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Research Article

Impact of worked-out examples via a Web 2.0 tool on fifth graders' achievement, attitudes, and motivation in mathematics

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This research examines the effects of worked-out examples, grounded in Cognitive Load Theory, which incorporate different solution methods through the Nearpod application—a Web 2.0 tool—on fifth-grade students' achievement in fractions, as well as their attitudes and motivation towards mathematics. The study group consisted of 77 fifth-grade students from two separate classes at a public secondary school in Istanbul. These two classes were randomly assigned, with one serving as the control group and the other as the experimental group. The intervention lasted for six weeks. The research was conducted using an explanatory sequential mixed design, which included both quantitative and qualitative methods. Quantitative data were collected through fraction achievement tests, a mathematics motivation scale, and a mathematics attitude scale. Qualitative data were obtained from students' responses to interview questions to evaluate the effectiveness of the intervention. The findings revealed a statistically significant improvement in the post-test scores for fractions achievement, mathematics motivation, and attitudes towards mathematics in favor of the experimental group, even after controlling for pre-test scores. The results of the interviews also supported these findings, with all interviewed students stating that they found the intervention helpful and engaging. This study contributes to the growing body of literature on the integration of technology in mathematics education, highlighting the need for further research on the application of different solution strategies in digital learning environments.

Keywords: Cognitive Load Theory; Fraction achievement; Multiple solution strategies; Web 2.0 tools; Worked-out examples

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1. Introduction

Mathematics, due to its abstract nature, poses significant challenges for many students in constructing mathematical knowledge and succeeding in lessons (Baykul, 2021). One of the abstract mathematical concepts that students experience is fractions. Although fractions have been a fundamental topic in mathematics since ancient times, research indicates that students at all grade levels struggle to understand the concept of fractions (e.g., Hansen et al., 2017; Lewis & Perry, 2017). These difficulties typically arise from the abstract structure and/or pedagogical methods employed in instruction (Orhun, 2007; Soylu & Soylu, 2005).

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Mathematics educators frequently emphasize the importance of abstraction of mathematical concepts. One of these educators is Zoltan Dienes. Dienes (1967) emphasized that it is important for the teacher to apply the proper methods to their students during the teaching of a mathematical structure. He based his mathematics teaching on a student-centered approach, utilizing different materials and engaging in exploratory activities (Fossa, 2003). The four principles put forward by Dienes are known as the "Dienes Principles": "dynamic, construction, multiple embodiments, and perceptual variability" (Sriraman & English, 2005). This study is based on Dienes' principles of multiple embodiment and perceptual variability.

According to the principle of multiple embodiments, conceptual learning is expected to be maximized in children who are exposed to a variety of physical environments and embodiments (Post, 1981). This principle requires the use of a wide variety of materials or activities designed to support the abstraction of the mathematical concept (Gningue, 2016). The principle of perceptual variability refers to providing students with the opportunity to make generalizations about the topic to be learned (Sarı, 2015). This requires providing many examples related to the topic (Cathcart et al., 2003).

Many curriculum documents advocate for the use of multiple representations in the learning and teaching of fractions (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2017; Ministry of National Education [MoNE], 2018; National Council of Teachers of Mathematics [NCTM], 2000). In this context, the Rational Number Project (Behr et al., 1992; Cramer et al., 2002) emphasizes the importance of students solving the same mathematical problem using at least two different fraction models and critically evaluating the strengths and weaknesses of each model. A key feature of this project is that it encourages students, thereby fostering a deeper understanding of mathematics. Presenting multiple solutions and allowing students to examine and select the most appropriate one for their learning is critical in mathematics education. This approach aligns with Dienes' principles of multiple embodiment and perceptual variability, which are crucial for abstracting mathematical concepts (Yılmaz & Köse, 2015).

The use of different models in solving questions related to fractions can be illustrated through worked-out examples. Studies show that worked-out example methods have positive effects on improving students' mathematical performance (e.g., Große, 2015; Hesser & Gregory, 2015; Özcan et al., 2018; Renkl et al., 2002). Presenting different solutions to students, along with worked-out examples, enables them to abstract mathematical concepts (Üner & Biber, 2020; Yılmaz & Köse, 2015).

The digitalization of the rapidly changing world has had a profound impact on education systems. This change has increased the need for digitalization of teaching methods and tools. Web 2.0 tools are essential tools that increase interaction and collaboration in education, providing student-centered learning environments. Web 2.0 tools such as Nearpod make the learning process more engaging and effective by presenting course materials to students in diverse and interactive ways (e.g., Abdrafikova & Ulianova, 2014; Hung & Yuen, 2010; Hurlburt, 2008). Such tools enable teachers to make their lessons more dynamic and interactive, thereby increasing student engagement and motivation.

The main purpose of this study is to examine the effect of presenting worked-out examples related to the subject of fractions, which incorporate and present different solution methods together, through the Nearpod application, a Web 2.0 tool, on 5th-grade students' fraction achievement, mathematics motivation, and attitudes. The research problems of this study are as follows.

RQ 1) How does the use of worked-out examples with different solution methods through the Nearpod application influence fifth-grade students' performance in fractions, as well as their attitudes and motivation towards mathematics?

RQ 2) What are the thoughts of students in the experimental group regarding their experience of the intervention?

2. Theoretical Background

2.1. Concept of Fraction

The concept of fractions is one of the most difficult mathematical concepts to understand in primary school years (Orhun, 2007). Research shows that students at all grade levels have difficulty in understanding the concept of fractions (Reys et al., 1998). The concept of a fraction is used in five different ways, including measurement, part-whole, division, operator, and ratio (Sinicrope et al., 2002). Students are usually first introduced to the concept of fractions through the meaning of "part-whole". In this sense, fractions are learned by dividing a whole into various equal parts and measuring one of these parts. For example, dividing a cake into 4 equal parts and expressing the size of one of these parts is an example related to this meaning of fractions. Students are then introduced to the concept of "measure" fractions. At this stage, fractions are used to represent a specific point on the number line and to compare and contrast. These two meanings form the basis for understanding the concept of fractions and provide a basic foundation for understanding more advanced topics related to fractions. Fractions are generally represented by three different models (Marmur et al., 2020). The first of these three fraction models is the area model. It refers to the part of a defined whole that is scanned and desired. The second is the set model. It shows the number of objects expressed as a whole. The third is the number line model. It expresses the lengths determined by a unit in a whole shown on a number line (Petit et al., 2010). The part-whole meaning in fractions is primarily understood through the area model, making it the dominant model compared to other models (Marmur et al., 2020).

There are many studies on students' difficulties and misconceptions about fractions (e.g., Biber et al., 2013; Hansen et al., 2017; Lewis & Perry, 2017). In particular, many difficulties with four operations with fractions are related to students' failure to develop basic concepts or 'schemas' related to fractions (e.g., Norton et al., 2012; Steffe, 2010). Students' progress through these schemas depends on how they interpret and construct fractions using of various models. While there are differing views about which meanings and models to introduce to students and at what developmental stage (e.g., Cramer & Wyberg, 2009), there is broad agreement that students need opportunities to make connections between different structures and visual representations of fractions.

