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The Effects of Mobile Technology on Learning Performance and Motivation in Mathematics Education

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Abstract

Due to rapid developments, mobile technologies started to play an essential role in designing seamless learning environments. Due to the availability of mobile technologies, students can access learning materials without being bound by time and place. On the grounds that these applications allow information exchange, time and space limitations such as classrooms or school bells have been eliminated. Therefore, this study aims to assess mobile-assisted seamless learning environments' effects on students' success and motivation in the secondary school 7th grade mathematics class algebra unit and student opinions about the application. The research is designed using the descriptive pattern of mixed-method research. The sample of the study is 73 middle school students (30 male and 43 female) in Turkey. Augmented Reality (AR) applications developed in teaching algebra to support individual learning and to utilize mobile technologies, WhatsApp groups were created. Algebra Achievement Test (AAT), Mathematics Motivation Scale (MMS), and semi-structured interview forms were used as data collection tools in the research. The results of the study showed that there were statistically significant differences in favor of the experiment group in AAT and MMS scores. However, no significant difference was found between the groups in intrinsic goal orientation and test anxiety scores, which are motivation sub-dimensions. The findings obtained from AAT, MMS, and the students' opinions showed that mobile technology applications used in out-of-school learning environments positively affect the learning process.

Keywords Mathematics education · Mobile technology · Seamless learning · Augmented reality · WhatsApp

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1 Introduction

Mathematics is one of the most important cognitive tools that we possess, and vital as it is the foundation of many disciplines and imperative for building modern civilization. Therefore, it is necessary to ensure that as many members of society as possible have a solid grasp and understanding of the fundamentals of mathematics (Daly et al., 2019). Despite this, many students may develop a negative approach to mathematics for various reasons (Ukobizaba et al., 2021). This whole situation, which starts during primary school, increases as the school years pass (Baykul, 2014). Therefore, educators suggest an enjoyable and exciting classroom environment while teaching a subject (Laurens et al., 2018).

Transition from arithmetic to algebra is important for middle school students to understand abstract concepts (Gürbüz & Akkan, 2008). Algebra enables individuals to operate with concepts at an abstract level and to apply these concepts in concrete terms. Understanding several mathematical concepts is a prerequisite for learning algebra (Ojaleye & Awofala, 2018). However, it is stated that even the students in countries with high mathematics achievement experience difficulties in learning algebra (Barbieri et al., 2019; Jupri et al., 2014; Kızıltoprak & Yavuzsoy Köse, 2017; Papadopoulos 2019; Star et al., 2015). The main difficulty in learning algebra stems from using symbolic language to represent numbers and expressions (Maharani & Subanji, 2018; Tatlah et al., 2017). Inadequacies in modeling and not knowing the different uses of the concept of variables (Gürbüz & Akkan, 2008), rote learning without conceptual understanding due to its abstract structure are among the difficulties experienced in learning algebra (Ferretti, 2020; Tatar & Dikici, 2008). It is recommended to use effective strategies to improve students' algebra skills (Star et al., 2015). It is highlighted that activities that will enable students to figure out basic concepts should be given more importance (Gürbüz & Toprak, 2014; Kaya et al., 2016; Papadopoulos, 2019).

Recent developments in the world and technology, made it imperative to use technology and traditional methods in teaching mathematics. Besides, compulsory situations such as pandemics may require the use of technology in education. Likewise, Bray & Tangney (2017) stated that using digital tools and technology-assisted mathematics education to improve learning experiences are important research areas. When this perspective is considered, technology helps students focus and understand mathematical concepts better (Khouyibaba, 2010). Technology and mathematics lessons are becoming more and more integrated (Tabach, 2011), using technology and computers in education can help the students to learn and teachers to teach mathematics (Doğan, 2012). In addition, as technology becomes widespread, the interest in using mobile devices to assist learning and teaching increases (Kearney & Maher, 2019). Technology-assisted learning environments allow new learning opportunities, enable educators to test new learning methods, and apply innovative approaches (Virtanen et al., 2018).

Even though it is accepted that mathematics education should be conducted face to face due to the nature of the subject matter (Khirwadkar et al., 2020), knowledge gained at school should be assisted through the out-of-school learning environments and establishing the relationship between these two elements is important (Galligan

et al., 2012; Wager, 2012). Kuh (1995) stated that out-of-class activities might create opportunities for students to apply the knowledge they gained in class. Teachers' decisions are essential for students to continue their learning during the pandemic period. Besides, even if the parents support their children's learning process, some challenges may be experienced (Bakker & Wagner, 2020). Mobile technologies and mobile learning concepts help and provide technical assistance to students to overcome these challenges (Yang et al., 2021). The definition of "seamless learning" has been updated as "mobile-assisted seamless learning" with the technological developments and designing out-of-school learning environments gained importance with the recent developments. In this context, AR and WhatsApp were used as seamless learning tools in this study.

