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ISSN: 2148-9378



Teaching Mathematics through Micro-Learning in the Context of Conceptual and Procedural Knowledge*

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ARTICLE INFO

Article History

Received 08.08.2022

Received in revised form
25.09.2022

Accepted 16.10.2022

Article Type: Research
Article

ABSTRACT

In light of technological development worldwide, the focus has been on how different types of digital technology can be used to provide activities that will enhance students' mathematical learning. Micro-learning is an innovative approach that will accelerate digitalization in mathematics teaching, attract students to mathematics, and combine technology and mathematics education. The study aims to reveal the effect of micro-learning teaching of the middle school 6th-grade mathematics lesson "Ratio" on students' conceptual and procedural knowledge. In the study carried out within the scope of qualitative research, the case study research design was preferred. In the study group, ten students studying in the 6th grade of middle school were studied. In the research, the conceptual and procedural knowledge definitions of the "Ratio" subject created by the researchers were created by reviewing the literature, and the status of the interview was examined based on the data obtained at the end of the study. During the data collection phase of the research, the Conceptual and Procedural Knowledge Test (CPKT) developed by the researchers and interviews with two students were used. The collected data was analyzed by content analysis. After the micro-learning teaching in the e-learning environment, it was seen that there was a 76% success rate in the procedural knowledge of the students, in which they generally acquired the conceptual knowledge of the "Ratio" subject. Thus, it has been demonstrated that micro-learning can be used in mathematics lessons.

Keywords:

Conceptual and procedural knowledge, e-learning, micro-learning, ratio

1. Introduction

Teaching math with digital technology is now an integral part of classroom practice in many classrooms worldwide. Digital technologies can improve mathematical knowledge and understanding and change school mathematics content (Heid, 2005; Olive et al., 2009). The range of available digital technologies has expanded significantly in the last two decades, and their power has increased dramatically (Clark-Wilson, Robutti, & Thomas, 2020). In light of these changes, the focus has been on how different types of digital technology can be used to create activities that will improve students' mathematical learning (Clark-Wilson, Robutti, & Sinclair, 2014). The use of technology in mathematics teaching has become a necessity for our age (Çevikbaş & Kaiser, 2020). According to the National Council of Teachers of Mathematics (NCTM), the existence, versatile use, and power of technology made it possible and required students to reconsider how they should learn mathematics and how they learn mathematics best (NCTM, 2000). The fact that students can access the internet whenever and wherever they want in their daily lives has made learning technology integrated into

*Part of this study was presented as an oral presentation at the 4th Global Education and Research Conference (GLOCER 2021) held in Florida, USA, between 8-10 June 2021.

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Citation: Gün-Şahin, Z. & Kırılmazgöl, G. (2023). Teaching mathematics through micro-learning in the context of conceptual and procedural knowledge. *International Journal of Psychology and Educational Studies*, 10(1), 241-260. <https://dx.doi.org/10.52380/ijpes.2023.10.1.1009>

the internet important (Hwang et al., 2008), so microlearning emerges as an ideal teaching technique for 21st-century learners. Micro-learning is an innovative approach that will accelerate digitalization in mathematics teaching, attract students to mathematics, and combine technology and mathematics education. Micro-learning is a new and effective approach. For this reason, studies on this subject are considered valuable, and new studies are needed.

1.1. Micro Learning

Micro-learning is a new learning area in e-learning environments that aims to discover new ways of learning and emerges from the need for lifelong learning (Job & Ogalo, 2012). Micro-learning arising from micro-content is a new concept that refers to the way information conveys small bits of digital information in concise, condensed small groups, so to speak, "pill information" (Bradley Mitchell, 2020). In micro-learning, which facilitates the learning process by breaking the concepts into small pieces, learning pieces are given to students gradually and appropriately (Mohammed et al., 2018). It is carried out with small learning content and personalized, flexible technologies that enable students to access information more efficiently at certain moments, such as during breaks or on the go. It is usually a single issue, limited in length, consuming fast and sharing resources, often limited to software or devices. Microlearning concepts provide the adaptable and dynamic alternatives required in times of media, social, and environmental change (Job & Ogalo, 2012). Although there are many definitions of microlearning, none of them has been accepted as a standard definition. Hug's definition of microlearning based on seven dimensions is perhaps the most widely accepted (Hug, 2006).

- Time: relatively short effort, operating cost, short time expenditure, subjective time, etc.
- Content: minimal parts, narrow topics, relatively simple points, etc.
- Curriculum: fragmentary curricula, module fragments, informal learning items, etc.
- Structure: parts, sections, chapters, "knowledge snippets," skill elements, etc.
- Process: discrete, interconnected or actual, situational or integrated activities, iterative method, attention management, awareness, etc.
- Media: face-to-face, electronic media, single versus multi-media, information goals or learning goals, symbolic value, etc.
- Learning Styles: iterative, action-based, reflective, utilitarian, conceptual, constructivist, connectionist, behaviorist, learning by example, task or activity, goal or problem-based, action learning, classroom learning, cohesive learning, conscious or unconscious, etc.

The seven dimensions stated by Hug constitute the framework of microlearning. Lin et al. (2020), showed the micro-content preparation step as in Figure 1.

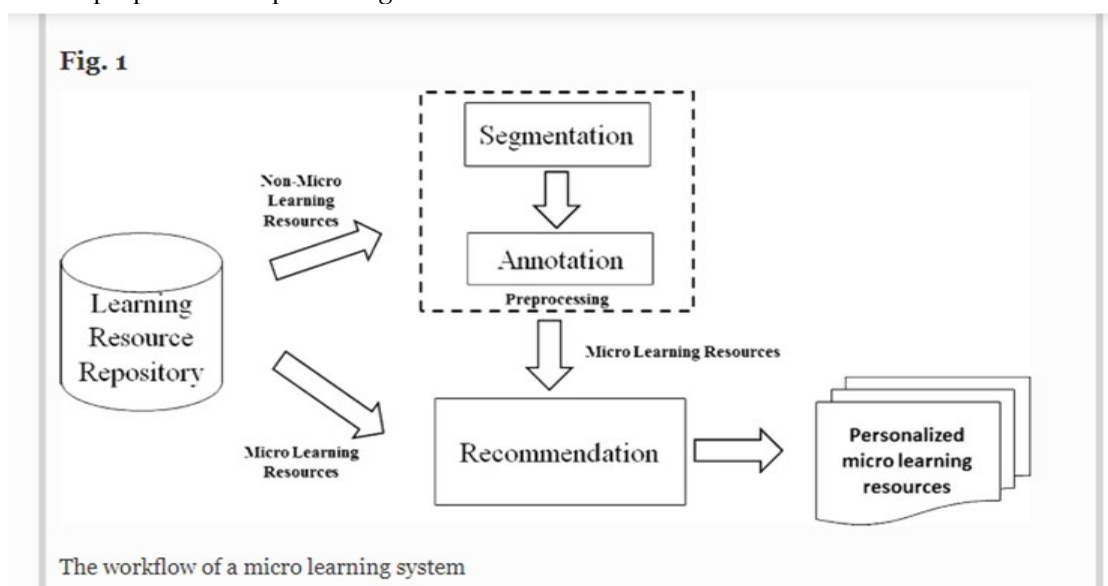


Figure 1. Micro-content Preparation Process (Lin et al., 2020).

As seen in Figure 1, while preparing micro content, it is checked whether it is suitable for micro-learning. If the content is not suitable for micro learning, it is divided into small and independent micro content that is

meaningful. A description is then added for each item. After the preprocessing is over, the content becomes available and can be used as a micro-learning resource.

