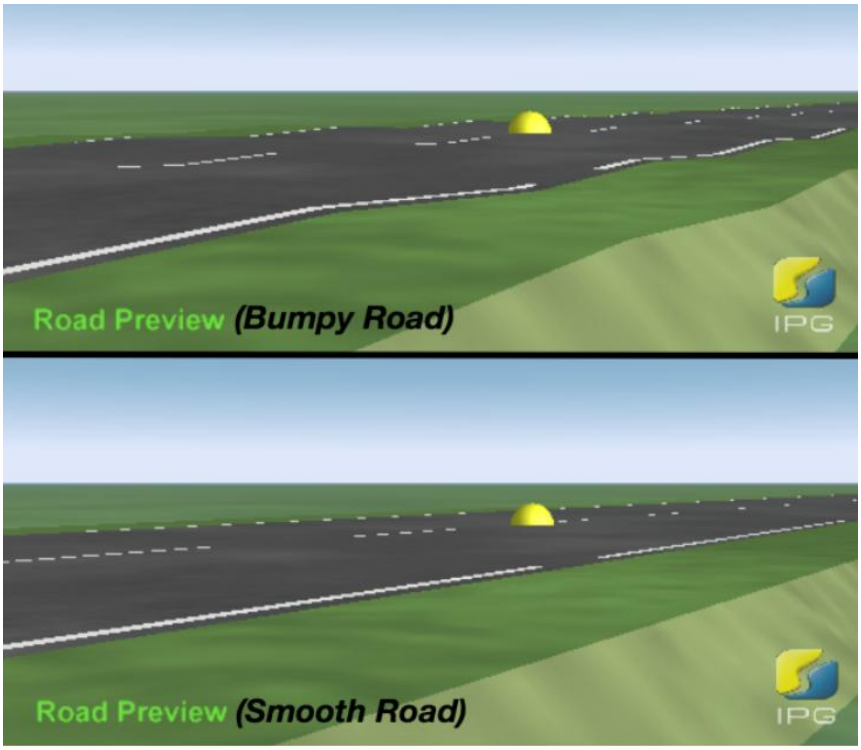

Figure 1. Smooth and Bumpy Road Preview in CarMaker

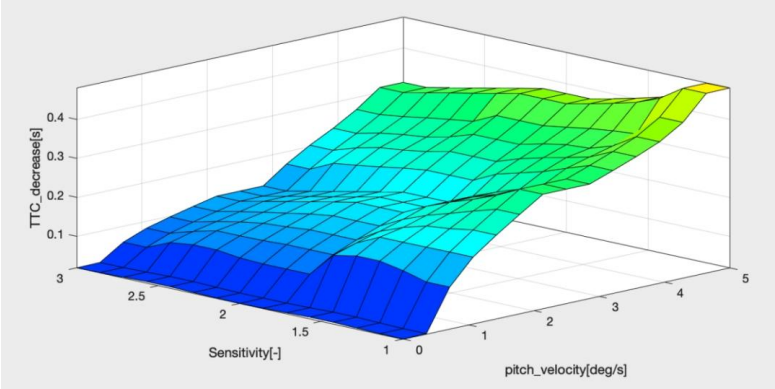

Figure 2. The Rule Based FLC Design to Calculate TTC Decrease

Results

The construction of the FLC was validated with the experiments in the previous part. Furthermore, the designed FLC was also verified in similar conditions. In the simulations, the vehicle was selected as presented in Table 1 and the road friction coefficient was defined as the same as a dry asphalt. The vehicle speed was set to 100 km/h constant speed before performing AEB maneuvers. The sensitivity option, which was mentioned in the previous part, was created for the calibration of the FLC controller to the other vehicles. In order to present the distinguishing results, the road parameters in cases 1 and 3 in Table 2 were used in this part.

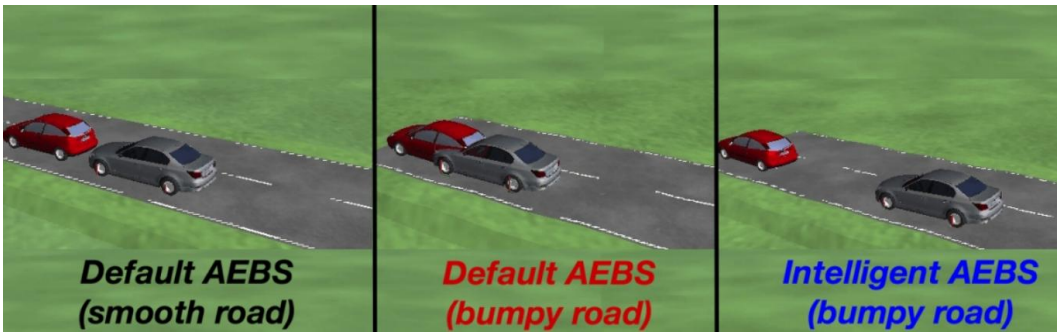

Figure 3. AEB Simulation Results on Smooth and Bumpy Roads in CarMaker

In the first scenario, the vehicle was not equipped with the FLC. The simulation was performed on the smooth road in Case 1 in Table 2. Therefore, the default AEB system avoided the rear-end collision on the smooth road as presented in Figure 3. In the second scenario, the vehicle was not equipped with the FLC. The simulation was performed on the bumpy road in Case 3 in Table 2. Therefore, the default AEB system was not avoided the rear-end collision on the bumpy road as presented in Figure 3. In the third scenario, the vehicle was equipped with the proposed FLC. The sensitivity level was set to 3 in Table 3 depending on the vehicle parameters and the simulations done in the previous part. The simulation was performed on the bumpy road in Case 3. Therefore, the developed (intelligent) AEB system avoided the rear-end collision on the bumpy road as presented in Figure 3. As illustrated in Figures 4-6, the intelligent AEB system started to brake earlier on the bumpy road depending

on the updated TTC proposed by the FLC starting from the 12th second. On the other hand, the default AEB system started to brake later on the bumpy road as same as the smooth road. Therefore, the usage of the default AEB system on the bumpy road resulted in a rear-end collision at the 15.75th second as clearly seen in Figure 5. Before the AEB systems started to brake in all scenarios, the effect of smooth and bumpy roads on the pitch velocity is clearly observed before the 12th second in Figure 7.

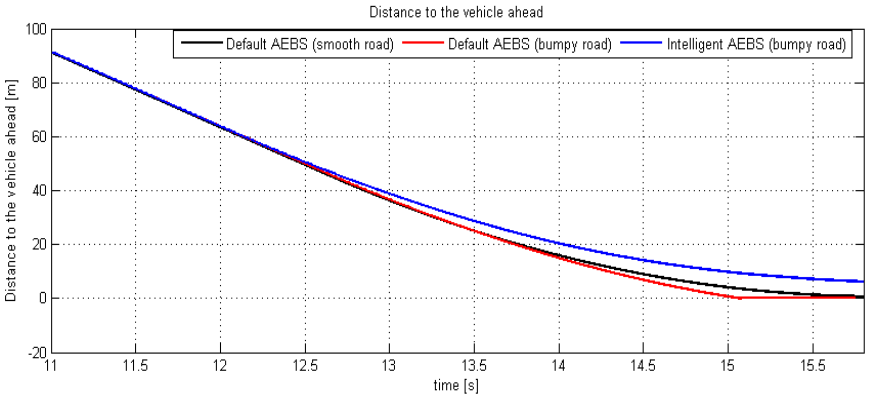

Figure 4. Distance to the Vehicle Ahead

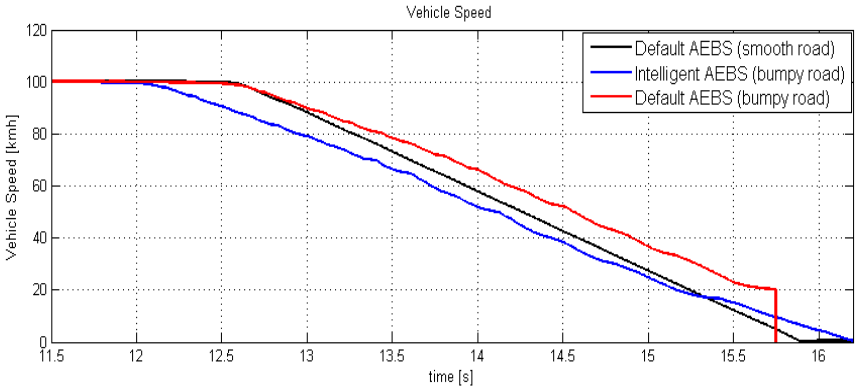

Figure 5. The Host Vehicle Speed

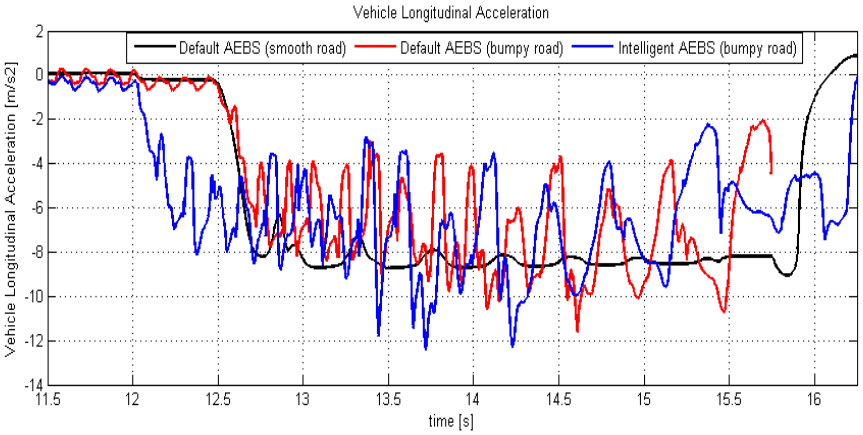

Figure 6. The Host Vehicle Longitudinal Acceleration

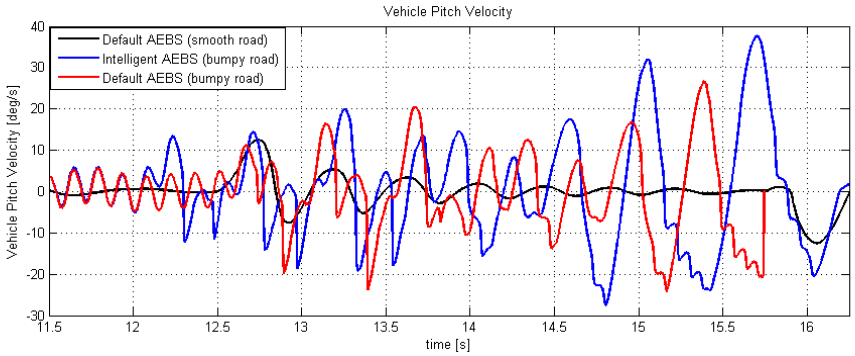

Figure 7. The Host Vehicle Pitch Velocity

Discussion

The main advantage of the usage of the FLC provides the decrease in the updated TTC to be limited. Therefore, it may prevent to brake too much earlier. Applying intelligent AEB assistance on bumpy roads provided meaningful results to overcome rear-end collisions. Moreover, the TTC decrease provided by the FLC not only depends on the road roughness, but also according to the sensitivity value calibrated to the vehicle.