2 Literature review

2.1 Seamless learning

The seamless learning concept was defined as the seamless integration of different learning experiences, such as formal and informal learning, individual and social learning, and real and virtual learning, on different levels (Wong & Looi, 2011). Continuity, which is the core of the concept, can act as a desired bridge between formal learning that is based on the principle of applying a preset curriculum within a designated time, and informal learning, which is a learning model that is intentional and attracting students' attention outside the school (So et al., 2008). Students can continue their learning activities without any interruptions among different scenarios and interact in different forms using their mobile devices at any given time and place using this technology. Cognitive learning is realized by supporting the learning processes with such learning scenarios (Chang et al., 2006).

It was stated that broadening teaching beyond the classroom will encourage inquiry-based- learning in various disciplines, and existing technologies can enhance the advantages by providing support for seamless learning, especially between contexts (Kali et al., 2018). The seamless learning environment acts as a bridge connecting learning in different contexts such as formal or informal, school or out-of-school, and special and general learning environments activated through individual or collective efforts (Looi et al., 2010). Mobile technologies and informal learning tools enforce the connection between learning experiences and enable knowledge gain anytime and anywhere (Fabian et al., 2016; Jumaat & Tasir, 2013; Otero et al., 2011). Since mobile devices are portable, they enable broadening the learning location and duration and allow students to maintain their learning experiences in different environments (Huang et al., 2007).

2.2 Mobile technology

Youngsters use mobile technologies almost daily. Students can easily access the Internet through smartphones and tablets, and such devices have become part of their daily lives (Korenova, 2015). Research on the objectives and scope of mobile learn-

ing in education increased when mobile devices became widespread (Crompton et al., 2017). Portable devices can provide rich and interactive multimedia learning content through mobile technologies. Besides, suitable learning strategies facilitate the mobile learning process and help educators attain educational objectives (Jeng et al., 2010). Integrating the mobile technologies that have an educational potential for all age groups improves the capacities of authentic and scientific research approaches that may involve learning beyond the classroom since mobile technologies are part of many students' daily lives. Mobile learning potential increases as mobile technologies develop (Sullivan et al., 2019). Mobile learning, informal learning, and flipped learning concepts emerged with mobile communication devices such as smartphones and tablets. The limitations of location and time, like school buildings and schedule, are eliminated through the applications enabling information exchange (Şad et al., 2016).

The prevalence of mobile devices provides a new perspective in learning mathematics and acting as a bridge between in-class learning and the real-world (Fabian et al., 2018). Mobile devices can be used as substitutes for desktop computers to support visualization and conceptualization of mathematical concepts. Further, mobile technologies help create a cooperative learning environment and be used for out-of-school activities (Fabian et al., 2016). One of the key possibilities of mobile technologies is the ability to extend the advantages of formal learning beyond learning environments. In this context, researching mobile technologies that can bridge the formal and informal learning environments is crucial (Bernacki et al., 2020). Using mobile technologies that help provide interactive and exciting new environments positively contributes to different mathematics learning styles (Kalloo & Mohan, 2012; Polydoros, 2021). Research evaluating mathematics achievement through mobile learning approaches and tools has focused on different grades and subjects from primary school to higher education. In mobile learning research, the positive effects of mobile learning approaches on students' performances in mathematics subjects such as algebra (Jagušt et al., 2018; Kalloo & Mohan, 2012; Riconscente, 2013), geometry (Chang et al., 2016), and probability (Cai et al., 2020), have been determined. Similarly, the research concluded that mobile learning in mathematics affects 21st-century skills such as problem-solving (Haydon et al., 2012; Volk et al., 2017), communication skills (Ashim et al., 2020; Kagohara et al., 2013), creative thinking skills (Atwood-Blaine et al., 2019; Septian et al., 2020), collaborative engagement (Tirado-Morueta et al., 2020; Sedaghatjou & Rodney, 2018). All these show that students will benefit from using technology in mathematics.

Other studies also point out the limitations of mobile technology, hence, mobile learning, as well. The increase in time spent with digital technologies also raises concerns about its impact on children's health. The routine and frequent use of mobile devices is associated with behavioral problems in childhood (Hosokawa & Katsura, 2018). When students use mobile devices either in classrooms or at home, screen time needs to be monitored. While mobile devices can be used as a success-enhancing factor, the possibility of them being used in distracting or unethical behaviors is also an issue that needs to be considered (McQuiggan et al., 2015). Many reasons, such as loss of concentration in learning with mobile devices, increased cognitive load due to rich information from the real and digital world, limitations of using touch screens,

attractiveness of social networking software, and inappropriate learning designs can affect learning performance. It is important to study the possible negative effects and limitations of mobile devices while studying their use in educational environments (Hwang & Wu, 2014).