The key benefits of microlearning:

- Increases student participation (Nikou, 2019)
- Enables the concepts to be kept in mind better (Giurgiu, 2017)
- Microlearning involves narrow and straightforward topics (Jomah et al., 2016)
- Provides the opportunity for repetition (Grovo, 2015)
- Micro-contents are attractive because they are also handled individually (Jomah et al., 2016)
- Increases students' motivation (Nikou & Economdies, 2018)
- Improves learning performance (Mohammad et al., 2018)
- Involves collaborative learning (Reinhardt & Elwood, 2019)

Micro-learning based on mobile web learning offers a modernized educational environment (Jomah et al., 2016). With micro-contents, the only relevant information is conveyed with the help of visual, interactive, and concise elements, thus facilitating the educational process (Redondo et al., 2021). It is thought that micro-learning can be an effective teaching method in mathematics teaching for e-learning environments, whose importance has increased even more during the epidemic process that has affected the world. In parallel with the research, it is emphasized that learning environments supported by mobile devices, as in microlearning, can enrich the learning processes of students and teachers, and Web 2. tools can be used effectively (Karaduman, 2018). In the content development study they designed for micro-learning, Park and Kim (2018) stated that digital tools should be simplified and widely used to develop content.

The effect of microlearning, which can be carried out anytime, anywhere, on the formation of mathematical conceptual and procedural knowledge, thanks to smartphones, tablets, and laptops, was found to be worth investigating. In the study, the subject of "ratio" from the 6th-grade mathematics curriculum was discussed. While microlearning, posters, digital boards, lecture videos, animations, quizzes, interactive presentations, short storytelling videos, photographs, and mind maps were used, many of which researchers prepared, many of which were prepared. These course tools are designed or selected by the micro-learning content.

1.2. Conceptual and Procedural Knowledge

Mathematical competence is based on the development of both conceptual and procedural knowledge. While there is some variability in how these constructs are defined and measured, there is a general consensus that the relationships between conceptual and procedural knowledge are often bidirectional and iterative (Rittle-Johnson & Schneider, 2015). Hiebert and Lefevre (1986), conceptual and procedural knowledge as a network of interconnected knowledge of mathematical concepts and mathematical symbols, formulas, algorithms, and operations.

- Conceptual knowledge refers to facts, meanings, structures, ideas, principles, laws, formulas, and concepts related to mathematical subjects.
- Procedural knowledge refers to how to use mathematical procedures, languages, and symbols, and to interpret and draw graphs and tables.

Having conceptual knowledge means knowing about definitions, formulas, and operations and being able to justify what has been done (Zuya, 2017). For example, the denominator of the unit fraction gives the number of parts of that size that make up the whole. Equally dividing (sharing) a whole into more parts causes each part to be more minor. Therefore, the larger the denominator, the smaller the unit fraction should be. This information given with justification is conceptual knowledge (Simon, 2017). Being able to associate a subject with daily life has also been accepted as a sign of conceptual knowledge (Karakoç, 2012), and it is known that this association makes the subject more permanent (Balgalmış & Ceyhan, 2019). However, when we look at the studies, it is seen that the answers given by the students at the stage of associating mathematics with daily life are similar (Baki et al., 2009; Kurtuluş Kayan, 2019). On the other hand, procedural knowledge is defined by Rittle-Johnson and Schneider (2015) algorithms as a predetermined sequence of actions that, when executed correctly, leads to the correct answer. Thus, procedural knowledge in mathematics can be constructed through specified operations to get a correct answer. If a step is performed incorrectly, there will be no answer. For

example, performing four operations in fractions and solving a given fraction problem is operational knowledge.

Conceptual and procedural knowledge are necessary structures for mathematical competence (Baroody et al., 2007). According to the standard view among researchers, increases in one conceptual or procedural knowledge lead to increases in the other (Kadijevich, 2018), and conceptual and procedural knowledge are mutually interdependent (Rittle-Johnson & Schneider, 2015). Therefore, both types of knowledge should be given importance for effective and meaningful mathematics education (Özyıldırım Gümüş & Umay, 2017). In the study, conceptual and procedural knowledge on the subject of "ratio" is discussed. The concept of ratio (Hohmann, 1991), which is closely related to the part-whole concepts, is widely used in mathematics, science, and daily life (Karplus, Pulos, & Sahne, 1983) The essential factor in choosing the ratio in the study is that it finds many uses in mathematics and other science and social studies courses. The concept of ratio is essential knowledge for many subjects. Most of the middle school mathematics curriculum content, such as fractions, percentages, probability, similarity, movement problems, and measurement, is directly or indirectly related to the concept of ratio. Similarly, the ratio describes various phenomena such as velocity, acceleration, force, and gravitational force in physics and specific gravity and density in chemistry. (Yakar, 2020; Abrantes, Serrazina & Oliveira, 1999; Post, Behr & Lesh, 1988). It is also suitable for the micro-learning method since the ratio subject does not have a complex structure.

In the studies, the first misconception of the students about the concept of ratio is that they think the ratio is the actual amount and act accordingly. It is seen that the students could not comprehend the ratio as a comparison or a fraction meaning in the given questions, and they thought of the ratio as an actual amount and acted accordingly. The second is the mistakes made in creating the concept of ratio. It was observed that the students found the numbers in the ratio separately but did not establish a ratio. The third is the misconceptions arising from readiness levels. For example, it is difficult for students who do not thoroughly learn about fractions to understand the subject of ratio (Bingölbali & Özmantar, 2009; Kaplan & Konyalıoğlu, 2002; Kaplan, İşlenen & Öztürk, 2011). The conceptual and procedural knowledge definition of the subject is given in Table 1.

Table 1. Description of the Conceptual and Procedural Knowledge of the Ratio Subject

Category	Describing
Conceptual knowledge	Understanding ratio concepts and rules; connecting ratio concepts to daily life; understanding the principles of setting ratios and solving ratio questions
Procedural knowledge	Knowledge of definitions of terms, formulas, and operations to solve ratio questions. Knowledge of notations, representations, and algorithms. Formula to solve different ratio questions.

In the study in which the effect of teaching the ratio subject through microlearning on the conceptual and procedural knowledge of the subject was examined, the researchers created the literature review. They presented the conceptual and procedural knowledge definitions of the subject in Table 1. This table was created as a result of a literature review. The definitions in the table are considered the conceptual and procedural knowledge symptoms sought in students. Thus, the Z generation, whose multitasking skills are pretty high and their patience thresholds are pretty low:

- Since they prefer to access fewer but valuable information sources in a shorter time (Erden, 2017),
- Since they make good use of unlimited access to information (Maioli, 2016),
- Since their attention can be distracted in a short time and therefore, communicating with a goal by giving simple messages yields more effective results (Törocsik, Szucs & Kehl, 2014),
- Since they are the first generation born in the digital world (Erden,2017),

It is thought that micro-learning may be one of the most suitable learning styles for them. The effect of micro-learning on the conceptual and procedural knowledge required for mathematical proficiency has been found to be worth investigating. In this context, the study aims to reveal the effect of micro-learning teaching of the middle school 6th-grade mathematics lesson "Ratio" on students' conceptual and procedural knowledge.

2. Methodology

2.1. Design of Research

In the study carried out within the scope of qualitative research, the unique case study research design, which is suitable for the qualitative research methodology, was preferred. The main objective of particular case study research is to determine the experiences, opinions, or thoughts of all participants about a particular situation and present the data obtained in a versatile and profound way in the context of the current situation (Creswell, 2017). Furthermore, especially in studies conducted with small participant groups, it is essential to provide a detailed examination opportunity and be economical in terms of time (Özden & Durdu, 2016). In this direction, the situation discussed and emphasized in the research is teaching the ratio subject in the 6th-grade mathematics course in the e-learning environment by supporting it with microlearning and its effect on conceptual and procedural learning in students.