Conclusion

Effectiveness of the AEB with the FLC on bumpy roads is investigated to reduce the risk of rear-end collisions, performing on a varying of road roughness in IPG/CarMaker environment with MATLAB/Simulink interface. A fuzzy logic controller is proposed to optimize the TTC. The TTC decrease not only depends on the vehicle pitch velocity, but also the selected sensitivity value. The correct tuning of the sensitivity value for the vehicle depends on a set of iteration of simulations which may be one of the disadvantages of the FLC construction. This could be time consuming for varying vehicle types. However, after selecting an appropriate sensitivity value, it is observed that the rule based FLC provided to maintain meaningful results to avoid rear-end collisions on bumpy roads. In the simulations, the road coefficient was selected as same as on a dry asphalt. On the other hand, the prediction of road friction coefficient is crucial in the withstanding realization of the TTC, which is beyond the range of this study.

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Turkish Parental Opinions About the Uses and Consequences of Tablet Use in Preschool Children

Mustafa Koc
Suleyman Demirel University, Türkiye, https://orcid.org/0000-0002-3276-7172

Mustafa Yuksel
Suleyman Demirel University, Türkiye, https://orcid.org/0009-0008-7417-5408

Abstract: This study aimed to explore Turkish parents' opinions and experiences about the uses and consequences of tablet computers among preschool children aged 1-6 in Türkiye. It was designed as a case study within qualitative research methodology. The informants were 50 parents selected using purposive sampling based on the criteria of having at least one child between the ages of 1-6 and a tablet computer at their home. Data was collected through online interviews via a structured form including open-ended questions inquiring children's tablet usage habits. The results from the descriptive analysis of the data indicated that most of the participants' children used the tablets 2-4 hours a day and mostly for gaming and entertaining purposes. Most parents thought that the games their children play or the videos they watch affected them positively in terms of motivation, confidence, and psychomotor development. On the other hand, some thought the opposite with symptoms of anxiety, trouble focusing, laziness and communication problems. Around one fourth considered their children addicted to their tablets and offered the use of tablet as a condition to carry out their daily responsibilities. Most thought that their children's tablet could disrupt their family and friendship relationships and thus tried to take precautions by making them aware of excessive use and its effects. Almost all of them believe that doing activities inside or outside the home has more positive results than spending time on the tablet.

Keywords: Parental Opinions, Preschool Children, Tablet Use, Case Study

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Introduction

Tablets, or in other words tablet computers/PCs, are smart mobile technology devices that are approximately the size of a book, wireless and can perform many computer operations. While tablets allow users to do almost everything they can do on a smartphone, tablets can also help them perform many of the operations of a computer. Nowadays, tablets mostly allow users to surf the internet, read and write e-mails, easily take notes

and prepare presentations, easily spend time on social networking sites, and watch movies and listen to music. The first tablets produced included an external pen unlike the ones we use today. The screen could be used by detecting touches on this pen. Today, the touch screen layout is used in all modern tablets because it is more useful. In the first decade of the 21st century, tablet PC use quickly spread around the world as well-known technology companies (e.g., Apple, Nokia, Microsoft) started to produce their tablet models and operating systems. In January 2011, 64 device manufacturers introduced 102 tablet models and started producing them. Steve Jobs sold three hundred thousand units of the first iPad the day it went on sale (Özkan, 2011).

According to the latest Digital 2024 Global Overview Report, approximately 31% of the internet users aged 16 to 64 all over the world own a tablet device, 26% of them access the internet and 16% of them play video games on their tablets (Datareportal, 2024a). As far as the statistics for Türkiye are concerned, as of January 2024, about 43% of the internet users aged 16 to 64 own a tablet device, 35% of them access the internet and 31% of them play video game on their tablets (Datareportal, 2024b). Tablets are attractive not only to young people and adults but also to children. Especially for kids, technological devices such as tablets and mobile phones, which are colorful, constantly changing in appearance and have very active games, are very attractive and eventually these devices create a desire to leave other toys aside and spend time only with them. Tablets have become an indispensable friend of children because they provide them with animated and colorful content that is more stimulating and making happy, easy fun that does not require sociability and physical activity and answers to all the questions with pictures and videos (Acikgoz & Akman, 2023; Gökozan, 2018). This situation raises the question of whether tablet use is beneficial or harmful especially in the preschool period and calls for conducting scientific investigations. Therefore, this case study aimed to explore Turkish parents' opinions and experiences about the uses and consequences of tablet computers among preschool children aged 1-6 in Türkiye

Although studies on technology use have been mostly conducted with school-age children and adolescents, it seems that studies covering early childhood, that is, the 0-6 age period, are also beginning to be conducted in the last decade. Using both quantitative and qualitative research approaches, Aral and Doğan Keskin (2018) examined 0-6 year olds children's use of technological devices from parents' points of view. They found that 45% of children aged 0-6 years used mobile phones and 43% used tablets (13% of these started using tablets at the age of two) and they used such devices mostly for watching animated films and playing games. Ateş and Durmuşoğlu Saltalı (2019) examined 55 parents' views on children's tablet and mobile phone use and concluded that almost half of the parents were positive about the effect of usage because of providing educational support, keeping up with the digital age and helping kids behave well. On the other hand, the majority stated that the usage could have negative consequences such as lack of socialization, modeling negative behavior, addiction risk, eye health problems, lack of movement, negative mental development and language. Ergüleç and Filiz Kiremit (2019) investigated the usability of tablets for drawing pictures as a support for child development on a sample of 3-6 aged children, their parent and teachers. Their results indicated that children were interested and curious about the use of tablets and the pictures they made with tablet computers were more creative, detailed and colorful than pictures compared to those made with traditional methods.

Şalcı, Karakaya and Tatlıeşme (2018) investigated the effects of using smart devices on the development of 3-6 year old children according to the opinions of preschool teachers. Their participants think that children should not use smart devices in preschool period and believe that parents do not have enough information about the use of smart devices such as smartphones, tablets, and computers. In a case study evaluating preschoolers' tablet use, Yılmaz Genç and Fidan (2017) conducted observations related to preschoolers' tablet use and interviews with parents. They concluded that preschoolers used tablets mainly for playing games and their parents' knowledge about tablets is generally limited to game applications and their educational features. Parents reported some specific criteria when determining tablet games, and they were worried about children's tablet PC use but took precautions against them. Similarly, Çevik (2023) examined parental attitudes towards tablet use in preschool children by means of surveying 221 parents. She found that participating parents had a low level of attitude, and this was not dependent on child age, working status, parental gender, cohabitation status, age, and the child's own tablet ownership. She also showed that parents with high school and undergraduate education levels had higher attitudes towards control than those with secondary school education level and below.

Method

The study was designed as a case study within qualitative research methodology. In qualitative research, a situation is tried to be understood from a holistic perspective within its related connections, and direct quotes are often made from the experiences, opinions, feelings and knowledge of the participants (Merriam, 1998). As a frequently employed qualitative model, case study is a method used to obtain detailed information about a special situation consisting of a person, community, society, institution, event, program, etc., within a certain period of time (Stake, 2005). Since this study aims to describe Turkish parents' opinions and experiences about their preschool children's uses tablet computers, it was decided appropriate to use the case study method.

The informants were 50 parents selected using purposive sampling based on the criteria of having at least one child between the ages of 1-6 and a tablet computer at their home. Data was collected through online interviews via a structured form including open-ended questions inquiring children's tablet usage habits. The reason for conducting online interviews was to obtain the most useful data, reach a large group and different regions, and access objective information by ensuring that the participant was not affected by the environment while answering the questions. The interview data were analyzed through descriptive content analysis, which is a technique of organizing and interpreting similar data by bringing them together under certain concepts and themes (Yıldırım & Şimşek, 2011). The data was first coded based on the purpose of the research and the interview questions, and then themes were determined from the sorting and combination of the codes. Each code was summarized with frequency analysis under the relevant theme and supported with direct quotations.

Results

The first theme generated from the data analysis was related to the main rationale for children's use of tablet

computers (Table 1). Parents reported that their children used their tablets most for playing electronic games (52%), followed by watching videos or cartoons (36%), listening to music (6%), and using drawing or painting applications (6%). Some of the participants' views included as follows:

"Since she cannot find friends to play with on the street and cannot go out in city life, she usually turns to playing games on her tablet computer at home."

"He is the only child in the house, and as a parent, I do not allow my child to play alone on the street. That is why my child is interested in games on the tablet.

"She prefers watching YouTube videos and cartoons because visual activities attract her attention."

Table 1. Main Reason for Tablet Use

Code	f	%
Gaming	26	52
Watching video/film	18	36
Listening to music	3	6
Drawing/painting	3	6

Those parents, whose preschool children played games on the tablet, were asked to explain the kind of games they mostly played. Around one third (28%) stated that their children preferred playing race and action style games while other preferred puzzle games (20%) and educational or intelligence games (16%).

The second theme was regarding daily time spent on the tablet (Table 2). Almost half of the parents said that their children spent 2 to 3 hours a day dealing with the tablet and others reported up to an hour (18%), 1to 2 hours (26%) and 3 hours or more (10%). The majority of the parents (80%) managed the time control of their kids tablet use since the kids could not control how much time they spent with tablets. Some answers from the participants are presented below:

"If we do not follow, the duration is not clear and they will play indefinitely, we determine the durations and hours."

"…drawing or playing games for a maximum of 45 minutes in the evenings…"

"Playing time is as long as I give, and I allow her to play between 0 and 1 hour per day."

"He does not realize how much time he spends. My wife and I are keeping track. I allow 2-3 hours in front of the tablet."

Table 2. Daily Time Spent on the Tablet

Code	f	%
3 hours and above	5	10
2-3 hours	23	46
1-2 hours	13	26
0-1 hour	9	18

The third theme was germane to parents' opinion about the consequences of tablet use on their children. Most of them (64%) think that the videos that their children watch on the tablet, the games they play and the programs they engage in affect them positively while some (36%) believe the opposite side. Positive effects they reported included high motivation, increased confidence and psychomotor development. Nevertheless, almost all parents believe that games played inside or outside the home are more positive than on tablets, such as making children happier and more relaxed. The negative ones were anxiety, trouble focusing, laziness and communication problems. Some of them highlighted the selection of tablet applications in its consequences (i.e., better quality apps lead to positive outcome). Some representative comments are given below:

"Yes, I think it affects him positively. He listens and learns English songs in the videos he watches. He learns animals, objects and colors in the games he plays."

"I think it varies depending on the type of video. My child gets grumpy and anxious when he watches game videos."

"In my opinion tablet makes my child passive or lazy…it takes him away from socializing with other kids, doing outdoor activities...hopefully this will not cause poor human relations in his later life"

"I believe that the continuous use of touch screen (tapping, pressing, zooming etc.) enables him to efficiently use of his small muscles of the hands and fingers…improving his drawing and painting photos, buttoning clothes and building legos."