2.2.1 Augmented reality

AR is defined as a dynamically consistent location of real-world content or a situation that overlaps with context-sensitive virtual information (Klopfer & Squire, 2008). Acquiring and implementing information at the right place and time is important in a rapidly changing society where much information is produced. In this sense, AR is a technology that significantly changes the place and time of education and training (Lee, 2012). AR can provide live and riveting teaching materials, instead of traditional two-dimensional images, for students and enhance their learning performances (Lu & Liu, 2015). AR, which links real-world content with digital learning sources at the right place and time, can increase student success through learning activities based on inquiry (Chiang et al., 2014). AR applications allow students to work individually in some teaching and learning contexts, shortening the teacher's time spent on re-explanations. A well-developed AR application can enable any learning process to be successfully realized. Inquiry-based AR activities have great potential in education and encourage cooperative and individual learning (Bressler & Bodzin, 2013; Martin-Gutierrez et al., 2015).

Augmented reality is a tool supporting students by filling the gaps between real-world situations and mathematical concepts using mathematical modeling (Cahyono et al., 2020). Augmented reality applications enable abstract concepts in mathematics teaching to be concretized through modeling or multiple displays (Özdemir & Özçakır, 2019; Zbiek & Conner 2006), and provides a better understanding of concepts (Bujak et al., 2013). However, it is stated that augmented reality applications usually target geometry in mathematics teaching and that there is a lack of subjects related to education and other learning areas of two-dimensional objects (Özdemir & Özçakır,2019). When the literature is reviewed in support of this view, it is seen that the studies focus on the teaching of three-dimensional objects, and many studies investigate the effect of augmented reality applications on spatial abilities (e.g., Flores-Bascuñana et al., 2020; Herrera et al., 2019; Kaufmann & Schmalstieg, 2003; Rashevska et al., 2020; Vakaliuk et al., 2020).

2.2.2 WhatsApp

Internet technologies shape content creation, sharing, and communication. Social networks that are very popular among youth become more widespread by nature to meet individuals' socialization needs and become essential daily elements (Çetinkaya, 2017). New communication technologies, especially mobile communication technologies, encourage communication between students and teachers, and increase learning efficiency (Rau et al., 2008). It is possible to talk about the educational advantages of WhatsApp, a smartphone application used for instant messaging. One of the application's benefits is that it enables users to create a group and communi-

cate (Bouhnik & Deshen, 2014). The application's favorable properties include the passive and shy students being more active on WhatsApp groups, peer communication clarifying the misunderstandings about concepts, creating cooperative learning environments, and continuing the out-of-school learning (So, 2016). The application is beneficial in creating opportunities to right the wrongs for the learners. The application is practical and straightforward, enabling mathematics to be learned regardless of time and location (Naidoo & Kopung, 2016). In addition, creating a sense of belonging in students, establishing a secure connection between the student and teacher, and strong friendships among students and inputs for creating a social environment can also be counted among the benefits (Awada, 2016).

It is stated that enabling students to share their worksheets and resources with each other through instant feedback can bring success (Naidoo, 2020). It is seen that the WhatsApp application is used as a tool in various learning methods such as blended learning (Nida et al., 2020; Qamar et al., 2019), self-regulated learning (Fathonah et al.,2020), digital learning (Mulenga & Marbán, 2020), flipped classroom learning (Fahmy et al., 2019), online learning (Aziza, 2021; Mukuka et al., 2021), problem-based learning (Yuliana & Firmansah, 2018).

2.3 Motivation and learning

Motivation refers to processes that instigate and sustain goal-directed activities (Schunk & DiBenedetto, 2020). Motivation, which has a fundamental role in learning, is a concept that triggers, directs and sustains human behavior. Increasing the students' motivation is a research area and innovative approaches are needed due to the constant change of the factors that play a role in motivation (Glynn et al., 2005). Studies mention two motivation types, as intrinsic and extrinsic motivation (Corpus et al., 2009). Intrinsic motivation can be expressed as the motivation that exists within the individual rather than being triggered by any external pressure (Tohidi & Jabbari, 2012). In contrast to intrinsic motivation, extrinsic motivation is the desire to engage in an activity to achieve positive results, such as an incentive, or to avoid negative consequences, such as a punishment (Deci & Ryan, 2000). Both intrinsic and extrinsic motivation correlate with each other in achieving learning success (Putri et al., 2019). It has been stated that motivation, which is a force that moves us and sustains our behaviors, is an important factor of success and effective teaching in the field of education, as in all areas of life (Ergin & Karataş, 2018). It has been stated that there is a positive correlation between learning outcomes and motivation (Liu & Chu, 2010), and in general, high levels of motivation is a precondition for success (Ebner & Holzinger, 2007).