The teaching of fractions is often recognized as the point at which problems start in primary school. There can be many reasons for this, but overuse of a single model (e.g., circular disks) can lead to gaps in understanding or misunderstandings. The Hungarian mathematician and educational theorist Zoltan Dienes advocated the use of a variety of materials that illustrate different aspects of a mathematical concept. This part of the article will give an overview of Dienes' principles.

2.2. Dienes' Principles

Dienes emphasizes the importance of the communication methods used by teachers to students during the teaching of a mathematics subject. Dienes based mathematics teaching on a student-centered basis in which different materials are used and exploratory activities take place (Fossa, 2003) and put forward four principles. These principles, also known as "Dienes principles," are "dynamic, construction, multiple embodiment/experience, and perceptual variability" (Dienes, 1967; Sriraman & English, 2005).

The first principle, the principle of dynamism, forms the basis of the system of mathematics teaching developed by Dienes (Bart, 1970). According to this principle, abstraction begins with experience. Dienes thinks that learning is an active process. As a preliminary preparation, he thinks that games consisting of practically planned materials should be presented to build mathematical concepts as well as to provide experience (Gningue, 2016). For Dienes, thinking is of two types. The first is constructivist thinking, and the second is analytical thinking (Post, 1981). Dienes argued that since analyzing the principle of constructivism is not included in the child's learning cycle until the age of twelve, games and activities should be designed to lead to structuring analysis (Gningue, 2006; Olkun & Tokluk-Uçar, 2012). According to the principle of multiple embodiment/experience, conceptual learning is expected to be at its highest level in children who are confronted with various physical and interactive environments and embodiments (Post, 1981). Dienes (1967) clearly states, "*To encourage children to abstract (that is, to determine the elements common to a large number of different situations), a large number of different situations must be provided.*" Multiple experiences (not the repetition of the same experience over and over again) are achieved through the use of a wide variety of materials or activities designed to support the abstraction of a mathematical concept (Gningue, 2016). The point emphasized by this principle is to provide different situations with opportunities to see a concept in various situations (Post, 1981).

Moreover, this idea is reinforced by Dienes's principle of mathematical variability, which asserts, "*To encourage children to generalize, one must try to vary the values of the mathematical variables that make up the mathematical concepts to be taught.*" In addition, this principle is based on the fact that there are different ways allowing students to reach the same result using different methods. It is also defined as mathematical questions that can be solved in more than one way, or mathematical situations that can be proved in multiple ways.

A significant part of the mathematics education literature is based on Dienes' fundamental ideas. For example, Dienes' principles influenced the Rational Number Project (Lesh et al., 1987) and Mitchelmore's (1994) theory of abstract-separate and abstract-general concepts in mathematical generalizations. Abstract-separate conceptions emerge when students fail to successfully recognize structural similarities across different situations. Later, Dienes' principles have been adapted by Lesh and Doerr (2003) to design authentic modeling activities.

Using and connecting multiple representations is a widely recommended instructional method to strengthen students' understanding of complex knowledge and mathematical concepts (e.g., Lesh, 1979; Moschkovich, 2013; NCTM, 2014). However, the presence of multiple representations alone is not enough. Many student difficulties with representations have been identified, and design features in learning environments that can help overcome these difficulties have been developed and evaluated (Ainsworth, 2006; Renkl et al., 2013). In recent years, various strategies have been developed to overcome these difficulties through methods such as worked-out examples and interactive digital tools.

2.3. Cognitive Load Theory and Worked-Out Examples

To better understand the effect of worked-out examples on the individual, it is necessary to begin by addressing the "cognitive load" theory. The concept of cognitive load is defined in many studies as "the effort needed to process information" (Sweller, 1988). In other words, it can also be expressed as all the efforts needed for the processes in short-term memory. There are three types of cognitive load: intrinsic cognitive load, extrinsic cognitive load, and effective cognitive load (Paas et al., 2003; Sweller et al., 1998).

Intrinsic cognitive load refers to the load on working memory caused by a subject that is difficult to learn. When the information is complex, the intrinsic cognitive load will also be high. Intrinsic cognitive load is usually high when the subject being learned is difficult. Extraneous cognitive load refers to the loading of working memory resulting from poorly designed instructional materials and inadequate design. Extraneous cognitive load will be high if the learning environment contains inappropriate information or materials that negatively affect the information processing process. Germane cognitive load, on the other hand, occurs in the processes that enable the formation and organization of mental structures. Since germane cognitive load and extraneous cognitive load are affected by instructional design, they are under the control of instructional designers. The most important point is that the sum of intrinsic cognitive load, extraneous cognitive load, and germane cognitive load should not exceed the capacity of working memory; in other words, learning should take place without cognitive overload. For this reason, it is essential for researchers to examine instruction by considering cognitive load theory to make learning processes more effective and efficient (Anglin et al., 2004; Baron, 2004; Paas et al., 2003).

When information is transformed into learning, it loses its load in short-term memory. To ensure that knowledge is effectively learned, it should be presented to learners in an appropriate manner. In the process of acquiring a new skill, the rapid mental processing of learning schemas can be facilitated by preparing the ground for the formation of effective cognitive load through worked-out examples (Atkinson et al., 2000; Bokosmaty et al., 2003). It has been stated in many studies that worked-out examples are efficient for students who do not have enough experience or who are in the process of gaining a new skill (Renkl & Atkinson, 2003).

Worked-out examples are a method that shows learners step by step how the application is carried out and how the solution is reached (Clark et al., 2005). This method is an effective and permanent approach for individuals who have not yet fully developed the skills required for application processes related to the subject being taught and whose relational schemas are not yet fully established. Thanks to this method, a series of solutions to the problem is presented just before problem-solving, and the principles to be followed in problem-solving and their application are focused on (Clark et al., 2005). By fading the solutions, it is ensured that the student understands the problem structurally. In addition to the student learning the subject by solving it themselves, it contributes to gaining a perspective on the problem, understanding the conceptual structure, and developing problem-solving skills (Atkinson et al., 2000). Worked-out examples serve as models to show how an expert solves a particular problem, and learning transfer is realized from similar examples to less similar problems (Cooper & Sweller, 1987).

When the types of worked examples are examined, it becomes apparent that these types serve different functions in supporting students' learning processes and can be classified in various ways. When we look at the types of worked-out examples in the studies, there are standard, self-explanatory (Booth et al., 2013; İltüzer, 2016; Lee, 2013), faded with explanation (Große, 2015; Hesser & Gregory, 2015; Özcan et al., 2018), and true-false (Durkin & Rittle-Johnson, 2012; Özcan et al., 2018). In addition, while some of the worked-out example types are technology-supported (Booth et al., 2013; İltüzer, 2016; Lee, 2013; Meşe, 2012), some of the non-technology-supported studies (Große, 2015; Große & Renkl, 2007; Hesser & Gregory, 2015; Özcan et al., 2018; Renkl, 2017; Retnowati et al., 2010; Van Loon Hillen et al., 2012; Yılmaz & Köse, 2015). In the literature, it is seen that the research on the presentation of worked-out examples in technology-supported environments within the scope of mathematics education is limited. Worked-out examples can be delivered to students through Web 2.0 tools, with Nearpod being one such application.