Table 3. Consequences of Tablet Use

Code	f	%
Positive effects	32	64
High motivation	15	30
Increased confidence	11	22
Psychomotor development	9	18
Language learning	2	4
Negative effects	18	36
Anxiety	7	14
Trouble focusing	5	10
Laziness	5	10
Communication problems	4	8

The final theme emerged from the data is about the abuse of tablets, in other words, becoming addicted to tablets and thus disrupting life quality and personal responsibilities. While the majority of the parents (77%) did not think that their kids were addicted to tablets, the remaining (23%) thought that their kids exhibited symptoms of tablet addiction including taking tablet with them when they go outside and withdrawing from responsibility and socializing. One parent said, "*Instead of spending time with her family and friends of the same age, she becomes interested in the tablet, gets carried away and spends most of her time on the tablet*." Another one added, "*He even forgets to eat. This affects both himself and his family badly*." Almost one fourth (24%) offered the use of tablet as a condition to carry out their kids' daily responsibilities (participating in

meals, going to sleep, etc.). A mother stated, "*We offered tablet because my child does not like to eat, but we may have caused him to become addicted while thinking about his health*." Most thought that their children's tablet could disrupt their family and friendship relationships and thus tried to take precautions by making them aware of excessive use and its effects (e.g., time control, supervising, raising their awareness).

Conclusion

The use of mobile technologies such as tablets and smartphones has become a necessity rather than a choice for today's needs and its importance should be taken into consideration for raising healthy generations. Tablets are very attractive for children and its usage is crucial for those aged 0-6 in order their cognitive and physical development, which are rapidly progressing in this period, not to be affected negatively. This study explored participating Turkish parents' opinions about the uses and consequences of tablets among their preschool children. The results from the descriptive analysis of the data indicated that most of the participants' children used the tablets 2-4 hours a day and mostly for gaming and entertaining purposes. This screen time is higher than the suggested value of one hour in children between two to four years by the World Health Organization (WHO, 2019). Most parents thought that the games their children play or the videos they watch affected them positively in terms of motivation, confidence, and psychomotor development. On the other hand, some thought the opposite with symptoms of anxiety, trouble focusing, laziness and communication problems. Around one fourth considered their children addicted to their tablets and offered the use of tablet as a condition to carry out their daily responsibilities. Most thought that their children's tablet could disrupt their family and friendship relationships and thus tried to take precautions by making them aware of excessive use and its effects. Almost all of them believe that doing activities inside or outside the home has more positive results than spending time on the tablet.

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Evaluation of Student Opinions on The Use of Hologram Technology in Accounting Education: An Application for Uşak University Students

Feden Koç
Uşak University, Türkiye, https://orcid.org/0000-0003-4413-5188

Muhammet Demirbilek
Suleyman Demirel University, Türkiye, https://orcid.org/0000-0001-7448-9206

Abstract: The study aims to evaluate the usability, contribution and disadvantages of this technology in line with the opinions and expectations of students studying accounting at Uşak University regarding the use of hologram technology in accounting education and to contribute to stakeholders in this field. The findings of the research show that 44.5 percent of the students studying accounting at Uşak University follow technological developments to a great extent, 45.1 percent have moderate knowledge about the relevant technology, and female students have less knowledge about hologram technology than male students. It shows that you have it. showed. The rate of participants who preferred the use of hologram technology in accounting education in higher education was 84.3 percent. The research also found that the participants' knowledge of hologram technology had a significant impact on making the course interesting in accounting education. In addition, the findings of the study show that the use of hologram technology in accounting education in higher education plays an important role in preventing carbon pollution, provides an interactive learning environment, accelerates the learning process, ensures the permanence of the information learned, makes learning easier, makes the lesson more fun, allows interaction with experts in the field and provides additional information in the learning process. revealed that it causes costs.

Keywords: Accounting, Accounting Education, Hologram Technology

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Introduction

In today's digital age, hologram technology, which offers a three-dimensional image of the photographic recording of real images by using a light source, without the need for special glasses (Rosen, 2023), pushes the spatial boundaries and provides applications from industry, medicine, art, security, storage, education, etc. in today's digital age. It is a technological innovation that is used in many areas and provides great convenience to

users. The basis of this technology dates back to the first recording in 1947 by Nobel physics prize winner Dennis Gabor, who carried out advanced research on electron microscopes (Sarı, 2022). Hologram technology, which provides great convenience to users in many areas today, provides three-dimensional visualization in the industry, provides non-destructive inspection, provides improvements in quality control processes, etc. Many aspects are used (Haleem et al., 2022a).

Medical imaging also provides three-dimensional imaging of anatomical structures and enables learning of anatomical structures at the same level as in the cadaver laboratory, contributes to medical education, provides three-dimensional imaging in diagnosis, treatment and surgical intervention, etc. In this regard, the use of hologram technology is preferred (Haleem et al., 2020; Hassan Ja'ashan et al., 2024). The use of hologram technology in the field of art is preferred because it provides entertaining visual experiences and protects valuable works of art (Işık, 2014). Another common application area of hologram technology is security. In order to ensure security and prevent fraud, holographic images on bank cards, IDs and passports are widely used today (Haleem et al., 2022a; Miao et al., 2019). In addition, hologram technology is widely used in data storage, as it has high storage capacity and fast data retrieval rate compared to traditional storage methods (Hossain and Razzak, 2022; Srivastava et al., 2020).

Integrating this technology into teaching methods is important thanks to its advantages such as attracting attention, more entertaining learning, increasing communication skills, improving learning outcomes and increasing spatial awareness (Hertford et al., 2023; Y. Li et al., 2022). In this context, the use of hologram technology as an educational tool in higher education institutions started with training in medicine, engineering education and science (Yoo et al., 2022), and its use continues in some other educational fields today. Hologram technology, which offers a new approach to improving students' learning experiences of complex accounting subjects in higher education, offers a three-dimensional visual representation for students to understand accounting concepts and complex accounting subjects more carefully, more entertainingly and interactively. In this context, educators can make the course more interesting for students by creating impressive demonstrations on accounting topics (Abdlfatah et al., 2022; Mohammad vd., 2023). In this way, students can be provided with a highly interactive learning environment and significant contributions can be made to the learning outcomes of the course. Therefore, it is possible to say that with this innovative approach brought by hologram technology in accounting education, the potential of educational experience can be increased, and the overall learning process can be improved by transforming the traditional accounting learning process.

In this context, in the study, hologram technology, which has not been generally discovered in Turkey as an educational tool, was evaluated from an accounting perspective, and the use of hologram technology as a new teaching method in accounting education in higher education, the conveniences and advantages of this technology, and the difficulties and disadvantages it brought were evaluated. In the study, where the working principle of hologram technology was explained, the opinions of students studying at Uşak University, a higher education institution, and studying accounting were evaluated regarding the usability of hologram technology in accounting education.

Literature Review

A summary of some studies in the literature on the use of hologram technology in the field of education and accounting education within the scope of the study is presented in Table 1 below.

Table 1. Information About Some Studies in Literature Discussing the Use of Hologram Technology in the Field of Education and Accounting Education

Authors	Year	Purpose of Study	Results Obtained from the Study	Type of Study	Identification of the Study
Jafari, Esmaeil	2023	This study aimed to evaluate the opinions and suggestions of faculty members regarding educational strategies regarding the use of hologram technology as an educational material.	The findings of the study revealed that hologram technology may be one of the basic technologies in the field of education. In addition, within the scope of the study, the necessary strategies for the use of hologram technology in the field of education, in the public private sector and in school curricula, are presented.	Article	(Jafari, 2023: 67-91)
Yoo, Hawon & Jang, Jaehong & Oh, Hyunju & Park, Innwoo	2022	This study aims to present a comprehensive review of the literature on the use of hologram technology in the field of education.	The findings obtained from the study revealed that the number of studies on the use of hologram technology in the field of education has increased in the last five years. Additionally, the findings revealed that studies in this field are limited to small age groups and certain topics.	Article	(Yoo et al., 2022: 104533)
Tyshchenko, IA	2022	In this study, an examination of the	According to the findings of the study, the use of	Article	(Tyshchenko, 2022: 68-74)

		use of holographic three-dimensional technologies in education is presented. In addition, the use of modern information technologies in the education process is discussed in detail.	modern information technologies in education is of great importance. Additionally, addressing the operational process of holographic three-dimensional technologies can optimize the bulk material development process.		
Abdlfatah, Reem F. & Alomaier, Alaa T. & Ahmad, Asma S. & Elmahal, Doaa M. & İbrahim, M.	2022	This study aims to provide teachers with the ability to control the hologram projector device using voice commands regarding the use of hologram technology in education.	With this study, teachers were given the ability to control the display of the content on the hologram projector regarding the transfer of visual education contents with hologram technology.	Conferenc e Papaer	(Abdlfatah et al., 2022: 230-236)
Luévano, Eduardo & Lara, Eduardo López de & Castro, Juan Edward &	2022	The study aimed to examine the experiences of university students regarding the use of telepresence robots and holographic projection.	According to the findings of the study, 72 percent of the participants feel the presence of the teacher when the robot approaches, looks at or speaks to them. Additionally, 95 percent of the participants stated that this technology could be used as an educational material. It was also revealed that 65 percent of the participants paid more attention when the teacher appeared on the holographic screen.	Article	(Luévano et al., 2015: 339-347)

Li, Nai & Lefevre, David	2020	This study aimed to evaluate the potential effects and participants' experiences of using holographic video conferencing in higher education compared to non-holographic video conferences.	The findings of the study revealed that holographic video conferences can make the educational presence of remote presenters felt and increase the participants' enjoyment of the seminar through the interaction between participants.	Article	(Li and Lefevre, 2020: 1-13)
Hoon, Loh Ngiik & Shaharuddin, Siti Shukhaila	2019	In the study, it was tried to determine the effect of animation show with hologram technology on the learning effectiveness of primary school students.	According to the findings of the study, 72 percent of the students achieved better scores in the post-test compared to the pre-test, after the animation show performed with the hologram method. It was also concluded that animation attracted the attention of students and captured their attention. The study revealed that this technology can increase the quality of education.	Article	(Hoon and Shaharuddin, 2019: 93-104)
Şahin, Osman N. & Uyar, Süleyman	2019	In this study, it is aimed to present a literature review on the usability of hologram technology, which is a result of technological developments, in the field of accounting	As a result of the study, it was concluded that accounting information can be learned more easily and the information learned through the method can be more permanent with the use of hologram technology in accounting education. On the other	Article	(Şahin and Uyar, 2019: 417-440)

education, the conveniences and innovations it can bring.	hand, it has been concluded that the use of this technology can enable information sharing by bringing together important academicians, students and other participants in the field of accounting from different parts of the world.