2.2. Participants

The study participants consisted of 10 sixth-grade students studying in a middle school in a province of the Eastern Anatolian region of Turkey and determined by the convenient sampling technique, one of the purposive sampling methods. The reason for choosing the 6th-grade level and using purposeful sampling in the current study is that there are no students with constant absenteeism at this grade level; each student has a smartphone or tablet and sufficient internet access. In this direction, the research was carried out in the second term of the 2020-2021 academic year with the determined participant group.

Nicknames were used for the participants. The distribution of the participants according to gender, academic achievement, and class variables is given in Table 2, with frequency (f) values as follows.

Table 2. *Distribution of Participants by Gender, Academic Achievement, and Class Variables*

Student's name*	Gender (F: Female; M: Male)	Academic Achievement Status
Musab	M	Middle
Mustafa	M	Good
Batuhan	M	Low
Kaan	M	Low
Fatma	F	Low
Hilal	F	Good
Ayşe	F	Middle
Mert	M	Good
İrem	F	Good
Hülya	F	Good

* Nickname

Table 2 shows that five of the ten students are female and five are male. According to their academic achievement, students were classified as low (f=3), medium (f=2), and good (f=5) according to their mathematics achievement scores compared to the period before the study started. According to the mathematics scores of the previous semester, students between 0-45 were considered low, students between 45-70 were considered good, and students between 70-100 were considered very good. In this direction, the participants were included in the research in a heterogeneous way, and each of them was at the sixth-grade level.

2.3. Data Collection Tool

The ratio subject is a sub-learning area in the number and operations learning area at the 6th grade level of middle school. It was determined that the students did not have any information about the ratio on the pre-test before the study. The achievements within the scope of the ratio sub-learning area are as follows:

- Uses ratio to compare multiplicities and represents ratios in different ways.
- In cases where a whole is divided into two parts, it determines the ratio of the two parts to each other or of each part to the whole; in problem situations, when one of the ratios is given, it finds the other.
- Determines the ratio of two multiplicities in the same or different units to each other.

In terms of these features, the topic "Ratio" was chosen considering that it can be easily and quickly integrated into micro-learning. This may be because the ratio of subjects is short compared to other subjects and achievements in the context of 6th-grade learning outcomes. In addition, the "ratio issue" is a priority among mathematics subjects because it is also effective in teaching other subjects such as fractions, percentages, and similarities (Duatepe et al., 2005).

2.3.1. Test of conceptual and procedural knowledge

In this context, a Ratio Conceptual and Procedural Knowledge Test (RCPKT) consisting of 22 questions was used to obtain the data in the study. First of all, the questions in the test were created in the context of "learning objectives" in the Ministry of National Education to ensure the subject framework and integrity. Secondly, during the development of the data collection tool, the relevant literature was reviewed. Finally, a draft 21-question test was created and presented for the opinion of an academician who is an expert in mathematics education and a mathematics teacher to ensure content validity and internal validity. The final version of the 22-question test was completed by making the necessary arrangements in accordance with the advice of an experienced Turkish teacher.

While creating questions for procedural knowledge, problems familiar to children were taken into consideration. Because when measuring procedural knowledge, it is often asked to solve a given problem, and the accuracy of the operation result is checked. The questions prepared to measure conceptual knowledge were formed by determining the concepts within the scope of the subject. While measuring conceptual knowledge, the questions are usually formed as the individual defines and explains the related concept (Rittle-Johnson & Schneider, 2015). However, no attempt was made to measure conceptual knowledge based on definitions alone because the more conceptual knowledge is measured, the stronger the results (Schneider & Stern, 2010). For this reason, in addition to the interviews with the students and the answers to the questions they solved, the definitions of concept knowledge stated in Table 1 were examined.

2.3.2. Interviews

Interviews were conducted to obtain sufficient data on conceptual knowledge and reveal the effects of microlearning in the teaching process. In the study, two students were interviewed, and saturation was achieved. The interviews with randomly chosen Hülya and Hilal lasted about half an hour. In the interviews, questions were asked based on the answers given by the students to the RCPKTs. For example, "Can you tell us how you solved this question?" or "Can you explain this answer a little bit?" "What effect did the teaching have?" etc. questions were asked.

2.4. Data Collection and Implementation Process

Within the scope of the research, the subject of ratio in the middle school 6th-grade mathematics lesson was supported by micro-learning activities. In the data collection process, first, communication was established with the parents of the students, necessary interviews were conducted; and information was given about the research. In this context, parents, voluntary participation forms were signed before participating in the research, and the necessary permission was obtained. The research was carried out in the 2020-2021 academic year, and the instruction lasted for three weeks. First of all, students were given brief information about micro-learning and Web 2.0 tools, and the interface and usage information of all tools were shown to students on smart boards. The following Web 2.0 tools and content are preferred in the research and where digital contents are prepared:

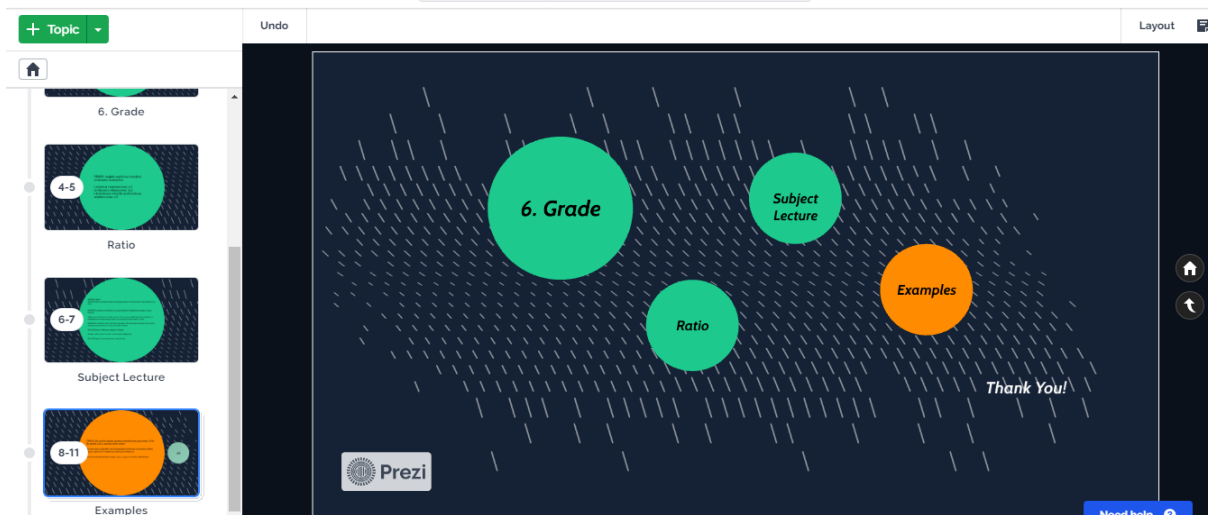


Figure 2. *The subject of Ratio Prezi: Interactive Presentation and video*

As shown in Figure 2, interactive videos were prepared with Prezi for a duration ranging from 3 minutes to 5 minutes. The content of the videos includes essential information and sample questions on the subject. In addition, from the beginning to the end of the application, separate presentations were prepared each week to ensure learning.