2.4. Web 2.0 Tools and Nearpod Application

Today, the knowledge and skills that teachers should possess are one of the issues being researched. There are different views and practices about the skills that teachers should possess (Shulman, 1986). Shulman categorized teacher knowledge as pedagogical knowledge, subject area knowledge, knowledge of educational context, curriculum knowledge, knowledge of historical and educational philosophical goals, and pedagogical content knowledge. In this classification, he specifically defined pedagogical content knowledge as the teacher's ability to organize specific subjects in a manner that is appropriate to student needs, combining content knowledge and methodological knowledge (Shulman, 1987). increasingly important. Pierson (1999) included technology knowledge among the knowledge that teachers should have. Similarly, Niess (2005) conducted studies on teachers' Technological Pedagogical Content Knowledge [TPACK] and emphasized the acquisition of the ability to teach with technology by including technology in education. He also emphasized that it is essential for teacher training programs to prepare environments where technology is used effectively. Mishra and Koehler (2003) stated that attention should be paid to issues such as how technology is used in education and what kind of knowledge teachers should have to incorporate technology into teaching appropriately. Web 2.0 tools, which are increasingly used in the educational environment as a means of integrating technology into education, allow people to interact simultaneously and produce information content (e.g., Hung & Yuen, 2010; Hurlburt, 2008; McLoughlin & Lee, 2007; O'Reilly, 2007). By offering interactive learning environments with Web 2.0 tools, independent learning environments can be designed, saving time and space.

In this study, Nearpod was used as a Web 2.0 tool. One of the primary purposes of using Nearpod in this study is that it is a multi-platform e-learning tool that enables students to interact with one another (Ryan & Deci, 2017). The Nearpod application is considered a Web 2.0 tool that facilitates student participation and increases motivation during lessons (Abdrafikova & Ulianova, 2014; Beranek et al., 2016; Putra et al., 2021; Sanmugam et al., 2019). The Nearpod application can be accessed with an internet connection. Nearpod, a virtual classroom application, offers numerous tools within itself. By preparing an interactive presentation, you can add lecture notes, fun quizzes, videos, questions, drawings, tests, and assignments to a single presentation. With the pin code or content link given by the teacher to the students, the interactive presentation can be accessed at the specified time, instantly or optionally online. The teacher also has the opportunity to monitor student performance in the activities they create. The Nearpod application can be accessed via tablet or phone. By logging in to https://nearpod.com, one can register and produce content. There is no membership requirement for students.

The literature review indicates that worked-out examples have a positive impact on students' mathematics achievement. Additionally, the use of technology and Web 2.0 tools in presenting worked-out examples is well-supported in the literature. CLT emphasizes the management of cognitive load in the learning process, and worked examples are considered an important strategy to optimize this load, especially in digital learning environments. Dienes' principles of mathematics learning encourage learning based on experiential and multiple representations for a better understanding of abstract concepts. In this context, this study is guided by CLT and Dienes' principles in the design of worked examples to help students understand mathematical concepts at both cognitive and experiential levels. Research indicates that students' attitudes toward mathematics and their motivation significantly influence their engagement, persistence, and overall academic performance. Since digital tools can shape students' perceptions of learning, it was essential to investigate whether the integration of worked-out examples in a digital environment not only enhances achievement but also fosters positive attitudes and motivation toward mathematics. This study aims to examine the effect of presenting worked-out examples involving different solution methods for fractions to fifth-grade students through the Nearpod application, a Web 2.0 tool, on their achievement in fractions, mathematics motivation, and attitudes.

3. Method

3.1. Research Design

In this study, a mixed methods approach was employed, combining quantitative and qualitative research designs (Creswell, 2012), specifically using the explanatory sequential mixed design. In the explanatory sequential mixed design, quantitative data are first collected and analyzed; then qualitative data are collected to explain and enrich the quantitative data. This design is to better understand the reasons behind quantitative findings, especially in complex educational processes, facilitating a deeper understanding of the underlying reasons. While the data obtained in the quantitative phase reveals specific patterns and trends, the qualitative phase allows for a more in-depth explanation of these results. The choice of an explanatory sequential mixed design facilitates a more comprehensive interpretation of the findings. Compared to alternative mixed designs, this method provides a systematic structure in the data collection process, understanding and enabling a better understanding of the relationships between variables. In this study, after collecting and analyzing data using the fractions achievement test, the mathematics motivation scale, and the mathematics attitude scale, qualitative data were gathered and analyzed through interviews to support the findings. In the quantitative part of the study, the quasi-experimental model, a type of experimental method, was used. In the qualitative part of the study, the case study model was employed, and semi-structured interviews were conducted with eight students from the experimental group to examine their views on the implementation.

3.2. Study Group

The study group for the research was determined using convenient sampling, one of the purposeful sampling methods (Christensen et al., 2014). This study group consisted of fifth-grade students attending a public middle school affiliated with the Ministry of National Education [MoNE] in Istanbul during the 2021-2022 academic year. The school was chosen for the research because one of the researchers works there, making the experimental process easier to conduct. Two classes from the fifth grade were selected within the research scope, and two equivalent groups were identified based on their fourth-grade end-of-year mathematics scores from the previous year. Among these two equivalent groups, one was assigned as the control group and the other as the experimental group through random assignment (Creswell, 2012). Of the students participating in the research, 36.36% (n = 28) were female, and 63.63% (n = 49) were male. In the experimental group, there were 37 students in total, with 43.24% (n=16) girls and 56.75% (n=21) boys. In the control group, there were 40 students in total, with 30% (n=12) girls and 70% (n=28) boys. An interview was conducted with the eight students from the experimental group to gather their opinions on the intervention of worked-out examples containing different solution paths. When selecting students for the interview, the researcher considered the average and standard deviation of mathematics scores for the first semester. A total of eight randomly selected students were interviewed, including two high-achieving students, three average-achieving students, and three low-achieving students.

3.3. Data Collection Tools

In this study, both qualitative and quantitative data collection tools were used. Quantitative data were gathered through the Fraction Achievement Test [FAT], Mathematics Motivation Scale [MMS], and Mathematics Attitude Scale [MAS]. Qualitative data were collected from students' responses to interview questions to determine the effectiveness of the intervention.