When the literature on the studies carried out in Turkey and other countries on the use of hologram technology in accounting education is examined, it is noted that the number of studies in the field of accounting dealing with the use of this technology is low and especially in Turkey, there are very limited number of applied studies dealing with the use of this technology in the field of accounting. In this context, this study, which addresses the usability of hologram technology in accounting education and evaluates the opinions of Uşak University students on the use of this technology, aims to make the following contributions;

- Contributing to the literature on the use of hologram technology in accounting education,
- Evaluating the conveniences and advantages and difficulties and disadvantages that the use of hologram technology can provide as a new teaching method in accounting education in higher education,
- Collecting the opinions of Uşak University students on the use of hologram technology in accounting education through a survey within the scope of quantitative research method and evaluating the opinions and expectations of the students,
- In studies where hologram technology is discussed and evaluated, the target audience is generally limited to children in the younger age group. With this study created in this context, it is aimed to make a significant contribution to the literature at this point, as the perspectives of students studying accounting at Uşak University, one of the higher education institutions, regarding hologram technology will be evaluated.

What is Hologram Technology?

Hologram technology, which has become widely used in many areas in today's digital age and emerged as a result of developments in science and technology in the past, is based on recording the images of objects in a way that they can be viewed in three dimensions and creating a reflection of the real object. This technology is used in industry, medicine, art, education, architecture and security fields, especially thanks to its ability to create three-dimensional visuals of complex and detailed images.

The way hologram technology works, which creates the illusion of three-dimensional images, a light source is projected onto the surface of an object and the light is dispersed. A second light illuminates the object and

creates interaction between both sources. Thus, two light sources interact with each other, creating the illusion of a three-dimensional image (Alhaji Ahmad, 2014). Since images obtained with today's cameras are photographed from a single angle, the sense of depth is lost during recording and the image is seen in two dimensions. In hologram technology, images are recorded on the surface in the three-dimensional form they appear in the real world (Sarı, 2022). Nowadays, hologram technology has been improved enough to make it possible to project a 360-degree holographic image (Kerstein, 2018). The first record of hologram technology, which is a very important development in terms of science and technology, was made in 1947 by Dennis Gabor, who also received the Nobel Prize in Physics and carried out advanced research on electron microscopes. There are many definitions in the literature regarding hologram, which is derived from the Greek words holos, meaning "whole, entire" and gram, meaning "to draw" (Sarı, 2022). Considering a few of these; According to Elmarash et al. (2021), a hologram is “a 3D image reproduced from the interference pattern recorded by coherent light beans, and holography is a reconstruction process” (Elmarash et al., 2021). According to Aslan and Erdoğan (2017), hologram is a technique based on recording light waves on a surface, and with this technique, it is possible to reflect the three-dimensional image of an object with a light source in an environment different from its current environment (Aslan and Erdoğan, 2017). According to Alhaji Ahmad (2014), hologram is a visualization tool that can be expressed as a three-dimensional image (Alhaji Ahmad, 2014).

In general terms, it is possible to express hologram technology as a three-dimensional reflection of the image that can be created from the real image by scattering a light source and hitting a real image and then interacting with each other.

An image of the principle of formation of a hologram of an image is presented in Figure 1 below.

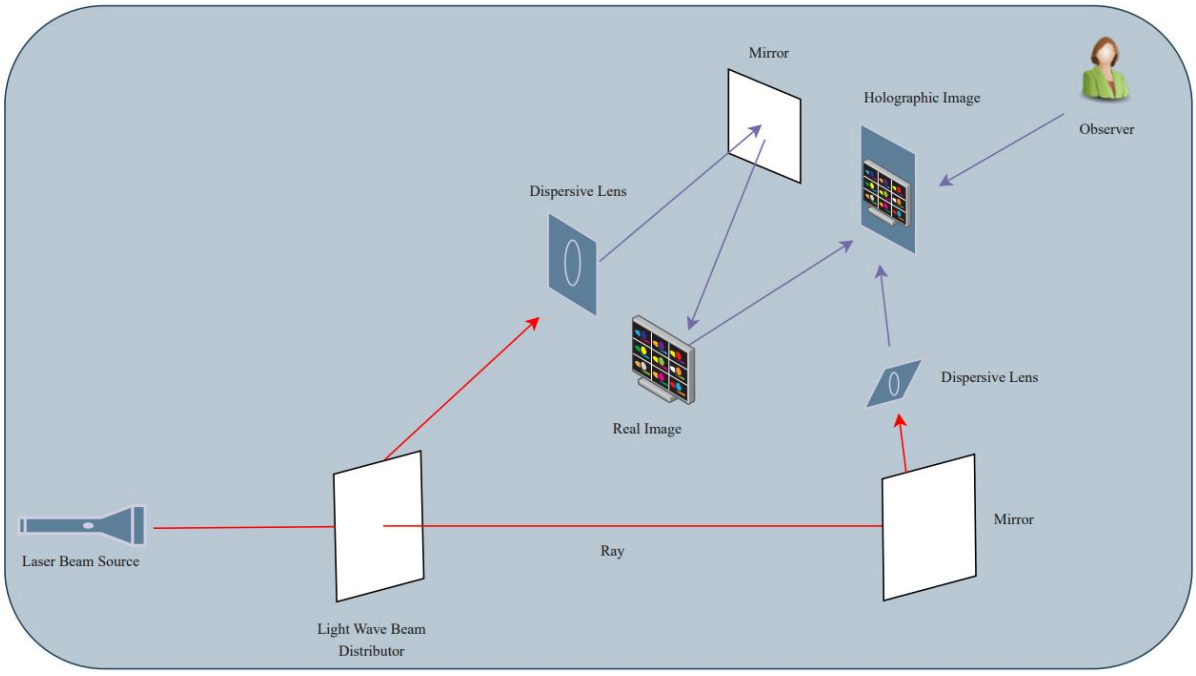

Figure 1. Working Principle of Hologram Technology (Adapted from Sarı, 2022 and Wilson, 2023)

When the image presented in Figure 1 is examined, it is seen that in the formation of a hologram of an image, a light source is first reflected to the light wave beam distributor that divides the light into two. Then, the mirrors disperse and create an interaction between the rays coming from two different paths. The laser passes the single-frequency rays coming from the light source through the dispersing lenses, transforming them into a wide light field, and the holography of the image is formed when the light hits the photographic emission of the real image. In the figure, the red arrows represent the direction in which the rays from the light source move. Purple arrows represent the direction in which the light waves formed after the red arrows hit the scattering lens move.

Today, thanks to the tremendous development of hologram technology, this technology has begun to be used more in many areas. Especially during the Covid-19 pandemic period, when travel restrictions were imposed, people's ability to attend places they cannot physically reach with hologram technology and interact with other people there has increased interest in this technology. In this context, it is predicted that hologram technology may replace video conversation technology in the future (BBC News, 2021). Nowadays, health, education, architecture, etc. With the use of hologram technology, which is widely used in other fields, in the field of education, educational tool can be made three-dimensional and this can be very beneficial for students. As a matter of fact, providing anatomy education in three dimensions can provide significant benefits for medical students, and it can be predicted that remote surgeries will be possible in the future, thanks to the secure transmission of the holographic image over the internet (Sarı, 2022). However, it is possible to foresee that hologram technology will be used in many more areas of our lives in the future and will play important roles in the exploration and construction of the virtual world.

Use of Hologram Technology in Accounting Education in Higher Education

The integration of hologram technology into educational processes and its use as an educational tool is a relatively new application in Turkey, and its use is limited due to its high costs. However, it is possible to say that the educational potential of this technology is quite high. The application of hologram technology in accounting education in higher education can be considered as an important transformation in education and teaching methods in that it offers students a platform that combines real-world experiences with augmented and virtual reality. As a matter of fact, students' learning with hologram technology in accounting education in higher education can be more interesting than looking at a pile of information in a book, and the learned information can be more permanent thanks to visual presentations.

With the development of information and communication technologies, interactive learning and promoting student-centered learning by placing students at the center of learning environments have become increasingly important (Haleem, Javaid, Qadri, et al., 2022b). With hologram technology, which is a new trend in the education process, students can be provided with a visual and interactive learning experience, ensuring that the information learned is permanent for a longer time (Abdlfatah vd., 2022; Hassan Ja'ashan vd., 2024). In addition, hologram technology can enable instructors to provide interactive training to students at different locations at the same time, remove the limits of traditional learning, and provide a more flexible and richer

learning experience (Mohammad et al, 2023). In addition, when the educational potential of hologram technology is combined with augmented and virtual reality, the learning process can be further improved (Liarokapis et al., 2004). Nowadays, with augmented and virtual reality, real-life experience can be offered to students during the learning process. According to educational researcher Sandra Andrews of Arizona State University's College of Education, the virtual world gives students a greater sense of presence than discussion boards, and thus they can better comprehend the topics presented by instructors (Harrison, 2009). As a matter of fact, Eschenbrenner et al. According to (2008), the use of virtual reality in education enables educational activities to be carried out collaboratively in a risk-free environment. In addition, it enables highly interactive learning by allowing the visualization of abstract and difficult concepts or ideas (Eschenbrenner et al., 2008). One thing to consider at this point is that the interaction between instructors and students must be carefully planned when incorporating holographic technology into the classroom. Kerawalla et al.'s (2006) analysis of teacher-child dialogue revealed that learners using augmented reality were less engaged and interacted less with the instructor than those learning using traditional methods. The main reasons for this situation may be that students examine visual presentations and focus on visual senses rather than auditory senses (Kerawalla et al., 2006). In this context, it is useful to emphasize the importance of instructors planning the interaction between students and students well and encouraging a learning environment that allows them to learn collaboratively from each other during the learning process where hologram technology is used as a learning tool.

With the use of hologram technology in higher education, instructors who may be miles away can participate in the education process in a common classroom with students. It is even possible for both real and virtual speakers to participate in these classes together (Kelion, 2018; Şahin and Uyar, 2019). In addition, people who lived in the past and are considered doyens in the field can be brought to life in these classes, in the virtual environment, and included in the education process (Ghuloum, 2010).

Like every new technology entering the accounting education classroom in higher education, the use of hologram technology requires additional costs for educational institutions. Some of the basic costs that educational institutions where hologram technology will be used as an educational tool should take into consideration at this point are 3D glasses, projector, computer, software cost, installation cost, maintenance and repair costs, etc. There are some costs. In addition, instructors should be informed about the use of this technology, preparation of appropriate presentation files, etc. They need to be trained to acquire technical knowledge on the subjects, which requires some additional costs.

In accounting education, students who learn with the relevant technology will be able to understand complex accounting information, accounting transaction processes, financial statements, etc. It is an important issue that should not be ignored that educational institutions have an important mission in learning abstract concepts related to accounting in a three-dimensionally visualized, more fun and interactive way. In addition, since the hologram technology to be used in accounting education is an important prestige tool that shows the adaptation of educational institutions to digitalization, educational institutions need to be supported in terms of the initial costs required by the integration of hologram technology into the education process.

Figure 2 below shows a visual of a joint course organized using hologram technology by Tecnológico de Monterrey, the University of Mexico, which developed the holographic projection system among educational institutions, and Delft University of Technology, located in the Netherlands, on the other side of the ocean.