Motivation strategies can be considered as elements forming motivational beliefs of individuals. These elements can explain the motivation characteristics of individuals. The elements that are closely correlated with academic success are intrinsic goal orientation, extrinsic goal orientation, controlling learning beliefs, self-efficacy, and test anxiety (Aktan & Tezci, 2013). Goal orientation is a student's perception of the reasons for being engaged with a learning task (Pintrich et al., 1991). Another factor that affects the motivation of learners is task value. Students with high task values generally identify suitable goals and can evaluate their learning process con-

stantly (Lin, 2021). Learning belief refers to the belief that learning efforts will lead to positive results, and it relates to the belief that results depend on one's own effort as opposed to external factors such as the teacher (Pintrich et al., 1991). Self-efficacy is the judgment of individuals to organize and exhibit the actions they need to perform to achieve a certain performance (Bandura, 1995). It does not remain static from the beginning to the end of the learning cycle, but can change rapidly (Schunk & DiBenedetto, 2020). The final element is test anxiety. Test anxiety, which has two elements as cognitive and emotionality (Pintrich et al., 1991), can affect performance negatively by lowering the learning motivations of students. Success expectations of students with high test anxiety may decrease, and this may lead to deterioration of learning outcomes (Bembenutty et al., 1998).

3 Aim of the study

When the studies conducted are examined, it is possible to see that technology, which is a part of our lives, has an intense reflection on education. The mobile technology concept is intertwined with designing a seamless learning environment following the rapid developments. It is vital to examine the effects of such tools on learners when considering that limiting learning to a designed location and time is impossible. The fact that mobile applications are in our lives and humans become individuals who continually learn, put forward learning continuity, and create a ground for seamless learning environments. Hence, the seamless learning concept, which has come to the fore with mobile technologies, enabled these concepts to be treated as research problems. Another important feature of seamless learning is being the bridge between personalized learning and social learning. Nevertheless, studies carried out in the field tend to discuss and analyze personalized and social learning separately (Wong & Looi, 2011). However, studying personalized learning and social learning together is important. In addition, another problem in the literature is that the augmented-reality applications are generally tailored for geometry. This study aims to visualize the lesson and to concretize abstract concepts with augmented-reality applications prepared for the field of algebra learning. The fact that the interests and perceptions affect the success and motivation are important, and the research problems also address these situations.

The research aims to evaluate the effect of mobile-assisted seamless learning environments in the 7th grade algebra learning area on students' success, motivation, and opinions. Answers to the following questions have been sought in line with this aim:

1. Is there a significant difference between the experimental group's post-test scores who participated in the mobile-assisted seamless learning process and the control group who continued to follow their usual education program?
2. Is there a significant difference between the post-test motivation scores of the experimental group who participated in the mobile-assisted seamless learning process and the control group who continue to follow their usual education program?

3. What are the opinions of the experimental group students who participated in the study on the mobile-assisted seamless learning process?

4 Methods

The explanatory method of mixed-method research was preferred in this study. Mixed method research is described as the research type in which the researchers collect and analyze data, combine findings, and make inferences using quantitative and qualitative methods in a single study (Tashakkori & Creswell, 2007). The pre-test and post-test control group patterns, which are the true experimental designs in which the subjects are randomly assigned to the groups according to the independent variable levels, were preferred in the study. The same teacher attended the experimental group and control group students. While the control group students continued their learning process through traditional teaching methods of doing homework, a seamless learning environment was created for the experimental group students. In this context, activities that allow seamless integration of in-class learning and out-of-class learning were organized in the study. AR activities and WhatsApp groups constitute the content of the mobile technology used. AAT was used to measure students' learning success, and MMS was used to determine their mathematics motivation. The research is supported by the qualitative data obtained from semi-structured interviews with students who participated voluntarily and whose gender, success, and motivation levels are different.

4.1 Participants

The research participants consisted of 73 7th graders (aged from 12 to 14) studying in a secondary school in Turkey. Forty-three of the students were female, thirty of them were male. The control and experimental groups were formed by randomly dividing 73 students. The experimental group consists of 36, and the control group consists of 37 students. An independent sample t-test was used for determining whether there was a significant difference between the algebra achievement and motivation pre-test scores of the students in the experimental and control groups in terms of group variables. The mean AAT score of the experimental group was 11.06, while the control group's mean score was 10.70. It was determined that there is not a statistically significant difference between the AAT pre-test scores of the students in the groups according to the group variable [$t(71) = 0.304$, $p > .05$]. The mean score of the MMS pre-test of the experimental group students was 4.07, and the control group students' mean score was 4.06. It was determined that there was not a statistically significant difference between the MMS pre-test scores of the students in the groups according to the group variable [$t(71) = 0.104$, $p > .05$]. According to these results, the students' algebra success and mathematics motivation levels in the experimental and control groups were equivalent to each other before the process.