3.3.1. Fraction Achievement Test (Pretest, Posttest, and Delayed Test)

To measure students' mathematics achievement in fractions, the Fractions Achievement Test was developed by the researchers in alignment with fifth-grade learning objectives in the area of fractions. Initially, a table of specifications was prepared to guide the test construction. For content validity, the questions were revised based on feedback from four mathematics teachers working at a public school, whose experience ranged from 4 to 12 years. The FAT was administered as a pre-test, post-test, and delayed post-test [DFAT] in the study. The test comprises 10 questions aligned with the fifth-grade fractions curriculum, consisting of 7 questions at the "application" level and three questions at the "comprehension" level, according to Bloom's Taxonomy. Scoring for each question is as follows: 10 points for a complete and correct solution, 5 points for a partially correct solution where the process is accurate, 3 points for partial or incorrect solutions, and 6 points for choosing the correct strategy but providing an incorrect solution. A score of 0 is assigned for entirely incorrect answers or no answers. The maximum score is 100. The authors reviewed student responses, and inter-rater reliability was high, with coefficients of 0.90 for the pre-test, 0.95 for the post-test, and 0.95 for the delayed post-test.

3.3.2. Mathematics Motivation Scale

In this study, the MMS developed by Aktan and Tezci (2013) was used to measure the motivation of fifth-grade students towards mathematics. The MMS consists of six dimensions and 27 items. The internal consistency coefficients of the scale range from .85 to .94, and the item-total correlation values range from .62 to .89. The Cronbach's alpha coefficient obtained for the reliability of the scale is .91. Within the scope of current research, the Cronbach's alpha internal consistency coefficient was recalculated for both the total score and subscales, with a total value of .80. The Cronbach's alpha coefficients for the sub-dimensions are .54 (Intrinsic Goal Orientation), .79 (Extrinsic Goal Orientation), .70 (Task Value), .68 (Learning Beliefs), .79 (Self-Efficacy), and .70 (Test Anxiety). These results indicate that the scale can be used to determine the motivational strategies employed by fifth-grade students in mathematics. Each item has five response options, rated on a scale from 1 ("strongly disagree") to 5 ("strongly agree").

3.3.3. Mathematics Attitude Scale

The MAS, originally developed by Erol (1989) and later shortened by Nazlıçiçek and Erktin (2002), was used to assess students' attitudes towards mathematics. The shortened form of the scale is titled "Your Thoughts About Mathematics." This version includes 20 items across three sub-dimensions: "Perceived Mathematics Achievement Level," "Benefits of Mathematics," and "Interest in Mathematics." Each item has five response options, rated from 1 ("never") to 5 ("always"). The Cronbach's alpha internal consistency coefficient for the original scale was found to be .74. For this study, the reliability of the scale was reevaluated, and Cronbach's alpha internal consistency coefficient was found to be .88. The Cronbach's alpha coefficients for the sub-dimensions were .78 for "Perceived Mathematics Achievement Level", .60 for "Benefits of Mathematics," and .84 for "Interest in Mathematics." These results indicate that the scale is reliable for measuring elementary students' attitudes towards mathematics.

3.3.4. Interview Form for Intervention with Worked-Out Examples with Different Solution Methods through Nearpod

An interview consisting of six questions was conducted with the 8 students from the experimental group to gather their opinions on the intervention of worked-out examples containing different solution paths. These questions were initially presented for expert review by the researchers. Feedback was obtained from two mathematics education experts. Based on their suggestions, the wording of the questions was clarified and simplified to enhance understanding. These interviews were conducted and recorded via the Zoom platform. The interview recordings obtained via the Zoom platform totaled twenty-seven pages, and themes were created by considering the characteristics of the coded data.

3.4. Experimental Procedure

The instructional design of the study, including the administration of pretests, posttests, delayed posttests, and interviews for both the experimental and control groups, is summarized in Table 1.

Table 1
Instructional design of the study

Groups	*Pretest*	*Instruction*	*Posttest*	*Delayed posttest*	*Interview*
Experimental group	FAT MMS MAS	Experimental Intervention through Nearpod (6 lessons)	FAT MMS MAS	DFAT	Interview
Control group	FAT MMS MAS	Course book activities through Nearpod (6 lessons)	FAT MMS MAS	DFAT	-

In the research, the FAT, MMS, and MAS measurement tools were administered to both groups as a pretest prior to the experimental intervention. Then the intervention was started. In the experimental group, the subject of "fractions" was explained through worked-out examples with different solutions using the Nearpod application, while in the control group, teaching and activities were conducted based on the MoNE textbook using the Nearpod application. In the experimental group, the number of questions solved was less than in the control group because the questions were presented with different solutions, and students' reflections and solution preferences were taken about the process after each activity. The intervention lasted for 6 weeks, with 4 hours of training per week. At the end of the intervention, FAT, MMS, and MAS were applied to both groups as post-tests. Eight students selected from the experimental group were interviewed with an interview form regarding the intervention. One month after the application, the retention of the information was tested by applying DFAT to both groups.

3.5. Instructional Design

The experimental and control groups were introduced to the Nearpod application during a 40-minute lesson before the intervention. Students were shown how to access the application using a code, allowing them to engage with the lesson content. A demonstration was provided on the smartboard in class. Nearpod, as a virtual classroom tool, offers a variety of features that enable interactive presentations, allowing lesson notes to be shared with students. Students can easily access the application via a code or link on their tablets, phones, or computers, without needing to download an app or create an account. One of the key benefits of using Nearpod is that students can revisit the lesson content later using the provided code. Participants were informed about the use of their data, and informed consent procedures were implemented. Additionally, data were stored only for the duration of the study and securely deleted upon its completion. These measures demonstrate the study's full compliance with ethical guidelines and its emphasis on data security.

For both the experimental and control groups, six activities related to fractions were prepared in alignment with the six learning objectives. Each activity included questions and multiple solution strategies, fostering conceptual understanding through varied representations. Activity 1 focused on unit fractions on a number line. Two questions were included, accompanied by three distinct solution strategies: modeling, number line placement, and rule-based calculation. Activity 2 addressed the concept of mixed numbers as the sum of a whole number and a proper fraction, as well as conversions between mixed and improper forms. Two questions were used with solutions presented through area models, number lines, and symbolic rules. Activity 3 targeted the comparison of whole numbers and improper fractions using one question and three different strategies. Activity 4 explored the concept of equivalence through simplification and expansion, presenting one question and four solution methods that emphasized both procedural and visual understanding. Activity 5 dealt with ordering fractions with common numerators or denominators and included three questions supported by consistent representational strategies. Finally, Activity 6 involved calculating a part or the whole using unit fractions, supported by three questions and an integrated solution path that included visual, numerical, and symbolic representations.

In the experimental group, worked-out examples with different solution methods (at least three) were provided through Nearpod, followed by the "Your Turn" section, which included exercises similar to the examples given. To understand students' problem-solving processes, two questions were asked after each activity, and students responded to both questions: their preferred solution and whether they considered multiple solution methods. For the control group, similar examples were used with only one solution. All of the solution types were presented in the control group. Similarly, the control group responded to "Your Turn" questions.