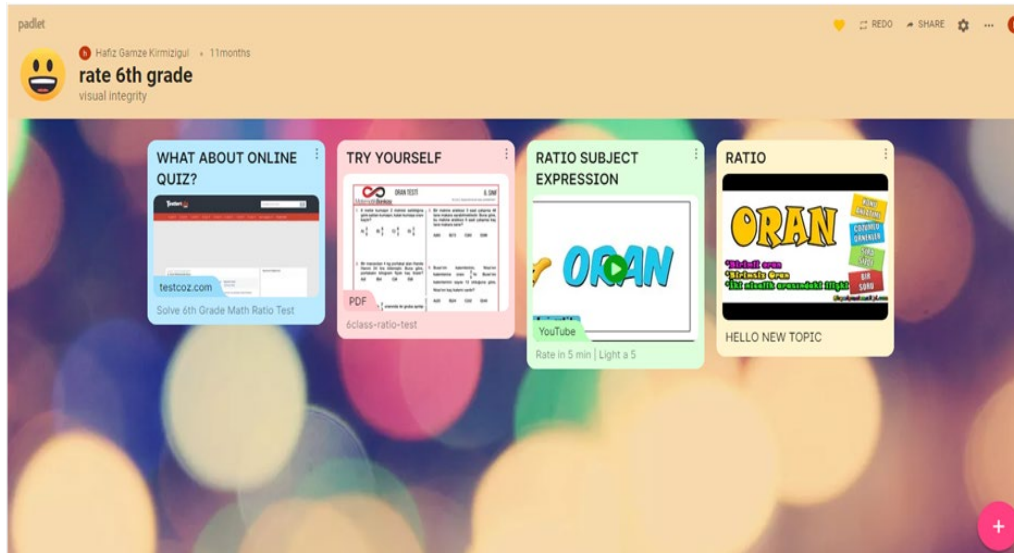


Figure 3. *Ratio Subject Digital Panel Padlet: Digital Board Full of Events*

As seen in Figure 3, the researchers prepared digital boards full of activities with Padlet. In addition, they prepared lecture videos separately for each week from the beginning of the instruction to the end by updating the content consisting of quizzes and sample questions. The content of the videos includes basic information about the subject and questions with sample solutions. There are also online tests and quizzes to provide repetition and meaningful learning and reinforcement.

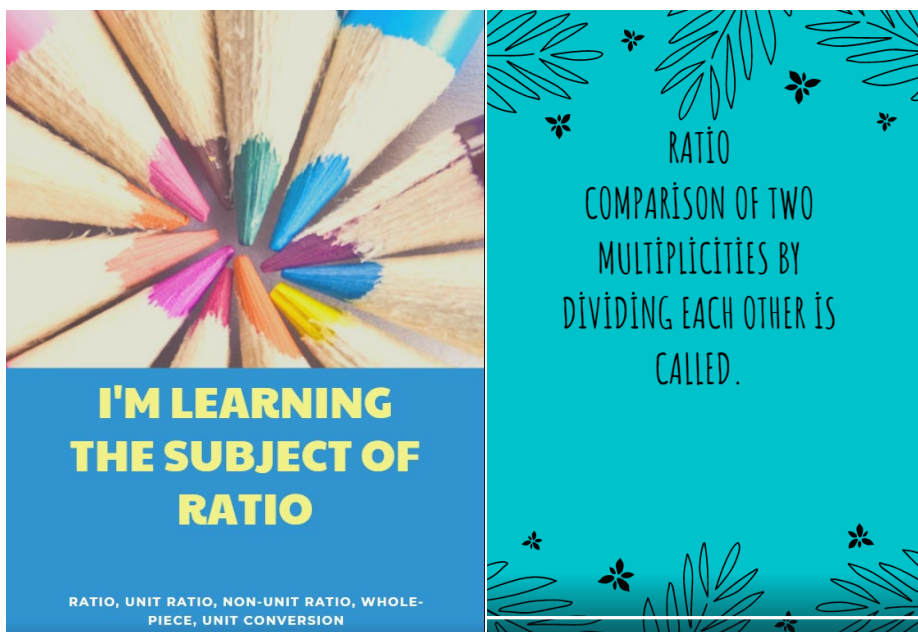


Figure 4. Ratio Subject with Animated Banners and Worksheets Canva: Animated Banners and Worksheets

As shown in Figure 4, animated and non-animated posters and logos were prepared with Canva, ranging from 1 page to 3 pages. The content of the pages includes basic knowledge, definitions, and formulas on the subject. In the literature review, the parts that the students had the most difficulty with were determined, and the digital contents were prepared accordingly. For example, in much digital content, it is explained that the ratio is a comparison where the actual amount is not, how the ratio is established, with an emphasis on fractions. These contents are given in a short, concise, and understandable way for micro-learning. With this aspect, it is aimed to facilitate students' learning. From the beginning to the end of the instruction, separate posters and logos are prepared each week, and it is aimed to make the learning permanent and reinforce it with visual repetition.



Figure 5. Ratio Mind Map Mindmeister: Mind Map

As seen in Figure 5, mind maps ranging from 1 to 3 pages were prepared with Mindmeister. In the content of mind maps, basic knowledge and definitions about the subject are included with a visual feast and integrity. Different mind maps were prepared from the beginning of the practice to the end, and knowledge and topics were presented with general integrity and a network of relationships, especially towards the end of each week.

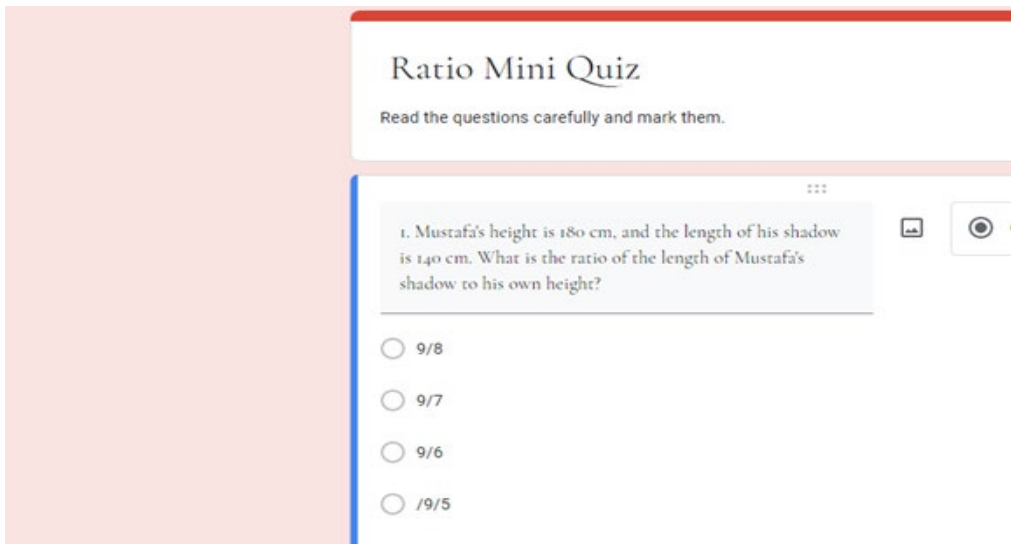


Figure 6. Mini Quizzes on Ratio Google Forms: Online Quizzes

As seen in Figure 6, quizzes with varying questions ranging from 5 to 10 were prepared with Google Forms. The content of each mini-quiz includes questions with basic knowledge about the subject. In addition, from the beginning to the end of the instruction, mini-quizzes were prepared each week separately, allowing the students to evaluate themselves at any time and place.