Figure 2. Visual on the Use of Hologram Technology as an Educational Tool (Campos, 2022)

The Conveniences and Challenges of Using Hologram Technology in Accounting Education in Higher Education

Some of the conveniences and advantages that can be provided by incorporating hologram technology into the accounting education process in higher education are discussed below:

- Holographic presentations that can be used in accounting education, because they are eye-catching, ensure that the information learned is better understood and that the information is permanent in the long term.
- Since accounting education includes abstract concepts such as accounting transactions and financial statements, it is possible to visualize these concepts by making them three-dimensional with hologram technology, and this can facilitate learning.
- Holograms technology to be used in accounting education provides an interactive learning environment, allowing students to handle accounting data, accounting transactions and financial statements in real time, and can provide a deeper interest compared to traditional teaching methods.
- Developments in virtual and augmented reality along with hologram technology enable students in accounting education to interact with accounting simulations interactively from any point in the world.
- Real-life accounting scenarios can be simulated with hologram technology, and thus, students can gain practical experience with hologram technology and be prepared for possible difficulties they may encounter in their careers.
- With hologram technology, distance learning can be provided by creating virtual classes with students studying accounting anywhere in the world.

- Although the hologram technology used in accounting education initially causes high installation costs, books, laboratories, software, etc. will be used in the future. Since the need for physical resources will decrease, cost savings can be achieved.
- With the hologram technology to be used in accounting education, students can prepare for a future in which technology plays an important role in an interactive learning environment.
- Hologram technology can improve the imagination and skills of instructors and students.

Using hologram technology in accounting education in higher education can be considered as a revolutionary innovation in accounting education in that it allows students to learn accounting-related subjects interactively and make the learned information more permanent. In addition, some of the difficulties and disadvantages that may arise from applying hologram technology in accounting education in higher education are discussed below;

- The use of hologram technology in accounting education provides infrastructure, equipment, software, maintenance, etc. Since it requires costs, covering these costs may be difficult for some educational institutions.
- Technical problems that may occur due to device malfunction or connection during the use of hologram technology may not be problems that can be solved quickly, and such situations may cause the lessons to be disrupted.
- Since the hologram technology to be used in accounting education will require an internet connection, some risks regarding data security and confidentiality may arise for instructors, students and businesses.
- If instructors are not trained in the use of hologram technology in accounting education and the preparation and presentation of hologram training tools, it may be difficult to find specialized personnel.
- In accounting education, some students may not have access to hologram technology or may have difficulty using the technology. This situation may create an obstacle to accessing the targeted learning outcomes.
- Watching three-dimensional virtual images with hologram technology in accounting education can cause visual fatigue, which is considered cyber disease.
- The use of hologram technology in accounting education may not be suitable for students with hearing and vision limitations. For this reason, it is important that technology is integrated with teaching methods suitable for each student.

In order to overcome the difficulties discussed here, it is of great importance that educational institutions in higher education act carefully in the process of integrating hologram technology into education, provide the necessary training and technical support for instructors and students, and ensure data security and confidentiality.

Methodology of Research

Under this heading, explanations about the purpose, importance, research group, data collection process and research method of this study, in which the use of hologram technology in accounting education is discussed and the use of this technology is evaluated with student opinions, are presented.

Purpose of Research

This study aims to evaluate the usability of hologram technology, one of today's digital technologies, in accounting education. In this context, the opinions and expectations of Uşak University students regarding the use of this technology, which can make great contributions to the development of learning experiences through its integration into accounting education, were evaluated.

Importance of Research

When the literature on the studies conducted in Turkey and other countries on the use of hologram technology in accounting education is examined, it is noted that the number of studies on the use of this technology is low and that there are very few applied studies on the use of this technology in the field of accounting, especially in Turkey. In this context, it is aimed to make a significant contribution to the relevant literature in this study, in which the usability of hologram technology, which offers an interactive learning environment with a three-dimensional visual representation, in accounting education is discussed and its contribution and disadvantages to the learning process are evaluated in line with student opinions and expectations regarding the use of this technology.

Research Group

The research group of this study consists of a total of 182 students, 108 female and 74 male, who were selected by purposeful sampling method from the accounting department students studying at Uşak University, a higher education institution. According to Patton (2002), the purposeful sampling method, which is also applied in the selection of students whose opinions and expectations regarding the use of hologram technology in accounting education will be evaluated within the scope of the research, is a widely used sampling method in qualitative research in order to identify and select information-rich situations and thus to use limited resources in the most effective way (Patton, 2002). According to Cresswell and Plano Clark (2011), the purposeful sampling method is based on the identification and selection of individuals or groups of individuals who are knowledgeable or experienced about a subject in accordance with the purpose of the research (Cresswell and Plano Clark, 2011).

Data Collection

In the study, in order to evaluate the opinions of students studying and studying accounting at Uşak University regarding the use of hologram technology in accounting education, a survey was applied to the students within the scope of quantitative research method as a data collection tool. The survey applied to the participants consists of 3 parts and 23 questions in total. The first part of the survey includes questions regarding the demographic data of the participants. The second part includes questions to determine the participants' level of following technological developments and to measure their level of knowledge about hologram technology. The

third and last part of the survey form includes questions to evaluate the participants' opinions on the use of hologram technology in the accounting education process and to determine their perspectives.

IBM SPSS Statistics 26 statistical software was used to analyze the data obtained from the surveys within the scope of the study. Frequency analysis, regression analysis, correlation analysis and cross-tabulations were used to analyze the data with this statistical software.

Research Method

This study consists of four main steps. In the first step of the study, the existing literature on hologram technology, the use of hologram technology in education, and the use of hologram technology in accounting education was scanned. Subsequently, hologram technology, which combines augmented and virtual reality and offers a three-dimensional and interactive visual representation, was generally introduced. In addition, in this step, the use of hologram technology as a new teaching method in accounting education was discussed, and the integration of this technology into accounting education and the advantages and disadvantages it could provide to the accounting education process were evaluated. In the second step of the study, a survey was administered to students studying accounting at Uşak University, within the scope of evaluating student opinions regarding the use of hologram technology in accounting education. The data obtained from the surveys were evaluated with SPSS Statistics 26 statistical software and the participants' level of knowledge about this technology, their opinions on the use of this technology in accounting education, and their opinions on the possible advantages and disadvantages that this technology can provide in the accounting education process were evaluated. In addition, the data obtained at this stage of the study can be analyzed by frequency analysis, regression analysis, correlation analysis, etc. The findings obtained through analysis were tabulated and interpreted. In the third step of the study, the purpose of the study and its importance in terms of the literature on the subject were revealed. The research group covered within the scope of the study was introduced and the data collection method was explained. In the last step of the study, the findings obtained from the study on the use of hologram technology in accounting education were evaluated in general and the current findings were evaluated by comparing them with the findings obtained from other studies in literature.

Findings of the Research

Under this heading, as a result of the surveys administered to students studying at Uşak University and studying accounting, findings regarding their opinions and expectations about the use of hologram technology in accounting education are presented and the findings are interpreted.

Table 2 below presents information about the demographic data of the participants and their level of following technological developments.

Table 2. Frequency Analysis Table Regarding Participants' Demographic Data and Levels of Following Technological Developments

Variables	**Options**	**Frequency**	**Percent (%)**
Gender	Female	108	59.3
	Male	74	40.7
Total		182	100
Age	17-21	162	89.0
	22-26	16	8.8
	27-31	4	2.2
Total		182	100
Education Level	Associate degree	182	100
Total		182	100
Participants' level of following technological developments			
	I follow very little	1	0.5
	I follow at a medium level	45	24.7
	I follow it adequately	55	30.2
	I follow quite a lot.	81	44.5
Total		182	100

When the data presented in Table 2 is examined, it is seen that 59.3 percent of the participants are female students and 40.7 percent are male students. In addition, according to the data presented in the table, 89 percent of the participants are between the ages of 17-21, 8.8 percent are between the ages of 22-26, and 2.2 percent are between the ages of 27-31 and consist of associate degree students. When the data regarding the participants' level of following technological developments is examined in the table, it is noted that 0.5 percent of the participants follow technological developments to a very low level, while 44.5 percent follow them quite a lot.

Below, information on whether the participants have heard of hologram technology before and their preferences regarding whether hologram technology should be used in accounting education is tabulated below.

Table 3. Frequency Table of Participants' Knowledge of Hologram Technology and Preferences for the Use of Hologram in Accounting Education

Propositions	**Options**			
	Yes	Percent (%)	No	Percent (%)
Have you heard of hologram technology before?	180	97.3	2	1.1
Do you prefer the use of hologram technology in accounting education?	156	84.3	26	14.1

	Have very little knowledge	Have moderate knowledge	Have sufficient knowledge	Has a lot of information
Participants' knowledge levels about hologram Technology	22	82	67	11
Percent (%)	12.1	45.1	36.8	6.0

When the data presented in Table 3 is examined, it is seen that 97.3 percent of the participants have heard of hologram technology before and 84.3 percent prefer the use of hologram technology in accounting education. Additionally, according to the table, 12.1 percent of the participants have very little knowledge about hologram technology. 45.1 percent have moderate knowledge of hologram technology, 36.8 percent have sufficient knowledge and 6 percent have quite a lot of knowledge about hologram technology.

Table 4 below presents information about the participants' responses to some propositions within the scope of the study.