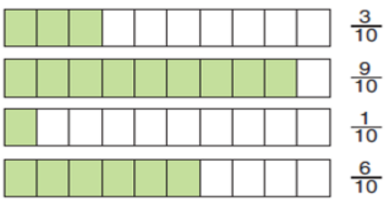
For example, the learning objective "ordering fractions with equal denominators" was addressed in both groups through the use of activity sheets. In both the experimental and control groups, the objective was introduced first. The control group continued with four example questions from the textbook activities through Nearpod. These questions were solved using the area model, number line, rule application, and concepts of proximity to a whole, half, or quarter, respectively. For example, for the question "Arrange the following fractions in order from smallest to largest: $\frac{3}{10}, \frac{9}{10}, \frac{1}{10}, \frac{6}{10}$" the answer is provided to the control group using an area model (see Figure 1).

Figure 1

A solution from the control group's activity sheet: The question was solved using the area model

Solution: Below is a visual model for each fraction using rectangular regions. Each rectangle is divided into 10 equal parts, and the number of shaded parts represents the value of the fraction.

So, we can order fractions as, 1/10 < 3/10 < 6/10 < 9/10.



For the experimental group, the solution to the same question was given with four different solution methods, allowing students to compare these methods. These solutions were also provided through the Nearpod application (see Figures 2, 3, 4, and 5).

Figure 2

A solution from the experimental group's activity sheet: The question was solved using the area model

Solution1: Below is a visual model for each fraction using rectangular regions. Each rectangle is divided into 10 equal parts, and the number of shaded parts represents the value of the fraction.

So, we can order fractions as, 1/10 < 3/10 < 6/10 < 9/10.

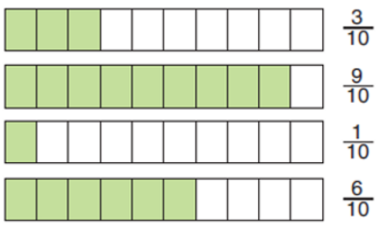


Figure 3

A solution from the experimental group's activity sheet: The question was solved using the formula method

Solution 2: Rule: Since all the fractions have the same denominator, we can compare them by looking at the numerators. The fraction with the smallest numerator is the smallest, and the fraction with the largest numerator is the largest.

So, we can order fractions as, 1/10 < 3/10 < 6/10 < 9/10.

Figure 4

A solution from the experimental group's activity sheet: The question was solved using the nearness to whole, half, and quarter methods

Solution 3: Let's examine the fractions 1/10, 3/10, 6/10, and 9/10 in terms of their closeness to a quarter, half, and whole:

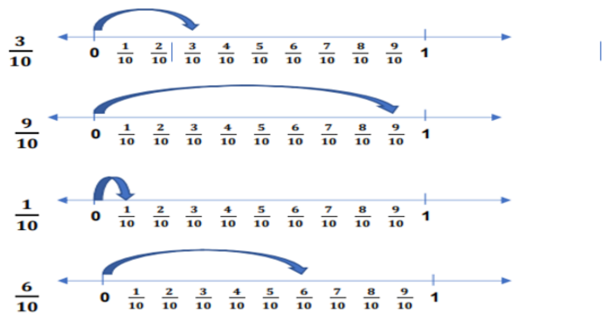
- 1/10: This is a unit fraction, much smaller than a quarter, half, or whole.
- 3/10: This fraction is close to a quarter (since 1/4 is 2.5/10).
- 6/10: This fraction is close to half (since 1/2 is 5/10).
- 9/10: This fraction is close to the whole (since 1 is 10/10).

When arranged from smallest to largest, the order is 1/10 < 3/10 < 6/10 < 9/10.

Figure 5

A solution from the experimental group's activity sheet: The question was solved using the number line method

Solution 4: Let's show the fractions on the number line.



When arranged from smallest to largest, the order is 1/10 < 3/10 < 6/10 < 9/10.

Before the study commenced, expert opinions were obtained from two mathematics teachers who each held a master's degree and had 10 years of teaching experience. The mathematics teacher for both the experimental and control groups was the first author of the study.

3.6. Validity and Reliability of the Experimental Process

To increase the internal validity of the experimental study, several measures were taken. First, a control group was utilized, ensuring a baseline for comparison. The participants' backgrounds were similar in socio-economic terms, minimizing external variability. Two classes with no significant differences in pre-test scores were selected, and an ANCOVA test was conducted to control for any initial disparities. Valid and reliable measurement tools were employed to ensure the accuracy of the data. The ANCOVA test also helped to eliminate differences between pre-test scores, providing a clearer picture of the intervention's effect. Both groups demonstrated greater advancement. Finally, the experimental and control groups were assigned randomly to avoid selection bias.

3.7. Ethical Principles of Research

In this study, the researcher adhered to ethical principles at all stages. Ethics committee approval was obtained, and research permission was granted by the governorship with the consent of the relevant authorities. Prior to participation, students were informed, and parental consent forms were obtained. The identities of the participating students were kept confidential, thereby safeguarding their rights.

3.8. Data Analysis

Before analyzing the quantitative data, the normality of the data distribution was assessed using the Shapiro-Wilk test, as well as the skewness and kurtosis coefficients. To answer the research questions of the study, comparisons between groups were made using the ANCOVA test.

The data obtained from the semi-structured interview form were analyzed and classified by content analysis. In content analysis, the goal is to create concepts and relationships that can explain the data obtained. Data that are similar to each other are grouped under certain concepts, and the data are organized in a way that allows the reader to understand them (Kuckartz & Rädiker, 2023). The interview recordings, obtained via the Zoom platform, were transcribed by the researchers. Open coding was applied to the transcribed data, where segments were assigned, initial codes based on the participants' responses. Two researchers performed the coding independently to ensure reliability. The coded data were then organized into themes, and to ensure the results reflected the students' opinions, direct quotations from their views were included, accompanied by code numbers (S1, S2, S3, …, S8). According to Miles and Huberman

(1994), the reliability coefficient was calculated using the formula Reliability = Agreement / (Agreement + Disagreement), and the reliability of the qualitative data was found to be 90%. This method provided a detailed, reliable, and trustworthy analysis of the students' perspectives.

4. Findings

4.1. Pilot Study

A pilot study was conducted to enhance the study's validity and identify any deficiencies before full implementation. The pilot, which began in September 2021 with fifth-grade students at a public middle school in Istanbul, involved volunteers after obtaining MoNE permissions. Four students were randomly assigned to experimental and control groups, and pre-tests were administered. The study included six activities conducted over 24 class hours across nine days. The pilot study revealed that consecutive lessons caused student fatigue, leading to a decision to spread the activities over a week. Additionally, some solutions were revised for better clarity, and drawings were adjusted to ensure they were more understandable. These changes were made to strengthen the study's validity and improve the quality of implementation.