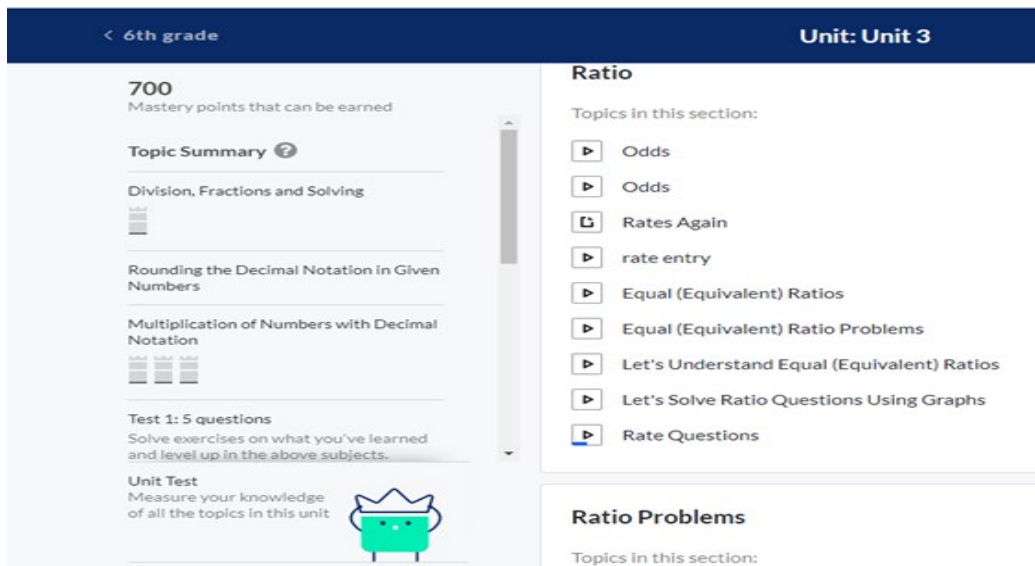


Figure 7. Learning and Working Videos in the Subject of RatioKhan Academytr: Lecture and Practice Videos

In the Khan Academy TR Web 2.0 tool shown in Figure 7, lecture videos range from 1 minute to 6 minutes. A video interior of Plum on the subject of basic knowledge and answering questions is located in particular. Every week, the students watched the videos, and the Khan Academy TR was instrumental in facilitating their learning on the subject.

The research was implemented in two stages. In the first stage, the subject of ratio was covered with micro-learning activities for three weeks. At this stage, a digital class was created in the Microsoft Teams application for the students, and each student was given a class code. Then, gradually, various digital contents were added to the classroom contents in a particular order. In addition, a WhatsApp group was established to ensure in-class communication, and students were informed about each stage and added content. From the beginning to the end of the subject, the content was arranged by considering the weekly order of learning objectives and the periods in the middle school mathematics curriculum. In this direction, students were given various tasks ranging from three to six minutes, which they could access whenever and wherever they wanted, regardless of time and place, following the learning objectives they learned about ratio and the subject headings.

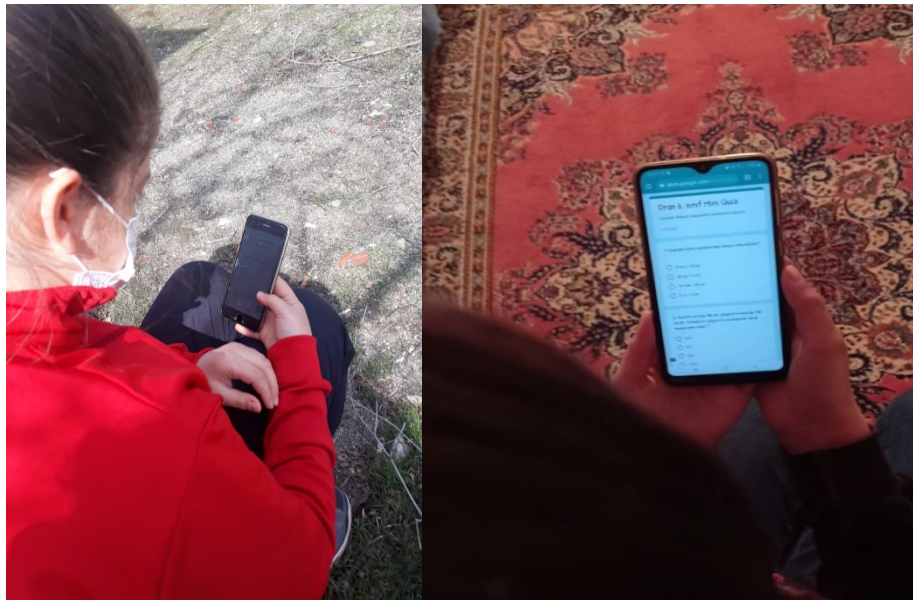


Figure 8. Students' Photos from *The Implication Process*

In particular, following a gradual process in parallel with the lessons, objectives such as teaching the subject, consolidation, repetition, evaluation of learning, and practice were taken as the basis. At the end of each learning objective, weekly quizzes created with Google forms were added to the digital board, and students were allowed to take online exams. In this respect, it has been ensured that they follow and do all the activities and add content from different Web 2.0 tools. All Web 2.0 tools were used with different content each week. Prezi, Khan Academy TR, and Canva were preferred at the beginning of the week, especially during the learning phase of the subject and for fundamental information. The Padlet digital board and Mindmeister mind maps were used to reinforce the subject and provide repetition. In particular, at the end of each week, Google Forms mini-quizzes took place to provide evaluation and feedback.

In the second stage, the Ratio Conceptual and Procedural Knowledge Test (PCPKT) was applied in line with the tasks and the learning objectives given to the students. Thus, it was tried to determine which outputs emerged in teaching the ratio subject, supported by micro-learning activities. In particular, two students were interviewed in order to reveal the signs of conceptual knowledge, and they were asked to explain their answers to RCPKT with their reasons. As a result, the study's data were collected and prepared for analysis.

2.5. Analysis of Data

Data analysis in qualitative research includes preparing and coding the data, reducing the codes to themes, and presenting the data in the form of figures, tables, or discussion in the final stage (Creswell, 2017). In this context, the data collected as part of the research were analyzed using the content analysis method. Content analysis is a method based on the interpretation and in-depth analysis of the collected data according to the determined themes. Thus, the aim is to analyze the data in an orderly and systematic way in line with the findings (Yıldırım & Şimşek, 2016). Content analysis is basically a technique used to make reproducible and valid inferences (Krippendorff, 2004). Within the scope of the current research, the content analysis method was preferred to classify and compare the data and thus to achieve conceptual and procedural results (Cohen, Manion, & Morrison, 2007).

Researchers have used many methods to measure conceptual or procedural knowledge. Rittle-Johnson and Schneider (2014) discussed the studies conducted to measure conceptual knowledge in the literature and examined the methods used in these studies. Rittle-Johnson and Schneider (2014) stated that implicit and explicit ways were used to measure conceptual knowledge due to the examination. For example, people with conceptual knowledge need to know which procedural procedure they do and why, which is an implicit way of revealing conceptual knowledge (Schneider & Stern 2010). The student's classical definition of the concept is an explicit way to reveal conceptual knowledge. Both explicit and implicit paths were used in the study. While analyzing the conceptual and procedural information data, the subject's conceptual and procedural knowledge definitions shown in Table 1 were taken as the basis, and content analysis was performed. Two

researchers did the analysis. During the analysis, the interview texts were read many times, evaluated by line-by-line reading technique, and created codes based on Table 1. While creating the codes, the data obtained from the relevant literature was taken into consideration. The status of the resulting codes according to the definitions in Table 1 was examined. With the help of the relevant literature, three concepts related to the subject were determined. There are three types of ratios: ratio, unit ratio, and unitless ratio. The process for measuring procedural knowledge is slightly easier than conceptual knowledge. In the study, the definitions in Table 1 were used to measure procedural knowledge. The categories, codes, and sub-codes obtained by content analysis are presented in Table 3. The categories, codes, and subcodes obtained by content analysis are presented in Table 3. The datasets collected in the study were analyzed and interpreted according to the categories and codes given below.