4.2 Experimental procedure

During the research on learning algebra learning in the mathematics curriculum, the experimental group students were supported by mobile-assisted seamless learning environments. At the same time, there was no intervention in the control group students' out-of-school learning environments. The students in the control group reviewed the subject from the textbook and did their homework assigned by their teachers. Both experimental group and control group groups work on the same homework assignments. Meanwhile, the experimental group uses App but the control group

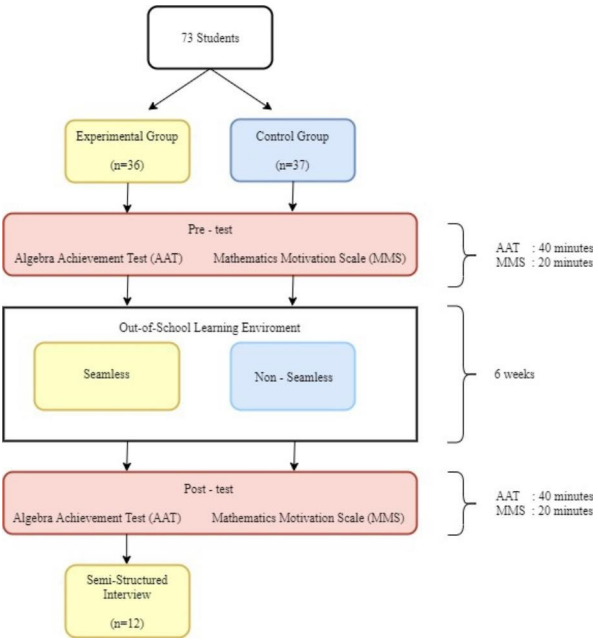


Fig. 1 Experimental procedure

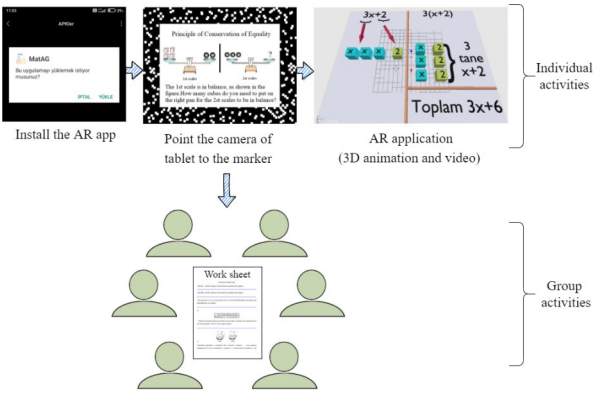


Fig. 2 The main framework for mobile technology

does not use App. Semi-structured interviews were conducted with the experimental group students at the end of the study. Figure 1 presents the experimental procedure.

4.3 Designing Mobile-Assisted Seamless Learning environments

Sixteen augmented reality activities regarding the algebra learning field were carried out in the study. In addition, WhatsApp groups were created to do group activities (discussion, brainstorming, etc.) on the solutions of the problems at the end of the activities (See Fig. 2).

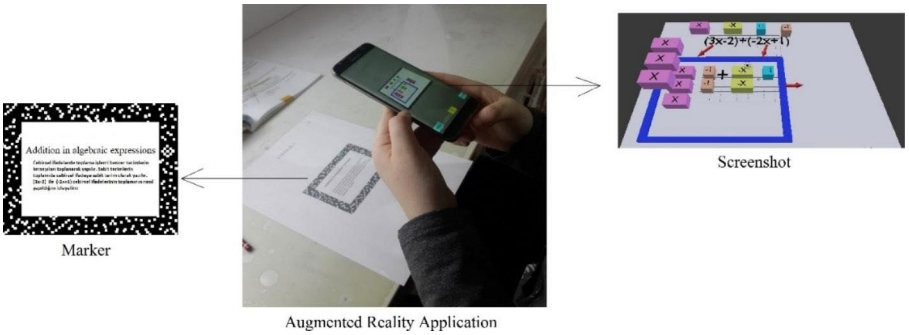


Fig. 3 AR application developed for addition in algebraic expressions

Table 1 Activity types and learning outcomes that the developed AR activities contain