4.2. Descriptive Statistics, Preliminary Analysis, and Results

Before performing the quantitative analysis on the collected data, descriptive and preliminary analyses of the dependent variables were carried out, with the results presented in Table 2. The normality of the data was assessed using skewness and kurtosis coefficients, as well as the Shapiro-Wilk test. Only the control group's pre-test scores for FAT, MMS, and MAS did not show a normal distribution according to the Shapiro-Wilk test (SW = .89, $p < .05$; SW = .98, $p < .05$; SW = .97, $p < .05$); however, since the skewness and kurtosis coefficients were between −1 and +1, this distribution was considered normal. The FAT pre-test for the experimental group (SW = .96, $p > .05$), the FAT post-test for the control group (SW = .95, $p > .05$), the FAT post-test for the experimental group (SW = .96, $p > .05$), as well as the delayed test scores for both the experimental group (SW = .96, $p > .05$) and control group (SW = .95, $p > .05$), all indicated normal distributions. For MMS, the pre-test for the experimental group (SW = .91, $p > .05$), the post-test for the control group (SW = .98, $p > .05$), and the experimental group (SW = .92, $p > .05$) also exhibited normal distributions. Similarly, for MAS, the pre-test for the experimental group (SW = .94, $p > .05$) and the post-tests for both the control group (SW = .97, $p > .05$) and the experimental group (SW = .92, $p > .05$) were normally distributed. Overall, based on the criteria outlined by George and Mallery

Table 2
Descriptive statistics and comparison of experimental and control groups

	Descriptive Statistics		*Comparison between EG and CG*
	CG Score mean (SD)	EG Score mean (SD)	
FAT			
Pretest	16.00 (12.40)	25.00 (15.23)	$t=-1.82$, $p>.05$
Posttest	39.60 (19.48)	62.37 (19.72)	$F_{(1,67)}=16.55$, $p<.001$; partial $\eta^2 = .21$
Delayed posttest	36.31 (16.39)	62.06 (18.23)	$F_{(1,67)}=30.31$, $p<.001$); partial $\eta^2 = .32$
MAS			
Pretest	72.00 (13.50)	73.92 (11.88)	$t=-.683$ $p>.05$
Posttest	71.05 (12.13)	80.33 (12.23)	$F_{(1,67)}=8.77$, $p<.001$; partial $\eta^2 = .14$
MMS			
Posttest	103.5 (9.23)	100.33 (4.52)	$t=1.031$ $p>.05$
Posttest	103.37 (12.98)	111.16 (11.34)	$F_{(1,67)}=8.18$, $p<.001$; partial $\eta^2 = .12$

Note. EG: Experimental group; CG: Control group.

(2010), it was concluded that the data met the normal distribution requirements, as indicated by the skewness and kurtosis coefficients. Specifically, as shown in Table 2, the skewness values falling between +1 and −1 suggest that the data distribution can be considered normal (George & Mallery, 2010).

For preliminary analysis, an independent sample *t*-test was used to compare the pre-test scores of the dependent variables between the experimental and control groups prior to the intervention. The results indicated no significant differences between the experimental and control groups for pre-FAT (t =−1.82, $p > .05$), pre-MAS (t =−.683, $p > .05$), and pre-MMS ($t = 1.031$, $p > .05$).

In order to examine the effectiveness of examining worked-out examples with different solutions to fractions through the Nearpod application leading to a significant improvement in the fraction performance, post-test scores of FAT were compared in terms of control and experimental groups using the ANCOVA test.

Initially, it was assessed whether the "homogeneity of regression slopes" assumption, a crucial requirement for ANCOVA, was met for FAT, DFAT, MAS, and MMS. To this end, the F-values for the interaction between the group type (independent variable) and the pre-test scores of the dependent variables were determined. The *F*-values were found to be 2.24 for FAT, 1.64 for DFAT, 2.15 for MAS, and 1.60 for MMS, with all of the *p*-values greater than .05. This result is interpreted as fulfilling the condition of matching regression slopes needed for ANCOVA. To examine another important assumption of ANCOVA, Levene's test was performed; the result ($F = 1.5$, $p > .05$ for FAT, $F = 0.65$, $p > .05$ for DFAT, $F = .27$, $p > .05$ for MAS and $F = .19$, $p > .05$ for MMS) of Levene's test for equality of variances specified that the assumption of the homogeneity of variances in the groups was satisfied. After these assumptions were satisfied, the ANCOVA test was conducted on dependent variables.

When controlling for FAT pre-test scores, a significant difference was found between the groups regarding fraction post-test scores ($F_{(1,67)} = 16.55$, $p < .001$). The post hoc test results indicated that this difference favored the experimental group over the control group. The effect size, a standard measure for determining the magnitude and direction of the observed difference, was calculated to be .21. According to Cohen (1988), a value greater than .14 represents a large effect.

Similarly, controlling for pre-test FAT scores revealed a significant difference in DFAT scores between the groups $F_{(1,67)} = 30.31$, $p < .001$). Post hoc test results showed that the experimental group outperformed the control group. The effect size was calculated as .32, which Cohen (1988) categorizes as a large effect as it exceeds 0.14.

Controlling for pre-test MAS scores also showed a significant difference in post-test problem scores between the groups ($F_{(1,67)} = 8.77$, $p < .001$). According to the post hoc test results, this difference favored the experimental group. The effect size for this comparison was .13. As per Cohen (1988), this value, being less than 0.14, indicates a medium effect.

Lastly, when pretest MMS scores were controlled, a significant difference in post-test problem scores was observed between the groups ($F_{(1,67)} = 8.18$, $p < .001$). The post hoc test results revealed that the experimental group performed better than the control group. The effect size was calculated as .12, which Cohen (1988) classifies as a medium effect, since it is below .14.

4.3. Views of Students Regarding the Intervention

To address the second research question, "What are the opinions of the students in the experimental group about the intervention?" Six interview questions were posed to eight students, and the interviews were conducted and recorded via Zoom. During data analysis, the students in the experimental study group were coded as S1, S2...S8. In this section, the answers to the research question were coded, emphasizing the important points in the collected data, and themes were identified. The theme emphasizes the most important point about the research question in the data and includes answers and meanings that form a pattern related to the research question (Braun & Clarke, 2019). The answers given by the students to the interview questions were collected within the framework of the students' 4 themes: enhanced comprehension and engagement through worked examples, cognitive gains through diverse problem-solving approaches, evaluation of the Nearpod application, and desire to use the method in other topics.

4.3.1. Enhanced comprehension and engagement through worked examples

Most (S1, S2, S3, S4, S5, S6, S8) indicated that the study involving worked-out examples helped them understand and reinforce the subject matter better. They generally found the study to be beneficial. The Nearpod application was also considered fun and valuable by the students (S1, S2, S7). They appreciated the advantages of solving problems in a digital environment and the ability to review lessons at their convenience. Although a few students experienced technical issues with Nearpod, overall, they found it productive and supportive. One student remarked, "I liked it very much because it supported the topic and made me understand something better at the same time." Another stated, "I understood and reinforced the topic better with the examples provided."

4.3.2. Cognitive gains through diverse problem-solving approaches

Students mentioned that seeing worked-out examples, including different solutions, helped them understand the topic better and learn different solution methods (S1, S2, S3, S4, S5, S6, S7). Although the variety of solutions initially caused some confusion for a few students, overall, it contributed to learning the topic more quickly and effectively. This method also helped improve students' problem-solving skills. For example, one student said, "Seeing different solution methods can be confusing at first, but eventually, I learn the topic better." Another student explained:

> When I was learning the subject, for example, when I was solving questions by myself at home, I really did not understand it at all. But when I saw examples with solutions and knew the solutions, when I learned how to do it, it helped me both positively and to understand that subject faster and to focus on that subject.