Table 4. Frequency Table of Participants' Responses to Different Propositions on the Use of Hologram Technology in the Accounting Education Process in Higher Education

Propositions	**Absolutely I agree**	**I agree**	**Undecided**	**I disagree**	**I strongly disagree**	**Total**
The use of hologram technology in accounting education in higher education plays an important role in preventing carbon pollution.	85.7	13.1	1.1	-	-	100
Using hologram technology in accounting education makes the course more interesting.	57.1	23.1	19.8	-	-	100
Using hologram technology in accounting education provides an interactive learning environment.	78	14.3	7.7	-	-	100
Hologram technology accelerates the learning process in accounting education.	78	13.7	8.2	-	-	100
Hologram technology ensures that the information learned in accounting education is permanent.	77.5	22.5	-	-	-	100
Using hologram technology in accounting education can make the lesson more entertaining.	77.5	22.5	-	-	-	100
The use of hologram technology in accounting education does not contribute to	-	-	-	23.1	76.9	100

the learning process.						
The use of hologram technology in accounting education allows interaction with experts in the field.	76.9	19.8	3.3	-	-	100
The use of hologram technology in accounting education provides easier access to accounting-related information.	58.8	25.3	9.9	6	-	100
The use of different technologies in addition to traditional learning methods in accounting education positively affects the learning process.	60.4	30.8	8.8	-	-	100
The use of hologram technology in accounting education causes additional costs in the learning process.	84.1	15.9	-	-	-	100
The university has sufficient technological equipment to use hologram technology in accounting education.	23.1	8.2	34.6	18.1	15.9	100
Hologram technology is an important tool in transforming the traditional accounting learning process.	27.5	58.2	14.3	-	-	100
Hologram technology is an important tool in increasing the learning level in accounting education.	40.7	50.5	2.7	6	-	100

According to the data presented in Table 4, 85.7 percent of the participants agreed that the use of hologram technology in accounting education in higher education played an important role in preventing carbon pollution, 57.1 percent agreed that the use of hologram technology in accounting education made the course more interesting, and 78 percent agreed that the use of hologram technology in accounting education played an important role in preventing carbon pollution. 78 percent stated that the use of hologram technology in accounting education provides an interactive learning environment, 78 percent stated that it accelerates the learning process in accounting education, 77.5 percent stated that it ensures the permanence of the knowledge learned in accounting education, and 77.5 percent stated that the use of hologram technology in accounting education makes the course more enjoyable. They strongly agree with the proposition that it provides 76.9 percent of the participants strongly disagree with the proposition that the use of hologram technology in accounting education does not contribute to the learning process. In addition, 76.9 percent of the participants suggested that the use of hologram technology in accounting education enables interaction with experts in the field, 58.8 percent of the participants suggested that it provides easier access to accounting-related information, and 60.4 percent suggested that using hologram technology in accounting education provides the opportunity to interact with experts in the field. 84.1 percent strongly agree with the proposition that the use of technologies has a positive effect on the learning process, and 84.1 percent strongly agree with the proposition that the use of hologram technology in accounting education may cause additional costs in the learning process. In addition, while 23.1 percent of the participants strongly agreed with the statement that Uşak University has sufficient technological equipment to use hologram technology in accounting education, 34.6 percent of the participants were undecided. In addition, 58.2 percent of the participants strongly agree with the proposition that hologram

technology is an important tool in transforming the traditional accounting learning process, while 50.5 percent of the participants agree with the proposition that hologram technology is an important tool in increasing the level of learning in accounting education.

Below is a cross-table regarding the gender of the participants and their level of knowledge about hologram technology.

Table 5. Cross Table Between Participants' Gender and Knowledge Levels About Hologram Technology

		Participants' Knowledge Levels About Hologram Technology			
Gender		Have very little knowledge	Have moderate knowledge	Have sufficient knowledge	Has a lot of information
	Female	22	82	4	-
	Male	-	-	63	11
Total		22	82	67	11

According to the data presented in Table 5, it can be said that female students have less knowledge about hologram technology than male students.

Below, the findings of the Regression Analysis between the independent variable of the participants' level of knowledge about hologram technology and the dependent variable of the effect of using hologram technology in accounting education in higher education on the interest of the course are tabulated.

Table 6. Summary Table of the Regression Model Between the Participants' Knowledge Levels About Hologram Technology and the Effect of Using Hologram Technology in Accounting Education on the Attractiveness of the Course

Model	R	R Square	Adjusted R Square	Std. Error of The Estimate
1	0.745[a]	0.555	0.553	0.53205

According to the data presented in Table 6, the R=0.745 value shows the amount of relationship between the predictor variable and the predicted variable in the model. When the data presented in Table 6 is examined, it is seen that the participants' knowledge levels about hologram technology are an important predictor of using hologram technology in accounting education in higher education in ensuring that the course is interesting. R= 0.745, R^2= 0.555, F (1,181)= 0.000.

Table 7. Analysis of Variance Between Participants' Knowledge Levels About Hologram Technology and the Effect of Using Hologram Technology in Accounting Education on the Attractiveness of the Course (ANOVA[a])

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	63.640	1	63.640	224.819	0.000[b]

Residual	50.953	181	0.283
Total	114.593	182	

a. Dependent Variable: The effect of using hologram technology in accounting education in higher education on making the course interesting.

b. Predictors: (Constant), participants' level of knowledge about hologram technology

When the data presented in Table 7 is examined, it is seen that the participants' knowledge level about hologram technology is an important predictor of using hologram technology in accounting education in higher education in ensuring that the course is interesting. Since R= R=0.745, R^2= 0.56, F(1,181)= 0.000 and p<0.01, it is possible to say that using hologram technology in accounting education in higher education has a 56 percent impact on the level of participants' knowledge about hologram technology in making the course interesting.

Table 8. Table of Coefficients Between Participants' Knowledge Levels About Hologram Technology and the Effect of Using Hologram Technology in Accounting Education on the Attractiveness of the Course (Coefficients[a])

	Unstandardized Coefficients				
Model	B	Standard Error	Standardized Coefficients Beta	t	Sig.
(Constant)	-0.955	0.177		-5.408	0.000
Video game play time average	0.766	0.051	0.745	14.994	0.000

a. Dependent Variable: The effect of using hologram technology in accounting education in higher education on making the course interesting.

According to the data presented in Table 8, the t value calculated for the constant term α is -5.408. The t value calculated for the regression coefficient β is 14.994. The simple linear equation in this context is y = - 0.955 + (0.766x).

Below, the findings of the correlation analysis between the participants' knowledge levels about hologram technology and the effect of using hologram technology in accounting education in higher education on making the course interesting are tabulated.

Table 9. Correlation Analysis of the Relationship Between Participants' Knowledge Levels About Hologram Technology and the Attraction of the Course Using Hologram Technology in Accounting Education in Higher Education

	Participants' knowledge levels about hologram technology	The effect of using hologram technology in accounting education on making the course interesting

Participants' knowledge levels about hologram technology	Pearson Correlation	1	0.745**
	Sig. (2-tailed)		0.000
	N	182	182
The effect of using hologram technology in accounting education on making the course interesting	Pearson Correlation	0.745**	1
	Sig. (2-tailed)	0.000	
	N	182	182

** Correlation is significant at the 0.01 level (2-tailed)

When Table 9 is examined, it is seen that there is a direct proportional and high-level relationship between the two variables. Pearson correlation coefficient is 0.745. Therefore, a change in one of the variables affects the other variable in the same direction by 56 percent. In the light of these data, it is possible to say that as the knowledge level of the participants about hologram technology increases, the effect of using hologram technology in higher education accounting education on the interest of the course increases by 56 percent, as well as the coefficient of determination ($r^2 = 0.555025$).

In addition, in the survey form applied to the participants, based on the open-ended question about what other technologies they prefer to use in accounting education in higher education, the participants stated that they generally prefer the use of artificial intelligence-supported learning, gamification and learning methods in accounting education, and the use of smart boards in classrooms.

Conclusion

In this study, the integration of hologram technology, which provides an interactive learning environment with three-dimensional visual representation, into accounting education as an educational material is discussed, and the usability of this technology is evaluated in line with the opinions and expectations of students studying accounting at Uşak University regarding the use of hologram as an educational tool in accounting education. It is aimed to evaluate the contributions it can make to the learning process and the difficulties it may cause in the learning process. Since the number of applied studies dealing with the usability of hologram technology in accounting education in higher education in Turkey is quite low in number, and the target audience in studies in Turkey and international literature is generally limited to children in the younger age group, in this study, the opinions of higher education students on the use of hologram technology in accounting education are evaluated and the use of this technology is evaluated. Its integration into accounting education has been addressed in a multifaceted manner.

In this context, the findings obtained from the study revealed that 44.5 percent of the students studying accounting at Uşak University follow the developments in digital technologies very much and 45.1 percent of the students have moderate knowledge about hologram technology. This study also found that female students had less knowledge about holograms compared to male students, and it was determined that 84.3 percent of the students preferred the use of hologram technology in accounting education. Another finding reached within the scope of the study is that the participants' level of knowledge about holograms is an important factor in making the accounting course interesting. In addition, the findings of the study reveal that the use of hologram technology in accounting education in higher education can provide an interactive learning environment, enable interaction with experts in the field, make the course more entertaining, accelerate the learning process, ensure the permanence of the learned knowledge and play an important role in preventing carbon pollution. has put.

Recommendations

It is possible to say that developments in digital technologies will enable the development of new and effective teaching tools in the future and that the integration of developments in this field into education will improve learning. However, today, more studies are needed in this field to evaluate the effectiveness of hologram technology as an educational tool in accounting education. In this context, it would be useful to investigate the relative effect of this technology on learning outcome by evaluating the use of hologram technology in a real learning environment or a simulative learning environment in future studies.

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The Effect of Computer Assisted Instruction on Student Achievement in Teaching Algorithm Subject in Primary Education Sixth Grade Information Technologies Course

Emrah Tosun

İstanbul University, Türkiye, https://orcid.org/0000-0003-1447-5907

Muhammet Demirbilek

Süleyman Demirel University, Türkiye, https://orcid.org/0000-0001-7448-9206

Abstract: While traditional teaching methods advocate a teacher-centered approach, contemporary teaching methods adopt a student-centered approach. One of the contemporary teaching methods is computer assisted instruction. In this study, the comparison and evaluation of the effects of computer assisted instruction and traditional teaching methods on learning in the teaching of the "algorithm" subject in the sixth-grade information technologies course in secondary school were carried out. The sample of the study consisted of 60 sixth grade students in middle school. There are experimental and control groups in the research. Within the scope of this research, pre-test and post-test were prepared for the students and the educational software prepared for this study was used. After the pre-tests were administered, the "algorithm" subject was taught to the groups in which traditional teaching method and computer assisted instruction method were used in accordance with the methods and then post-tests were applied. The data obtained from the pre-test and post-test results were analyzed and t-test and Mann Whitney u test were performed. As a result of the analysis, it was found that there was a significant difference between the traditional teaching method and computer assisted instruction method in learning the algorithm subject. The experimental group that received education with the computer-assisted instruction method was more successful than the control group that received education with the traditional instruction method.

Keywords: Algorithm, Computer and Education, Computer Assisted Instruction

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Introduction

Today, there is a very rapid change in communication, information exchange and technology. The social, economic and cultural development of countries by catching up with this change is only possible with well-

educated individuals in a modern education process. According to Alkan, well-educated individuals will be realized by revealing the intelligence, free and creative thinking in individuals (Alkan, 1995).

Education is "the process of bringing about a change in an individual's behavior through his/her own experience and intentionally in the desired direction (Ertürk, 1979). Behavioral change in the individual takes place in a shorter time and in a more meaningful way with the developing technological opportunities. Considering these technological products, the importance of computers in education has a great share.

It is possible to make use of computers, which were first made to be used for military purposes, in many fields from medicine to sociology, from mathematics to educational sciences (Arslan, 2003).

In our country where the computer age is rapidly experienced, the education given in this field and how the computer phenomenon affects our educational life is an important issue. The computer is used in three different ways in teaching service as "Computer Education", "Computer Education" and "Computer Assisted Education" (Kahvecioğlu, 2007). In this research, Computer Assisted Instruction is emphasized. Computer Assisted Education (CAE) can be defined as the type of teaching that students can use according to their own learning speed by interacting with a course software prepared by taking into account the various reactions that students may show at a computer and the application and research area related to this problem (Köksal, 1981). In addition, computer aided education is a teaching method used to teach a subject or concept to students through courses programmed into the system of computers and to reinforce previously acquired behaviors (Acikgoz & Akman, 2023; Ozturk, 2023; Yalın, 2003). The aim of this research is to compare the effects of computer assisted instruction and traditional teaching methods on learning in secondary school grade VI information technologies course.