Learning Outcomes	Number of Activities	Activity Type
Adds and subtracts using algebraic expressions.	2	3D Animation
Multiplies an algebraic expression with a natural number.	2	3D Animation
Expresses the rule of number patterns by letters, finds the requested term of the pattern whose rule is expressed by letters.	3	3D Animation
Understands the principle of conservation of equality.	5	3D Animation
Identifies first-order equations in one unknown and equates the first-order equation in one unknown appropriate for the given real-life situations.	1	Video
Solves first-degree equations with one unknown.	1 + 1	3D Animation and video
Solves problems requiring equating first-order equations with one unknown.	1	Video

4.3.1 Augmented reality applications

The learning outcomes and textbooks of the mathematics lesson were evaluated first within the study. During the design process of the application, each activity was planned in line with the interviews conducted with the mathematics teachers teaching the subject matter and the expert educators in the field. As a result, sixteen activities were thought to comprise the learning outcomes, and thirteen of them were suitable for 3D animations. The 3D animations of the determined 3D modeling were developed, and lecture videos to run within the AR application were shot. Figure 3 presents the screenshot of the AR application developed for the addition of algebraic expressions.

Table 1 presents the general information about the activities in the final version of the application. Figure 4 presents the screenshot examples of the AR application.

Sixteen activities were prepared for the research. Screenshot examples of the activities prepared for each of the learning outcomes are presented below:

4.3.2 WhatsApp activities

WhatsApp groups were created among the experimental group students to enable them to follow activities since mobile technologies will be used as a tool for seamless learning in informal learning environments, and social learning is intended. One of the crucial factors in understanding online learning's potential effects is group size (Qiu, 2010). Lowry et al.(2006) stated that being in smaller groups positively

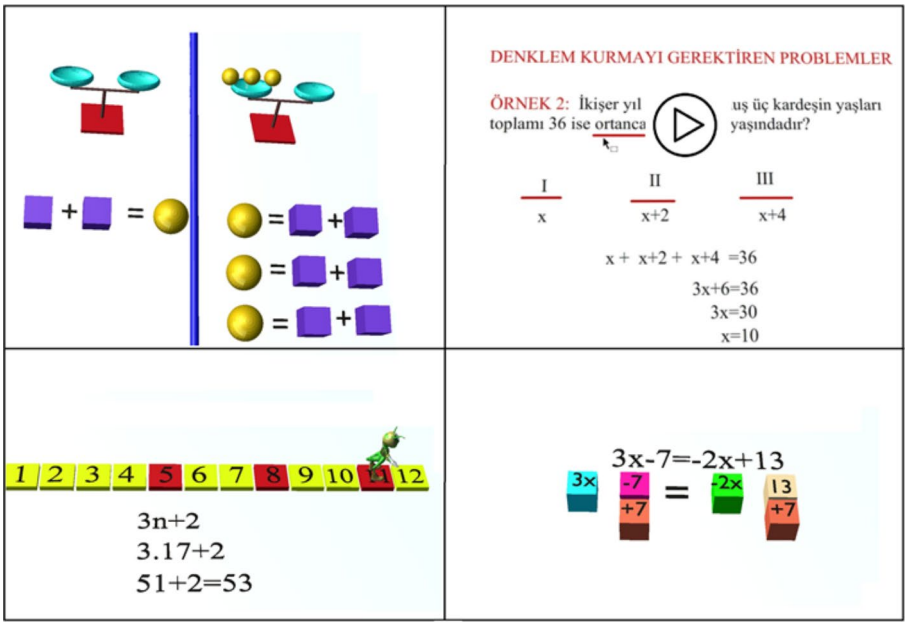


Fig. 4 Screenshot examples of the application

impacts students' communication experiences in terms of their perceptions of the appropriateness and accuracy of messages and their willingness to participate and interact with others. If the goal is consensus generation and negotiation, then smaller (or mid-size) groups are suggested. In this fashion, online groups' size should be tailored to the situation's specific needs and affordances (Qiu et al., 2014). Therefore, 36 students in the experimental group were randomly divided into seven groups once the study commenced. Measures were taken to ensure unity within the WhatsApp groups and prevent students from being always busy with their phones to send untimely messages, but the same measures enabled the students in a group to meet in a virtual environment at the same time outside of the classroom. In this context, learning continued outside the classroom, and seamless learning was realized.

The groups were asked to study the worksheets individually and discuss the monitored AR activities and the unsolved/solved questions together. Hence, the students could see the difference between their and others' solutions and discussed the reasons for different solutions. Unless it was necessary, the solution process was not interrupted, and the aim was for the students to discuss among themselves. Appropriate interventions were made on the subjects that the students disagreed on, and the attention of the students in the group was tried to be called by introducing non-routine problems to create curiosity to enable the students to learn the subject in depth. Figure 5 presents examples of WhatsApp group discussions.



Group 4

D2: How?