Other students expressed similar views, such as "This method enabled me to solve problems faster and more effectively." and "I mean, for example, if we cannot do one, we can try the other. If we cannot do that one, we can try the other one, so it is easier by doing more than one. We are more likely to do it."

4.3.3. Evaluation of the Nearpod application

Students generally found the Nearpod application efficient and helpful (S1, S2, S3, S4, S5, S6, S7). They noted that it was both enjoyable and a significant advantage to have access to the lesson material at any time. Working through Nearpod helped students understand and reinforce the topic better. However, a few students mentioned experiencing technical issues that sometimes caused confusion. Overall, their comments reflect a positive attitude toward the digital platform and highlight its role in supporting learning in an engaging way. One student simply stated, "The Nearpod application was efficient and useful." Another elaborated on its benefits:

> Teacher, for example, you are sending links from things, that is, about Nearpod. Teacher, when I went there, I mean, the examples were very good for me. When I was studying, for example, I was learning from there as if I wrote in a notebook. I think it was a very good application." A third student added, "Teacher, I think Nearpod is a good application. You send questions. We can solve the questions by drawing, that is, by drawing or something, teacher. We can look at whether we got it right or wrong, teacher. A nice application.

Finally, a student emphasized the accessibility of the content by saying, "The application was fun, and having access to the lesson material anytime was a great advantage."

Nonetheless, one student expressed some confusion, especially when first encountering the Nearpod-based activities:

> Umm, the fourth question was about Nearpod… I thought it was good, but it confused me. I was already struggling a bit with fractions. As I said, I was confused by the methods at first. But after thinking about it more, I was able to figure out both Nearpod and the fractions.

This feedback highlights the importance of scaffolding when introducing new digital tools alongside instructional strategies, particularly for students who may already be struggling with the content.

4.3.4. Desire to use the method in other topics

All students expressed a desire to use this method in other mathematics topics as well. They stated that the method helped them understand and retain the topics better, emphasizing the importance of solving problems using different solution methods. Students believe that if this study is applied to other topics, their overall understanding and success in mathematics would increase. This collective preference suggests that students not only found the method effective for the current topic but also saw its potential to enhance their learning across various mathematical domains. One student simply stated, "I would like to use this method in other mathematics topics as well." Another elaborated:

> I would like it because showing a topic with examples with a solution and then explaining the solution really helps us both to understand the topic better and to learn the topic. For this reason, I would like it to be used.

Similarly, another student emphasized the impact on broader performance:

> I would like it, teacher, because it would increase our rate of doing it in other subjects as well as in this subject. I mean, if we can't do one, we don't have the rate of doing something else in other things, but if there were, we could do it again from a few methods.

This feedback highlights students' perception of the method as a transferable learning strategy that could contribute positively to their long-term academic success in mathematics.

5. Discussion and Conclusion

This study examined the effect of using worked examples with different solution methods via the Web 2.0 tool Nearpod on the achievement of fifth-grade students in the topic of fractions. When controlling for the pre-test scores of the FAT, a significant difference was found between the groups, favoring the experimental group. The high effect size further indicates that the applied program was effective for the experimental group students, which aligns with findings from recent research. Recent research has consistently demonstrated that worked-out examples are practical instructional tools for enhancing students' learning and understanding of mathematical concepts. Their use, particularly when combined with strategies such as self-explanation prompts, has been shown to improve conceptual understanding and support deeper learning. These findings highlight the importance of incorporating worked-out examples into instructional designs to enhance student achievement (Barbieri et al., 2023). The results of the current study align with Dienes' theories, demonstrating that when students were exposed to different solution methods through the Nearpod application, they were able to engage in more flexible thinking and conceptualize fractions more effectively. For instance, students reported that if they could not recall one solution method, they could use another, supporting the idea that multiple representations help bridge the gap between concrete and abstract understanding. Among the eight students interviewed, only one expressed initial confusion but eventually achieved clarity, reflecting Dienes' progression from concrete experiences to abstract concepts. Moreover, several students expressed a desire to see this approach applied to other subjects, suggesting that the use of multiple representations and varied instructional methods enhances their ability to abstract and generalize mathematical ideas.

The process of comparing multiple solution methods, as highlighted by Rittle-Johnson and Star (2007), aligns closely with the findings of this study, where students in the experimental group were exposed to different solution strategies through Nearpod. Similar to Rittle-Johnson and Star's findings, the students in this study reported enhanced understanding and problem-solving flexibility when presented with multiple worked-out examples. In particular, students found the opportunity to compare various methods beneficial in terms of reinforcing their comprehension and boosting their confidence in applying different approaches to new problems. This suggests that the use of comparison-based instructional strategies can foster more profound procedural knowledge and greater adaptability in mathematical problem-solving.

This idea is further supported by Yılmaz and Köse (2015), who argue that mathematical problems solvable in multiple ways enhance students' questioning, reasoning, research skills, and their ability to articulate their thoughts. Their findings are closely related to Dienes' principles, particularly those of multiple embodiment and perceptual variability, which emphasize presenting mathematical concepts in various forms to facilitate deeper conceptual understanding and abstraction. Since there is limited research specifically exploring the integration of multiple solution methods within worked examples through Web 2.0 tools like Nearpod, it is necessary to turn to the broader literature on worked examples. Research in this field has consistently demonstrated that presenting questions alongside their worked-out solutions enhances learning by reducing cognitive load, guiding students through complex problem-solving processes, and promoting greater retention and transfer of knowledge (e.g., Retnowati et al., 2010; Van Loon & Hillen, 2012). Therefore, the findings of this study build upon and extend the existing literature on worked examples by introducing a novel approach that integrates technology and multiple solution methods to support student learning further.

Research on the integration of Web 2.0 tools in educational contexts, such as that by İltüzer (2016) and Lee (2013), indicates that online platforms featuring self-explanatory worked-out examples produce significant positive effects for experimental groups, which is consistent with the current study's findings. Similarly, Meşe (2012) concluded that software enhanced with audio-supported worked-out examples led to substantial gains in students' academic achievement and learning experiences, further corroborating these results. In line with these studies, Uysal (2020) investigated the impact of Powtoon, another Web 2.0 tool, on the academic achievement, basic skills, attitudes, and motivation of fourth-grade students in a science class, finding that the video-assisted approach significantly improved academic performance. Uysal's findings, both methodologically and substantively, align with the results of this study, suggesting that the Nearpod application has the potential to uniquely influence academic achievement, a possibility that merits further exploration in the literature.