For this purpose, answers to the following questions were sought in the research:
Is there a significant difference in terms of student achievement between the two groups in which traditional teaching method and computer assisted instruction method are applied?
Is there a significant difference between the two groups in which traditional teaching method and computer assisted instruction method are applied in terms of gender factor?

Traditional Education

Traditional education is a teaching method in which the teacher leads lessons, usually in a classroom setting, and students learn from textbooks (Smith, 2019). This approach involves a teacher-centered model and often limits student engagement.

In traditional education environments, the individual is equipped with a lot of information that is not necessary for him/her in his/her daily life, he/she cannot take responsibility for his/her own learning process, adequate and continuous communication between the student, teacher and family cannot be provided easily and quickly, and

research and development issues cannot be emphasized at all (Çankaya, 2007). Since the continuation of education life on these bases will create a lack of self-confidence in individuals, it will become an inevitable situation that human communities who have difficulty in making the right decision in their future lives and who cannot express themselves will grow up.

With the aim of eliminating these and similar problems with computer assisted education, which is one of the contemporary teaching methods, the system in which the individual is centered in the learning environment has been implemented in Turkey since 2005. When we look at the education systems in the world, there is a transition from traditional learning to contemporary learning environments. Visual materials provide concreteness for the objects and concepts to be taught or explained. For example, a geometry teacher can bring oranges to the class to explain the sphere to students more easily (Uzunboylu, 2008).

Computer Assisted Education

Computer assisted instruction (CAI) is an educational method in which instructional materials and activities are delivered via computer (Smith, 2020). CAI uses specialized software designed to support students' learning processes (Johnson, 2019). The historical development of CAI began in the 1950s in the USA and continued in Turkey in 1984 with the introduction of microcomputers in secondary education institutions (Kaya, 2021). CAI programs include various types such as drill and review, one-to-one instruction, affinity programs, educational games, and problem solving (Öztürk, 2020). As a valuable tool for teachers, CAI is frequently used in exam preparation and evaluation processes, making education more effective and efficient (Demir, 2022).

Computers are used in many areas of education and training. CAI has provided many benefits to students and teachers. Many researches have been conducted on this subject and it has been concluded that the use of computer in education contributes to education. With this result, the importance of CAI in contemporary educational approaches has been mentioned and it has started to be used in educational programs.

CAI enables students to learn the subject at their own pace. Students are provided with the opportunity to monitor their performances by ensuring their active participation in the lesson. While the quality and quantity of instructional activities increase, it also provides the opportunity to practice and repeat outside of class hours (Yanpar, 2006).

With computer aided education, students' interest in the lesson is always kept alive. Dangerous or expensive experiments or studies can be done easily with simulation method in CAI. Students save time by learning in a shorter time and in a systematic way. At the same time, attention levels can be kept quite high by means of drawings, colors, shapes, pictures while students are watching the lesson. In CAI, the teacher has the opportunity to use the computer at different places and times in the lesson according to the hardware and software possibilities and the characteristics of the subject and the student. The teacher covers the subject, and those who miss the lesson or do not understand it can be given the opportunity to repeat the lesson. Here the role

of the computer is tutoring. It can be in the form of the teacher doing the evaluation with the help of the computer after teaching the subject. The teacher covers the subject in the classroom, and practice and exercises are done with the computer. The teacher counsels, counsels and supervises the students (Demirel, 2005).

Besides the benefits of computer aided education, it also has some limitations. The use of computers in education weakens human relations. The number of computer software is limited. There is no consistency between course programs and the content of some course software. For this reason, the desired level of efficiency cannot be obtained from computer assisted education. Computer systems are expensive, and it is questionable how educational systems, especially schools, can afford such an expensive application. Lack of technical staff is an important problem in the elimination of malfunctions related to hardware. Violent games make children impatient and intolerant. This leads to gains that are incompatible with the aims of education. The computer should not be seen as a magical tool that can solve every problem in the educational environment. During teaching in computer laboratories, the teacher may have difficulties in class-room management. Because students may focus on the computer and the program and may not hear the teacher's guidance commands (Kahvecioğlu, 2002).

As in every field, technology and tools in education reach every field of education, but they do not always give positive results. One of the reasons why these positive results are not obtained is that technology cannot reach the desired satisfaction with the burdens it brings to educators and students. However, it should not be forgotten that it is wrong to give up many positive effects of technology because of a few negative or neutral effects (Dinçer, 2006). Since the positive aspects of computer assisted instruction in education are of greater importance than the negative aspects in the education of the individual, it would be a mistake to ignore these advantages. CAI is a process that enables self-learning and is based on the principles of programmed teaching method (Arslan, 2003).

The problem statement of this study:
What is the effect of CAI on the success of secondary school students in teaching the subject of "Algorithms" in Information Technologies course?

Sub-problems are:
Is there a significant difference in the pre-tests of the groups in which traditional teaching method and CAI method were used?
Is there a significant difference between the pre-test and post-test scores of the control group in which the traditional teaching method was applied?
Is there a significant difference between the pre-test and post-test scores of the control group in which CAI method was applied?
Is there a significant difference between the post-test scores of the groups in which traditional teaching method and CAI method were used?
Do the achievements of the group in which traditional teaching method is used differ according to gender?

Do the achievements of the group in which CAI method is used differ according to gender?

Method

Research Model

In this study, the effectiveness of CAI and traditional education methods in teaching "Algorithm" in secondary school grade 5 information technologies course was tried to be examined and the role of computer assisted education was investigated. The research includes experimental and control groups and has an experimental design consisting of pre-test and post-test measurements. In the design, there is an experimental group in which CAI method is applied and a control group in which traditional education method is applied. It was investigated whether there was a difference between the groups to which computer assisted instruction and traditional education method was applied. Table 1 shows the experimental design.

Table 1. Experiment Design

Groups	Pre Test	Method	Final Test
Experimental	Achievement Test	Computer Assisted Instruction	Achievement Test
Control	Achievement Test	Traditional Education	Achievement Test

Population and Sample of the Study

The population of the study consisted of students attending Grade VI of the Ministry of National Education in Kahramanmaraş City Center in the second semester of the 2010/2011 academic year, showing normal development and without any visible health problems.

A sample group consisting of 60 students was selected from the secondary schools in the city center of Kahramanmaraş, taking into account the availability of computer laboratories in the school. After obtaining the necessary permissions, the application was started. A total of 60 students in Dumlupınar Secondary School Grade five A and D classes were included in the study. Among these children, 30 children formed the group to receive computer-assisted education, and 30 children formed the group to receive traditional education. Care was taken to select a close number of boys and girls.

Table 2. Distribution of the Sample Students According to the School They Attend and Gender

Group	Branch A		Branch D		Total	
	Boy	Girl	Boy	Girl	Boy	Girl
Computer Assisted Instruction (Experimental Group)	-	-	13	17	28	32
Traditional Education (Control Group)	15	15	-	-		

As seen in Table 2, the experimental group consisted of 13 boys and 17 girls, totaling 30 students; the control group consisted of 15 boys and 15 girls, totaling 30 students. The total number of students participating in the study was 60.

Data Collection Tools

First, a literature review was conducted to collect data, related publications were examined (articles, theses, books, etc.) and internet searches were made.

As a data collection tool, an achievement test was used to measure the behaviors required by the Algorithms unit. The Educational Software prepared by Vahit Gönen was used for computer assisted instruction method. After obtaining the necessary permissions, the applications were carried out at Dumlupınar Secondary School between May 4-18, 2011.

At the beginning of the application, a pre-test was applied to the students and as a result of the test, the course application was started with students equal to each other in terms of knowledge level. The control group taught the subject of "Algorithms" with the traditional teaching method in their classrooms and the experimental group taught the same subject with the computer assisted instruction method in the computer laboratory. The applications were completed with the post-test applied at the end of the lessons.

Achievement Test

In the study, a 10-question "Algorithms" achievement test developed by the researcher and Vahit Gönen, an Information Technologies teacher at Dumlupınar Elementary School, was used. The reliability of the achievement test was analyzed with two half test reliability. The same achievement test was used in the pretest and posttest. In this test, 12 multiple choice (four-option) questions were prepared, covering the subject achievements proportionally. After preparing for this test, it was decided to use 10 questions by taking expert opinions and applying the necessary additions, deletions and corrections. This test was applied to both groups before starting the application process. This test was applied again after training was given to the experimental and control groups. The scores obtained as a result of the tests were compared.

Two Half Test Reliability: It is explained by the correlation coefficient calculated for the whole test using the Sperman Brown formula based on the relationship between the two halves of the test by dividing the items of the test into two equal halves as odd-even first-half-final-half or neutral. Two-half test reliability, also known as test halving method, shows the consistency between the test scores obtained (Büyüköztürk, 2010).

The achievement test has a total of 10 questions with 4 options. The correct answer to each question is 10 points and it is evaluated over a total of 100 points. The data obtained in the application were converted into scores of 0 and 1. Table 3 shows the reliability and correlation values found with the test split method.

Table 3. Two Half Test Reliability

Group	Test	Reliability	Correlation
Experimental	Pre Test	0,770656	0,626883
	Final Test	0,82594	0,703491
Control	Pre Test	0,82207	0,697899
	Final Test	0,80037	0,667180

Educational Software

The educational software titled "Understanding Algorithm" prepared by Vahit Gönen, Information Technologies Teacher at Dumlupınar Elementary School in 2005 by taking into account the programmed teaching steps, was used by the experimental group for computer assisted instruction.

Figure1. Examples Section of Educational Software

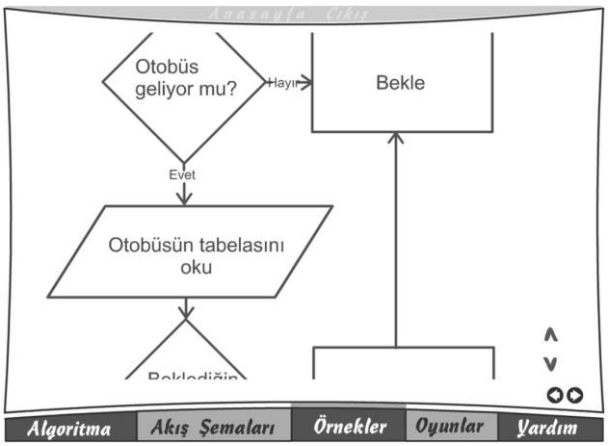

Figure 2. Flowcharts Section of Educational Software

The educational software was prepared in 2005 as the final project of the Project course at Dokuz Eylül University, Buca Faculty of Education, Department of Computer and Instructional Technologies Education. The

software explains the subject of algorithms, gives examples and includes games to reinforce the topics.