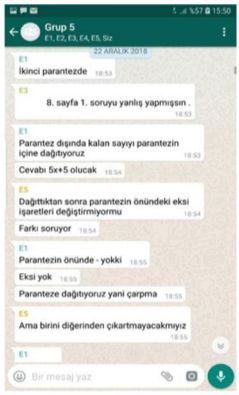
D5: I have calculated 6x+11

D1: The father = 8x+7

D2: Isn't it like this?

D5: Yes, it is.

D3: I have calculated 6x+8
because I have added 3 to only one person's age.



Group 5

E1: The second one is between parentheses.

E3: You got the first question on the 8th page

wrong.

E1: We distribute the outside multiplier to each number in the parentheses so that the result would be 5x+5.

E5: Wouldn't the distribution change the negative sign in

front of the parentheses? The question asks for the difference.

E1: There is no – in front of the parentheses. There is no negative sign. We distribute the outside multiplier into the parentheses, meaning we multiply the numbers.

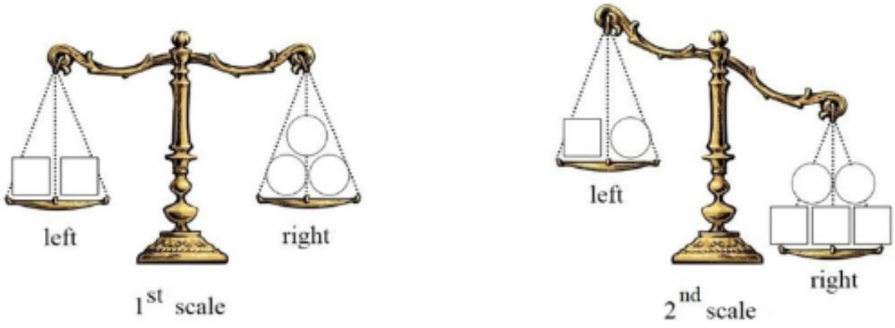
E5: But don't we have to subtract one from the other?

Fig. 5 Examples of WhatsApp group discussions

4.4 Data collection instruments

4.4.1 Algebra unit achievement test

Researchers developed AAT in line with the learning objectives regarding "algebraic expressions" and "equality and equation" in mathematics curriculum to measure cognitive learning achievements of the students. The achievement test's trial form was applied to 378 (N_{female}=193, N_{male}=185) students studying in the 8th grade of the secondary school, different from the research sample, to determine the item statistics. The discrimination parameters of the items in the test are as follows: scores between 0.40 and 1 are very good, 0.30–0.39 are good, 0.20–0.29 should be improved and corrected, and the items that score 0-0.19 should be removed from the scale completely or revised. It was stated that the ideal value for mean item difficulty, another important index in item analysis, should be around 0.50, yet, it was stated that partially easy and difficult items should also be included in the tests, as well (Büyüköztürk et al., 2016, p. 123). According to the analysis results, the discrimination parameters and mean item difficulty of the final test consisting of 28 items (see Fig. 6 for example) were calculated as 0.530 and 0.523, respectively. In addition, within the scope of reliability studies, the KR-20 internal consistency coefficient of the final test was calculated as 0.862. In this context, it has been determined that the achievement test is reliable (Büyüköztürk, 2016).



The 1st scale is balanced, as shown in the figure.

Which of the following operations should be done so that the 2nd scale is balanced as well?

A) Taking one □ from the right pan and adding it to the left pan.

B) Adding three ○ to the left pan.

C) Taking two ○ from the right pan and adding them to the left pan.

D) Adding two ○ and one □ to the left pan.

Fig. 6 A multiple-choice question example

4.4.2 Mathematics motivation scale

Pintrich et al. (1991) developed the Motivated Strategies for Learning Questionnaire. Aktan & Tezci (2013) adapted the questionnaire to Turkish and mathematics education and the questionnaire was used for determining the students' mathematics motivation levels. The confirmatory factor analysis was conducted with the data obtained by applying the scale to 251 seventh grade students in the research. The scale consists of 27 items and six sub-dimensions. These six factors are "intrinsic goal orientation" (3-items), "extrinsic goal orientation" (4-items), "task value" (5-items), "learning belief" (5-items), "self-efficacy" (6-items) and "test anxiety" (4-items). Composite reliability and Cronbach's Alpha values were calculated to measure the reliability of the scale. Cronbach's alpha reliability coefficient of the factors were calculated as 0.80, 0.90, 0.91, 0.83, 0.90, and 0.85, respectively. Composite reliability values were calculated as 0.81, 0.91, 0.91, 0.83, 0.90, and 0.85, respectively. In addition, the Average Variance Extracted (AVE) values were calculated to determine the convergent validity, and the AVE values of the variables were found as 0.58, 0.73, 0.67, 0.50, 0.59, and 0.58, respectively. In the current study, the MMS was applied to groups as both pre-test and post-test.