The results of the student interviews further bolster these findings. All eight interviewed students reported that the Nearpod application was practical, memorable, and contributed to their understanding of the subject. Additionally, seven students emphasized the ease of access, noting that the application facilitated their learning by allowing them to engage with the material at their convenience. These observations mirror the findings of Putra et al. (2021), who also found that Nearpod enhanced accessibility and ease of learning. Furthermore, students in this study highlighted that worked-out examples featuring multiple solution methods positively impacted their comprehension, reinforcing the study's quantitative results. Similarly, the work of Sanmugan et al. (2019) on promoting student interaction in online environments through Nearpod aligns with these findings. Their research demonstrated that Nearpod increased student participation, particularly in crowded classrooms, improved opportunities for monitoring progress, and created a meaningful learning experience, which resonates with the outcomes of this study.

Examining the use of worked-out examples with different solution methods through the Nearpod application revealed a significant improvement in the mathematics attitudes and motivation of the experimental group compared to the control group after controlling for pre-test scores. When we examine the effect value, which is a standard measurement, it indicates medium effectiveness. From this effect. It can be stated that explaining worked-out examples with different solutions through the Nearpod application has a positive impact on students' mathematics motivation and attitude. At the same time, the results of the interviews with the students support this finding. Interviews with the students showed that the use of various solution methods was memorable, fostering mathematical thinking from different perspectives. Similarly, Abdrafikova and Ulianova (2014) that the application significantly increased student motivation. Their findings suggest that integrating Web 2.0 tools into lessons has a positive impact on student engagement, further supporting the findings of this study. Their findings suggest that integrating Web 2.0 tools into lessons has a positive impact on student engagement, aligning with the results of this study. Positive results of the studies conducting a Web-based education process (Arabacı, 2021; Barnes, 2018; Hossain & Quinn, 2012; Kartika, 2018; Kurt et al., 2019) support the findings of this study. In addition, Erduran et al. (2019) used Kahoot, a Web 2.0 tool, in their study, which is in line with the results of this study because it increased students' attitudes and motivation towards the course. When this study is analyzed in terms of qualitative dimension, most of the students liked the study. At the same time, the students stated that they found it more enjoyable to explain the solved examples with the Nearpod application, a Web 2.0 tool. On top of that, explaining the solutions of the worked-out examples in different ways with the Nearpod application was highly appreciated by the students. Putra et al. (2021) concluded that the use of the Nearpod application can increase students' participation in the online environment. Most students agreed that the Nearpod application has a fun feature. Sanmugam et al. (2019) found the Nearpod valuable application in their research because it increases student participation in crowded classrooms, allows students to monitor their progress, and provides a meaningful learning environment. Arabacı (2021) stated in his research that it had a positive impact on students' attitudes and motivation. Tatlı et al. (2016) stated that pre-service teachers liked the Web 2.0 tools they used in their research and were considering using them in their professional lives. The above studies support this research in terms of their findings. Specifically, this study is supported by the research of Hussein et al. (2024), which emphasizes that student self-efficacy and attitude influence the use of learning management systems and their effectiveness. This suggests that, even though positive attitudes exist, individual factors such as self-efficacy may still mediate the effectiveness with which such technologies are utilized in educational contexts.

The study's findings suggest several practical implications. First, integrating worked-out examples with multiple solution methods through digital tools such as Nearpod can be an effective strategy to enhance student engagement, motivation, and achievement in mathematics. Educators should consider incorporating diverse solution methods in their teaching practices to promote flexible thinking and deeper conceptual understanding. The application of Web 2.0 tools can provide an interactive and accessible learning environment that encourages active participation, as seen in studies by Arabacı (2021) and Tatlı et al. (2016), where pre-service teachers appreciated the benefits of these tools. However, the guidance role of teachers is critical for the effective implementation of such digital tools. In particular, providing more concrete instructions to teachers about integrating different solution strategies into classroom digital environments can increase the efficiency of implementation. By addressing the challenges teachers face in this process, future research can develop practical guidelines to improve the applicability of technology-enhanced teaching methods. In this context, designing professional development programs that teach teachers how to use digital tools pedagogically more effectively may support the more widespread and effective adoption of multi-solution strategies in educational settings. A recent study from the Irbid region significantly highlighted two major challenges in educational digital transformation: teacher burnout and the integration of technology. Findings revealed high emotional exhaustion among teachers and lower confidence in managing digital platforms and technical issues, despite adequate basic tech skills. Teachers showed cautious optimism toward AI in grading, administration, and personalized learning. The study emphasizes the importance of developing localized strategies that prioritize teacher well-being and support the context-appropriate use of AI in education (Beirat et al., 2025).

Although cognitive load types were not directly measured in this study, the effectiveness of the instructional design suggests that the intervention may have contributed to the optimization of cognitive resources. Specifically, the structured use of worked-out examples and digital tools likely helped reduce extraneous load and support germane load, thereby facilitating deeper learning. While this remains a theoretical assumption based on the learning outcomes, future studies could incorporate validated cognitive load measurement tools to empirically examine how instructional design influences intrinsic, extraneous, and germane cognitive load. This would provide a more comprehensive understanding of the mechanisms underlying the effectiveness of such interventions.

However, this study has several limitations. The sample size was relatively small and confined to a single grade level and subject area, which limits the generalizability of the findings. Future studies should address this limitation by increasing the sample size, incorporating multiple grade levels, and exploring a wider range of mathematical topics to determine whether the observed benefits hold across diverse educational contexts. Moreover, while the effect size was medium, further research is needed to explore the long-term impact of these interventions and whether the observed effects are sustained over time. Expanding the scope of future research in these ways would enhance the validity and applicability of the findings, providing more robust evidence for the effectiveness of the intervention across various learning environments.

Additionally, future research could investigate the potential impact of integrating Web 2.0 tools with higher-level mathematics topics or with students of varying cognitive abilities to determine the broader applicability of these methods. Studies could also focus on whether digital tools create a novelty effect that might diminish over time, affecting student motivation and engagement. Furthermore, the long-term effects of combining worked-out examples with these tools on improving problem-solving skills could also be explored. However, the lack of equal access for all students can make it difficult for them to use digital tools effectively, potentially leaving some students behind in the learning process. This can be particularly pronounced for students living in low-income or rural areas. Understanding the effects of the digital divide is a crucial step in accurately assessing the effectiveness of digital tools in teaching. In addition to student access, teacher-related factors also play a crucial role in the integration of educational technologies. A recent study conducted with high school teachers in Riyadh, Saudi Arabia, found that while teachers acknowledged the high importance of the Internet of Things in education, they also reported significant challenges in its implementation. Variables such as subject area, teaching experience, and technical training were found to influence these challenges, indicating that teachers with more training or in computer-related fields encountered fewer difficulties, whereas those with. In contrast, less experienced teachers were more open to using new technologies. Therefore, future research should consider both student access and teacher readiness to ensure the equitable and effective use of digital tools in education (Aloufi et al., 2024).

Author note: This study is part of the first author's master's thesis.

Data availability: The datasets generated and analysed during the current study are not publicly available due to privacy but may be available from the corresponding author upon reasonable request.

Declaration of interest: The authors declare no conflict in interests.

Ethical statement: Ethical approval was obtained from the Istanbul Medeniyet University Ethics Review Authority on 4 October 2021 (2021/10-08). All participants were informed, and consent was obtained.

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