Table 3. Codes and Subcodes Obtained From Content Analysis

Category	Codes	Subcodes	Description
Conceptual Knowledge	Concept and understanding the rules	using different representations	Expressing the "ratio" symbol in different ways. Like " : , - , / "
		set and interpret ratios	To be able to set and interpret ratios correctly.
		not specifying the amount	The ratio given does not indicate the actual amount.
		distinguish	Differentiate between unit and non-unit ratios.
		classic of terms definition and interpretation	Expressing and interpreting the specified terms correctly
		equivalence	The value does not change if the given ratio is reduced or expanded.
		Connection with daily life (real life connection)	Being relevant to real / daily life Being related to real / daily life
Procedural Knowledge	Understanding of the principles of solving questions	Representations, notations, algorithm knowledge	Correct use of mathematical symbols and operations
		Accuracy of results	Correct or incorrect solutions

2.6. Validity and Reliability of the Research

Concepts such as validity and reliability are often emphasized more in quantitative research. However, the concepts of validity and reliability in qualitative research are stated that is evaluated within the scope of essential terms such as transferability, consistency, credibility, and confirmability (Yıldırım & Şimşek, 2016). In this context, if we touch on the ways to ensure validity and reliability in the research, all the data obtained to ensure the credibility and consistency of the research were examined by experts. In particular, the content validity was ensured by using expert opinions to create the data collection tool. Furthermore, in the research conducted, direct quotations were included in the findings section to ensure internal validity, and the research was clearly stated with all its dimensions and processes.

Coding all data for which reliability is obtained in qualitative studies means harmony or compromise between the coding of different coders (Creswell, 2017). In order to ensure the internal consistency of the research, the reliability of the analysis was calculated according to the formula developed by Miles and Huberman (1994), and it was found to be 88%. Miles and Huberman (1994) emphasize that the reliability level should be at least 80% agreement level for excellent qualitative reliability. Considering this ratio, it can be said that the agreement between the analysts in the study was at a reasonable level. In order to ensure transferability in the study, the research process is explained in detail. At the interpretation stage of the findings, quotations from the students' answers were included, and the findings were supported. In addition, the analysis and interpretation of the data collected in many qualitative studies, sharing the results with the participants and

confirming them at some points, increased the accuracy and credibility of the explanations (Creswell, 2017). This shows that the study is reliable.

3. Findings

The RCPKT and interviews used to collect data in the study are analyzed in this section. Conceptual knowledge and procedural knowledge analysis are presented under separate headings.

3.1. Conceptual and Procedural Knowledge

This section tried to determine the conceptual and procedural knowledge that the students had formed as a result of the study. Accordingly, in the research, "What is the effect of teaching the "Ratio" subject in the 6th grade mathematics course through micro-learning on students' conceptual and procedural knowledge?" the answer to the question has been sought.

3.1.1. Conceptual knowledge

In this section, it was tried to determine the students' conceptual knowledge of the subject "ratio." Concepts specific to the subject were determined, and the signs of conceptual knowledge in Table 1 were sought. Concepts pertaining to the subject: ratio, unit ratio, and unitless ratio concepts were determined. According to the conceptual knowledge definitions in Table 1, codes and, if any, sub-codes were created under the codes. Thus, the level of data interview and the conceptual knowledge definition in Table 1 were examined. Table 1 defines conceptual knowledge as understanding of concepts and rules, associating with daily life, and understanding the principles of problem solving.

- Code of understanding of concepts and rules;

Six subcodes were created under this code. These are using different representations; establishing and interpreting the ratio; not specifying the amount of the ratio; distinguishing; classical definition and interpretation of terms; equivalence.

Table 4. Sub-Codes of the Understanding the Concepts and Rules Code

Category	Code	Sub Codes	Student Name	Sample Student Answer
Conceptual knowledge	Concept and understanding of the rules	different representations use	Ayşe	Örnek: $\frac{21 \text{ km}}{12 \text{ sa}}$ 21 km yalın 12 saatte oranı Örnek: 4:12 Sınıfteki güçlü öğrencilerle güçlü öğrencilerin birbirine oranı
		set the ratio and interpret	Mert	Bir sınıfta 10 kız öğrenci 5 ise erkek öğrenci vardır erkeklerin kız oranını yazınız. $\frac{5}{10}$ ya da $\frac{1}{2}$
		not specifying the amount	Hülya	18 tane kalem iki çocuğa $\frac{2}{7}$ oranında paylaşırsa fazla kalem alan çocuk kaç tane alır? $\frac{2}{7} = 9$ bütün 1. Çocuk = 4 14 tane $18 : 9 = 2$ 2. Çocuk = 14 almıştır.
		to differentiate	Ayşe	Aşağıdaki oranların türlerini karşılarına yazınız. Herhangi bir kişinin boyunun başka bir kişinin kilosuna oranı: $\frac{170 \text{ cm}}{50 \text{ kg}} \rightarrow$ Birimli Mavi kalem sayısının kırmızı kalem sayısına oranı: $\frac{20}{20} \rightarrow$ Birimsiz
		classic definition and interpretation of terms	İrem	İki saduğun karşılaştırılmasına oran denir. $\frac{2}{4} : 2:4$ 2/4 2'ın 4'e oranı

equivalence Mustafa

Nedeni: $\frac{40}{88}$ sadeleşse de genişletilse de $\frac{15}{36}$ olamıyor.

In the sub-code of using different representations, it was observed that the way of representing the ratio changed while the students were solving the ratio question. The use of different representations while expressing the ratio was positive in terms of their mastery of the subject and was accepted as an indicator of conceptual knowledge. The sample student answer given by İrem for this code is shown in Table 4. As can be seen, while İrem gives examples of the ratio, she has shown the ratio as ":" and "___." When RCPKTs were examined, three different representations were seen for the ratio. ":", "___" and "/" are examples. All three representations are correct. Like İrem, her seven friends are aware that the ratio will be represented differently, and they used different representations in their question solutions. Below is an excerpt from the interview with Hülya.

Researcher: How did you learn to represent ratios with different representations?

Hülya: The ratio was shown in different ways in the content we watched. This caught my attention. I learned from there.

As seen in the interview section above, Hülya learned that the ratio could be shown with different representations thanks to digital content.

When the answers given by the students to the questions in the RCPKTs were examined in the sub-code of setting and interpreting ratios, it was seen that they generally established and interpreted correct ratios. In addition to solving the given questions, they were asked to write questions and make solutions. It was observed that all students wrote questions and made correct solutions. The sample answer from Mert is given in Table 4. As can be seen, Mert gave the number of male and female students in the class in his question and asked for the ratio of male students to female students. The question written by Mert on the subject of ratio is appropriate, and the answer he gave to the question is correct. After finding out that Mert's answer was 5/10, he wrote "half" next to it. In other words, he stated that the number of boys is half of the number of girls at the ratio he found. Part of the interview with Hilal is below.

Researcher: You gave correct answers while Hilal solved, wrote, and interpreted questions. How did you get this information?