"Understanding the Algorithm" educational software has been prepared by taking into account the basic steps of programmed teaching. Educational software subjects are divided into small pieces, the smallest units of knowledge and skills so that the subject to be taught can be easily learned by the student in line with the target behaviors of the course. The student progresses in the subject by following, solving and using these units of knowledge step by step. This progress can be linear, that is, gradual, or divided into branches and options according to student preference (Arslan and Ege, 2008). It has been prepared by taking into consideration the principle of small steps by giving the subjects to be taught in small parts, the principle of active participation by ensuring the active participation of the student, the principle of individual speed in which students can progress at their own pace, the principle of instant correction by providing instant feedback to students, and the principle of success by making students taste success.

Data Analysis

Within the scope of the research, after the data related to the research were collected, statistical procedures were performed using the statistical program. In addition, two half test reliability was calculated using Microsoft Excell (2010) program. For these procedures, data were first entered into the program and arithmetic mean, standard deviation, reliability, correlation, variance values were calculated; independent sample t test, paired sample t test and Mann Whitney u test were applied. P significance level was taken as 95% (p=0.05) in the applica-tion of these procedures. With these calculations, the differences between the control and experimental groups were analyzed.

Results

While forming the control and experimental groups, the opinions of the classroom teachers and the course teacher were sought, and it was ensured that the students were close to each other in terms of their knowledge levels.

Table 4. Independent Sample T-Test Results for the Comparison of Pre-Test Scores of The Control and The Experimental Group Students

Groups	N	$\bar{X}$	SS	sd	t	p
Control	30	31,00	11,84	58	-0,236	0,814
Experimental	30	31,66	9,85			

As seen in Table 4, the pretest achievement average of the control group $\bar{X}$=31,00 and the mean pretest achievement of the experimental group was $\bar{X}$=31,66. Here, it is seen that there is no significant difference in the pre-test scores of the control and experimental groups at 0.05 significance level (t=-0.236; p>0.05). From

this result, it is seen that the control and experimental group students are not different from each other in terms of their knowledge about "algorithms" in the information technologies course.

A paired sample t-test was used to determine whether there was a significant difference between the pre-test and post-test scores of the control group in which the traditional teaching method was applied. The control group, consisting of 30 students in total, was taught "algorithms" using the traditional teaching method. Before the lesson, students solved the achievement test (pre-test). After the lesson, the same achievement test was applied again (post-test). Table 5 shows the pre-test and post-test results of the control group students.

Table 5. Paired Sample T-Test Results for The Comparison of Pre-Test and Post-Test Scores of Control Group Students

Groups	N	$\bar{X}$	SS	sd	t	p
Pre Test	30	31,00	11,84	29	-10,666	0,000
Final Test	30	66,33	12,45			

As can be seen in Table 5, the pre-test mean $\bar{X}$=31,00 and post-test mean $\bar{X}$=66,33 in the control group in which the traditional teaching method was applied. When the pre-test and post-test mean scores of the students are compared, it is seen that there is a significant difference at 0.05 significance level (t=-10.666;p<0.05).

The paired sample t-test was used to determine whether there was a significant difference between the pre-test and post-test scores of the experimental group in which the computer-assisted instruction method was applied. The experimental group in which the computer-assisted instruction method was applied consisted of a total of 30 students. Before the lesson, the students completed the achievement test (pre-test). The subject of "algorithms" was taught to this group with computer assisted instruction method. In the first week, the students were introduced to the educational software called "Understanding Algorithms". In the second and third weeks, the students used the educational software completely on their own. After the third week, the same achievement test was applied again (post-test). Table 6 shows the pre-test and post-test results of the experimental group students.

Table 6. Paired Sample T-Test Results for the Comparison of Pre-Test and Post-Test Scores of the Experimental Group Students

Groups	N	$\bar{X}$	SS	sd	t	p
Pre Test	30	31,66	9,85	29	-17,902	0,000
Final Test	30	81,33	10,41			

As can be seen in Table 6, the pretest mean $\bar{X}$=31,66 and the posttest mean $\bar{X}$=81,33 of the experimental group in which computer assisted instruction method was applied. When the pre-test and post-test mean scores of the students are compared, it is seen that there is a significant difference at 0.05 significance level (t=-

17,902;p<0.05).

The independent sample t-test was used to determine whether there was a significant difference between the post-test scores of the control group, in which the traditional teaching method was applied, and the experimental group, in which the computer-assisted teaching method was applied.

Table 7. Independent Sample T-Test Results for the comparison of the Post-Test Scores of the Control and Experimental Group Students

Groups	N	$\bar{X}$	SS	sd	t	p
Control	30	66,33	12,45	58	-5,061	0,000
Experimental	30	81,33	10,41			

In Table 7, it is seen that the mean post-test score of the control group students in which the traditional teaching method was applied was $\bar{X}$=66.33 and the mean post-test score of the experimental group students in which the computer-assisted instruction method was applied was $\bar{X}$=81.33. Considering the mean scores, it is seen that the experimental group students have higher mean scores than the control group students. It is seen that there is a significant difference at 0.05 significance level (t =-5,061; p<0.05). From this point of view, it is seen that the mean score of the experimental group students, in which computer-assisted education was provided, was higher than the mean score of the control group students, in which traditional education was provided (Control Post Test $\bar{X}$=31,00 < Experimental Post Test $\bar{X}$=66,33).

The Mann Whitney u test was used to determine whether there was a significant difference in the pre-test and post-test scores of the control group using the traditional teaching method according to gender. The control group, in which the traditional teaching method was used, consisted of a total of 30 students, 15 of whom were male and 15 of whom were female.

Table 8. Mann Whitney U-Test Results of the Pre-Test and Post-Test Scores of the Control Group Students with Respect to Gender Factor

Tests	Gender	N	Rank Mean	Rank Sum	MWU	p
Pre Test	Boy	15	16,10	241,50	103,50	0,694
	Girl	15	14,90	223,50		
Final Test	Boy	15	16,23	243,50	101,50	0,639
	Girl	15	14,77	221,50		

As seen in Table 8, the Mann Whitney u test was applied to the pre-test and post-test scores of the control group in which the traditional teaching method was used, and it was examined whether the achievement differed according to gender. According to Table 8, it is seen that there is no significant difference in the pre-test scores of the control group students according to gender (p>0.05). When the rank averages of both gender groups are

examined, it is seen that the averages are close to each other (Boy=16,10, Girl=14,90). According to Table 8, there was no significant difference in the post-test scores of the control group students according to gender (p>0.05). When the rank averages of both gender groups are examined, it is seen that the averages are close to each other (Boy=16,23, Girl=14,77).

The Mann Whitney u test was used to determine whether there was a significant difference in the pre-test and post-test scores of the experimental group in which computer assisted instruction method was used. The experimental group, in which the computer-assisted instruction method was used, consisted of a total of 30 students, 13 of whom were male and 17 of whom were female.

Table 9. The Mann Whitney U-Test Results of the Pre-Test and Post-Test Scores of the Experimental Group Students Regarding the Gender Factor

Tests	Gender	N	Rank Mean	Rank Sum	MWU	p
Pre Test	Boy	13	15,46	201,00	110,00	0,983
	Girl	17	15,53	264,00		
Final Test	Boy	13	16,12	209,50	102,50	0,715
	Girl	17	15,03	255,50		

As seen in Table 9, the Mann Whitney u test was applied to the pre-test and post-test scores of the experimental group in which the computer assisted instruction method was used and it was examined whether the achievement differed according to gender.

According to Table 9, it is seen that there is no significant difference in the pre-test scores of the experimental group students according to gender (p>0.05). When the rank averages of both gender groups are examined, it is seen that the averages are close to each other (Boy=15,46, Girl=15,53).

According to Table 9, there was no significant difference in the post-test scores of the experimental group students according to gender (p>0.05). When the rank averages of both gender groups are examined, it is seen that the averages are close to each other (Boy=16,12, Girl=15,03).

Discussion

Many studies prove that computer-assisted instruction yields more positive results than traditional instruction. Researchers have shown that computer assisted instruction in many courses increases the interest of students and teachers. The use of computer assisted instructional material in the teaching environment provides various benefits for the instructors. The fact that the courseware used makes the teacher's work a little easier, reduces the time allocated to teaching, and thus ensures the active participation of the student in the teaching process has been a situation that has been constantly observed and determined by the researchers. During the

implementation of this research, it was observed that the students had positive attitudes towards the use of computer assisted instruction and wanted to use computers continuously. It is seen in the research findings that more effective results are obtained with the use of computer assisted instruction methods. According to Gömleksiz and Sertdemir, computer-assisted English teaching was found to be more effective than traditional teaching methods (Gömleksiz and Sertdemir, 2005). With this result, the findings obtained in English language teaching support the research on algorithm teaching.

In a study, it was found that the computer-aided lecture presentation method in geography education was more successful than the classical method, albeit with a small difference. It was found that students with insufficient or low computer use were more successful in the lesson thanks to the computerized lecture presentation method with great curiosity and interest. (Özgen et al., 2006) It is inevitable that the computer, which is one of the most important tools of our age, is taken into the service of teaching activities and it is inevitable to make more use of them. According to the studies conducted with computer assisted lecture presentation method, it is seen that female students are more successful than male students. (Özgen et al., 2006). The use of computer assisted instruction and traditional teaching methods did not differ according to gender in this study.

Computer assisted education manifests itself in many stages of life and reveals its effectiveness. As a result of the research, it was found that the computer assisted teaching method used in preschool education period is more effective than the traditional teaching method currently used (Kaçar and Doğan, 2002). Children of our age are highly skilled, knowledgeable and enthusiastic about computers. According to Kahvecioğlu (2007), teachers should enable them to use this knowledge and skills in the field of education and show them the benefits of computers from different perspectives. The results obtained from different research support our research on the effect of computer assisted instruction on student achievement. It is supported by the findings that computer assisted instruction is an effective method in student attention and achievement.

Our age is the age of science and technology. To find the truth, research should be done, literature should be scanned, comparisons should be made, and suggestions and criticisms should be evaluated. Therefore, our students should be encouraged in every corner of our country and new ideas and new products should be put forward. All students, from rural areas to cities, should participate in the global world and be open to innovations (Engin et al., 2010).

Conclusion

In this study, computer assisted instruction methods and traditional teaching methods were applied to different groups (experimental control) in algorithm teaching and the effects of these applications on student achievement were examined. According to the results obtained, the post-test average of the experimental group, in which the computer-assisted instruction method was applied, was higher than the post-test average of the control group, in which the traditional teaching method was applied. Therefore, it can be said that computer assisted instruction

methods are more effective than traditional teaching methods in teaching "Algorithm" subject. As a result of the research, it was found that there was no significant difference in student achievement according to gender in computer assisted instruction methods and traditional instruction methods. The use of educational software and computers in education has a positive effect on student achievement. The use of computer technology in education will provide meaningful learning.

Recommendations

Computer assisted instruction methods, which are effective in teaching the subject of algorithms, can also be used in teaching other subjects.

Students can be provided with educational software related to their courses so that they can learn at their own pace.

The computer assisted instruction method, which is effective in the Information Technologies course, can also be used effectively in other courses.

The research covers only public schools. Such a study can also be conducted in private schools.

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