Hilal: There were sample questions in what we watched (content prepared with Prezi, Khan Academy). Their solutions were also very nice. I learned from them.

Researcher: What would you say about the content we offer?

Hilal: Everything was obvious. The subjects were explained one by one, simply and briefly, and I was never bored. I watched all the subjects with the same enthusiasm. I also loved the mini-quizzes. I already answered all the questions correctly.

As seen in the interview section above, Hilal stated that she followed the subject's content without finding it intense and getting bored. She attributed it to their ability to understand the subject and solve the questions correctly.

In the sub-code of the ratio not specifying the amount, the students were asked to divide a certain number of multiplicity in the determined ratio. Five students made their solutions, knowing that the determined ratio did not report the actual number. The sample answer given by Hülya to the question is shown in Table 4. In the question asked, "If 18 pencils are shared between two children in a ratio of 2/7, how many pencils does the child buy the most?" was asked. While solving the question, Hülya added the numbers 2 and 7 in the ratio of 2/7 and considered the result as 9 whole. Hülya divided 18 into 9, since 18 pencils would be divided into 9 wholes, and found that 2 fell into each whole. Then, she divided the whole into parts again as in the ratio of 2/7 and found 2 wholes and 7 wholes. She assumed that the first child had two wholes, and since two fell to

each whole, she multiplied two by two and got four. Assuming that the second child got 7 whole, she multiplied 7 by 2 to get 14. From here, she found out that the second child bought more pencils and expressed the result as "he bought 14". It has been seen that Hülya quickly performs mental operations without some intermediate operations. She chose the correct result. She solved the problem by realizing that the ratio given here is not the actual amount. In the sub-code of differentiate, the students were presented with expressions covering different types of ratios and were asked to distinguish between these mathematical expressions as ratios with or without units. In addition, the definitions and examples of ratios with and without units were asked of the students. Eight of the students made this distinction correctly, defined it, and gave examples. Ayşe's sample answer to this code is given in Table 4. As can be seen, Ayşe expressed "the ratio of a person's height to his/her weight" as a unit ratio. She gave an example of the statement by writing "(170 cm)/(50 kg)" after her statement. Likewise, she expressed "the ratio of the number of blue pens to the number of red pens" as a ratio without a unit and gave an example as "20/20". Ayşe's statements and the examples she gave are correct.

In the sub-code of classical definition and interpretation of terms, all of the students made the correct classical definitions of the specified terms. It was observed that the students correctly defined the terms ratio, unit ratio, and unitless ratio and gave appropriate examples. The definition made by İrem for the term ratio is shown in Table 4. As it can be seen, when İrem defines the ratio, "Comparison of two multiplicities is called a ratio." and gives examples with three different representations while giving ratio examples. Then she made a statement next to the examples she wrote as "the ratio of 2 to 4".

It was observed that when the students were asked about the ratios that were equivalent to the ratios given or not, they explained the answers with their reasons. For example, Mustafa's statement regarding the solution to a given problem is shown in Table 4. As can be seen, Mustafa stated that the ratio of 15/36 would not be equivalent to the ratio of 40/88 given. He explained the reason by saying that it does not equal the given number even if he expands or simplifies. Thus, seven students are aware that the ratio will not change when simplification or expansion is made. In addition, it was observed that these students wrote the result by simplifying the ratio they found after solving the questions.

- Code of connection with everyday life;

It is critical in conceptual knowledge that students associate the subjects they have learned with daily life. To this end, questions were asked to associate the subject of ratio with daily life, and it was seen that all of the students gave answers to this question. However, two students stated that they encountered the subject of ratio in the subject of fractions in mathematics, and it was seen that they accepted it as daily life. It was observed that the other eight students gave correct examples from daily life. Hülya's answer to this code is given in Table 4.

Table 5. Sample Student Response for Associating with Daily Life

Category	Code	Student Name	Sample student answer
Conceptual Knowledge	Associating With Daily Life	Hülya	Örnek olarak arabalarda sürati bulurken oran kullanılır,altında da oran kullanılır,tek yaparken oran kullanılır.

Hülya stated that ratio is used in calculating speed in vehicles, ratio is used in gold (such as 22 carat, 14 carat), and ratio is used when making cakes. In the interview with Hülya, she was asked to open up this answer a little more. A portion of the interview is below.

Researcher: Hülya, can you explain your answer a little more?

Hülya: Teacher, we primarily use them to find speed. For example, in traffic. It is used in cooking, for example, in making cakes. To set the dimensions. It comes up constantly. It is everywhere. Even in our house, there is a ratio now. There should be specific dimensions in our room in our building. The drawings must be proportioned to make the designs look good.

As seen in the dialogue above, Hülya stated that the ratio is used to find the speed (like km/h) that they encounter in traffic, and that it is used to provide a beautiful appearance in buildings and places with a

drawing design to adjust. She also stated that it is used to adjust the measurements while cooking. As seen in the examples given, it is seen that Hülya correctly relates the subject of ratio with daily life.

- Code of understanding the principles of solution of questions;

Different problems were asked of the students, covering the learning objectives related to the ratio subject. When the solutions are examined step by step, it is seen that the students make solutions by applying the solution principles correctly.

Table 6. Sample Student Answers

Question	Student Name	Solution
The ratio of male students to the number of female students in a class is 3/5. What is the ratio of female students to all students in the class?	Hilal	$\frac{E}{K} = \frac{3}{5}$ $\frac{K}{T} = \frac{5}{8}$ <p>Erkek = 3 Kız = 5 Tüm öğrenciler = 8</p>
56 apples will be divided into two groups at a ratio of 3/5 and will be filled into the small basket, which is less, and the large basket, which is more. How many more apples are in the large basket than in the small basket?	Hülya	$\frac{3}{5} = 8 \text{ bölün}$ $56 \div 8 = 7 \text{ kelme}$ <p>7 7 7 7 7 7 7 7</p> <p>B = 35 K = 21 35 - 21 = 14</p>

Table 6 shows the solutions Hilal and Hülya have made. In the interview, they were asked to explain how they solved the questions. Some of the interviews are below.

Researcher: Hilal, how did you solve this question? What did you think?

Hilal: Teacher, I have established a part-whole relationship. Girls and boys are ratioed by 3 and 5. So I summed up and found 8. I set out from here and wrote the numerator and denominator of the desired ratio. So I went from the parts to the whole. The ratio of girls to class size was requested, and I found 5/8. So 5 pieces represent the female students, and 8 pieces represent the whole class.

Researcher: Well, did this ratio reflect real number values? So the class is 3 boys and 5 girls, 8 people?

Hilal: No, the ratio can be simplified. The given ratio has been simplified.

As you can see, Hilal has solved her solution by understanding it step-by-step. Below is a part of the interview with Hülya.

Researcher: Hülya, how did you solve this question? What did you think? Can you tell me how you did modeling in fractions?

Hülya: Teacher, I both drew a model and thought about the part-whole relationship. There are 3 and 5 parts in the ratio, so I drew 8 parts (whole). I got 7 by dividing 56 by 8.

Researcher: Why did you divide by 8?

Hülya: I have 8 parts because when I divide 56 by 8, I get 7. The 7 I found shows how many times the given ratio is simplified.

Researcher: How did you get the apples in the small and large baskets after that?

Hülya: For this, I multiplied each of the pieces by 7. So I found the actual value of the parts. Thus, I reached the number of apples in the small and large baskets. Then I subtract the values you found to find the difference.

As seen in the dialogues above, Hilal and Hülya reached the correct conclusion by thinking step by step while solving the questions. According to Hilal and Hülya's statements, it is seen that they solved the questions using the same strategy (part-whole). However, Hülya followed a different path while solving the question and visualized the solution. In addition, it is seen that both of them have knowledge that the given ratio is not a real number and that the ratio can be simplified. In short, it is seen that Hilal and Hülya are aware of what operation they are performing and why. Similarly, it is seen that 6 students made their solutions step by step.

3.1.2. Procedural knowledge

Procedural knowledge definitions for the subject of "Ratio" were determined (Table 1), and determinations were made regarding this. Thus, the level of data interview, the definition of procedural knowledge in Table 1, was examined. Subject-specific procedural knowledge definition: knowledge of terms, formulas, and operations to solve ratio questions. The representations are determined as knowledge of representations and algorithms. In the RCPKT's given to the students, some questions include all the achievements related to the ratio subject. When the solutions were examined, it was seen that all of the students correctly expressed the terms, representations, and representations about ratio. The answers given by the students to the questions were analyzed as true-false and shown as a percentage in order to reveal knowledge of operations, algorithms, and formulas.

Table 7. Percentage of Correct Answers by Students

Learning objectives	Correct answer percentage
S/he uses ratios to compare multiplicities and shows the ratio in different ways. (Question 4, 6, 14, and 17)	72%
In cases where a whole is divided into two parts, s/he determines the ratio of two parts to each other or each part to the whole; in problem situations, when one of the ratios is given, s/he finds the other. (Question 8, 9, 12, and 15)	75%
S/he determines the ratio of two multiplicities of the same or different units to each other. (Question 7, 10, and 16)	84%
Total	76%

Looking at the table above, it is seen that the greatest achievement of the students is "determining the ratio of two multiplicities in the same or different units to each other." In general, it was observed that the success ratio in solving procedural questions was 76%. This percentage is considered a successful ratio. Therefore, it can be said that students' procedural knowledge is at a sufficient level.

4. Discussion and Conclusion

Based on the findings obtained within the scope of the research, it can be said that both the conceptual and procedural knowledge of the students on the subject of "Ratio" is at the desired level after the micro-learning teaching in the e-learning environment. The study observed that students generally formed the conceptual and procedural knowledge definitions given in Table 1. The answers given by the students to the concepts related to the subject in general, reflecting these concepts to the problem solution, associating the subject with daily life, making solutions by applying the solution principles correctly, being aware of which operation and why, and giving correct answers at the ratio of 76% to the procedural questions support this result. The ratio subject was presented to students who did not know the ratio before, only through micro-learning. Considering that they generally answer the questions correctly, it can be said that micro-learning can be used in mathematics teaching. Nikou and Economides (2017) stated that the mobile-based micro-learning approach improves students' basic psychological needs, increases exam performance, and provides more learning opportunities. Sirwan Mohammed et al. (2018) stated in their study that the microlearning method increases learning and productivity more than the traditional learning method. These results are in agreement with the study.

Mateus-Nieves and Castillo (2021) stated in their study that the use of micro-learning content contributed to students' learning of mathematical operations and their adaptation to daily life. The study showed that the students associated the subject of "ratio" with daily life. The study seems to support the study of Mateus-Nieves and Castillo (2021). In the study, it was seen that the students associated the subject of "ratio" with daily life. This is important in terms of conceptual knowledge, and it was observed that almost all students made this association with different examples and explanations. This shows that with microlearning, students can be taught that mathematics is a lesson from life. It can be said that the teaching provided prepares the ground for students to realize the place and importance of mathematics in daily life. It can be said that giving examples of daily life on the subject of ratio in animations and short stories is effective in the emergence of this result. In addition, students' associating the subject with daily life indicates the formation of conceptual knowledge about the subject (Karakoç, 2012). Many of the Common Core State Standards for Mathematics [CCSSM], 2010, which many states have accepted in the United States in recent years, have also emphasized

the need for students to associate a subject with another mathematics subject or daily life while learning. Because students' associating mathematical concepts with daily life makes knowledge more permanent than forgettable (Balgalmış & Ceyhan, 2019). Thus, individuals understand the logic of the concepts they have learned and can apply them to solve the problems they encounter in daily life (Akgün et al., 2015). It is seen that the answers given to the questions about the relationship between mathematics and daily life are mostly similar and inadequate answers, such as financial affairs, course environment, shopping, and calculation (Baki et al., 2009; Kurtuluş Kayan, 2019). The fact that students gain the ability to associate a subject with daily life is an indication that they can transfer other subjects to daily life (Beswick, 2011). Thus, it can be said that instead of memorizing the rules and making applications that seem meaningless, it contributes to their orientation towards applications that make sense for them. The solutions and interviews given by the students support this situation.

Individuals who learn the concepts correctly perceive and solve events and problems more easily (Ayyıldız & Altun, 2013). From the study, it can be said that the concepts related to the subject were understood by most of the students. It was observed that the students understood the concepts and transferred them to problem-solving. Thus, they established a relationship between concepts and questions. As a result of their studies, Mateus-Nieves and Moreno (2021) stated that digital resources produced positive and productive results in mathematics lessons. The study supports this result.

Hohmann (1991) stated that learning the concept of proportion is closely related to the concepts of part and whole. The fact that the students generally reach the correct answers with the part-whole relationship in the solutions they have made indicates their understanding of the ratio issue. In the interviews, it was seen that while Hilal and Hülya were describing the solutions they had made, they had made the solution by justifying it with the part-whole relationship. According to Zoya (2017), having conceptual knowledge means knowing definitions, formulas, and operations and justifying what is done. Likewise, Simon (2017) stated that the justifications made by the students are an indication of conceptual knowledge. The results obtained from the students' answers and opinions in the research conducted in this direction show that the students made these justifications. According to the results obtained; in general, the students correctly solved different problems, including the acquisitions related to the ratio subject. Procedural knowledge, defined by Rittle-Johnson and Schneider (2015) as the sequence of actions that lead to the correct answer when the algorithms and operations are carried out correctly, was revealed by the research students. There is not much supporting evidence in the literature about the effects of microlearning training on improving student performance in academic settings (Taylor & Hung, 2022). This study revealed the contribution of microlearning to students' conceptual and procedural knowledge.

5. Recommendations and Limitations

Based on the results obtained within the scope of the research, some suggestions were made. In this context, in e-learning environments or traditional learning environments, the micro-learning approach can be handled with different topics in the mathematics course. The use of qualitative methods in the current study and the preference for the 6th-grade ratio topic are among the research limitations. In this respect, large-scale studies can be conducted at different grade levels using quantitative or mixed methods. The microlearning approach can be integrated into open and distance learning systems or traditional learning and face-to-face classroom environments. By supporting 21st-century skills using different digital content, learners can develop content and adopt digital technologies. Not only in mathematics lessons but also in different lessons, with an interdisciplinary approach, students can be given a micro-learning experience and a digital learning adventure. By age requirements, e-learning environments should be enriched with mobile devices and digital content to break the monotony. Conceptual and procedural knowledge should be considered as the basic building blocks of learning at the same time. In this context, it should be aimed at conducting comprehensive and different approaches based on conceptual and procedural knowledge.

There are some limitations to the work done. Using the qualitative method and working with 10 students is limited in terms of method and participants. In addition, it is limited to the 6th grade "Ratio" topic.

Acknowledgement:

Conflicts of interest/Competing interests: The authors have no conflicts of interest to declare relevant to the content of this article.

Ethics approval: All procedures performed in the present study was in accordance with the ethical standards of the Ethics Review Committee (ERC) of the Kilis 7 Aralık University.

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