4.4.3 Interview form

A student interview form was prepared by consulting experts to determine the effectiveness of using mobile technology within the study's scope. This form was directed to students to ask their opinions on using mobile technology in teaching mathematics, and the aim was to support the quantitative data. Interview questions consist of nine items to identify students' opinions on AR activities and WhatsApp groups. The interviews were recorded by recording the voices of the interviewees and the notes taken by the researcher. The data were analyzed through content analysis technique. The examples of the interview questions included: "What do you think about AR activities?", "In your opinion, how did the AR activities affect the process of learning the subject?", "Do you think that AR activities help to solve problems during the process?", "What are your opinions on WhatsApp groups during the lesson activities?" and "How were the group interactions in the created WhatsApp groups?"

4.5 Data analysis

A multiple-choice AAT was applied to determine 7th grade students' achievement levels in the algebra learning area. One point was allocated to the correct answers, and no points were allocated to the false answers in the test consisting of 28 items. The test's maximum score was 28, and the minimum score was zero. 27 items in the MMS were applied to determine students' mathematics motivation levels. The necessary steps to decide whether the data were distributed normally were followed before analyzing points obtained from AAT and MMS tests. The test results indicated that the values were calculated to be $p > .05$ for pre- and post-test (see Table 2). Therefore, an independent sample t-test was used to determine differences in posttest scores between groups. SPSS, TAP and Microsoft Excel programs were used for statistical

Table 2 The results of normality analysis of students' academic achievement test and mathematics motivation scale

	Group	Test	Skewness		Kurtosis		Test of Normality		
							Kolmogorov-Smirnov		
			Statistic	Std. Error	Statistic	Std. Error	Statistic	df	Sig.
AAT	Exp.	Pre-test	,639	,393	,765	,768	,086	36	,200
	Control		,505	,388	,033	,759	,118	37	,200
	Exp.	Post-test	-,311	,393	-,862	,768	,145	36	,053
	Control		,346	,388	-1,110	,759	,120	37	,199
MMS	Exp.	Pre-test	-,499	,393	-,838	,768	,143	36	,060
	Control		-,594	,388	-,014	,759	,130	37	,116
	Exp.	Post-test	-,652	,393	-,584	,768	,135	36	,093
	Control		-,624	,388	,146	,759	,107	37	,200

analysis within the study, and the level of significance of the analysis results was calculated as 0.05. The interviews were recorded using a voice recorder and written notes to prevent data loss in the research. Direct quotations from the interviews are provided in the findings to support the obtained data. In addition, the formula Percent of Agreement (P)=Agreement/[Agreement+Disagreement] developed by Miles & Huberman (1994) was used to measure the reliability of the qualitative data of the research. Three researchers analyzed the data independently and as a result of the analysis, 0.91 agreement was found between the coders. The researchers met and discussed the points where no agreement could be reached, and they recoded the findings according to the consensus results. As a result, qualitative findings were grouped under two categories as the advantages and limitations of AR and WhatsApp applications in learning.

Skewness, kurtosis, z-skewness, z-kurtosis, and Kolmogorov-Smirnov test of normality were used for checking whether the parametric test assumptions were met. Various methods were used for examining the normal distribution of the scores obtained from the data. Coefficients of skewness and kurtosis between +2 and −2 are stated as a normal distribution (Cameron, 2004). Can (2016) stated that the z-scores obtained by dividing the skewness and kurtosis values by the standard errors within the limits of +1.96 and −1.96 indicate a normal distribution. According to the results of normality analysis, the data show normal distribution. Parametric statistical tests can be used to analyze quantitative data with a normal distribution (Can, 2016).

Table 3 Comparison of AAT post-test scores of experimental and control groups

Group	N	M	sd	df	t	*p*	*Cohen's d*
Experimental	36	18.97	5.45	71	3.005	0.004	0.703
Control	37	14.76	6.48				

5 Results

5.1 Learning performance

Independent samples t-test was used for determining whether there was a significant difference between the post-test scores that the students obtained from the multiple-choice achievement test in the algebra learning area. Table 3 presents the test results regarding whether the AAT post-test scores of students differ significantly according to the group variable. Figure 7 presents the pre-test and post-test values together.

Figure 7 shows that AAT pre-test scores are close to each other; however, the difference between the post-test scores measured after the experimental process is in favor of the experimental group. According to Table 3, the mean score of the AAT post-test of the experimental group students is 18.97, and the mean score of the control group students is 14.76. The AAT post-test scores of the students in the groups differ in favor of the experimental groups [$t(71)=3.005, p<.05$; $d=0.703$]. Cohen's d

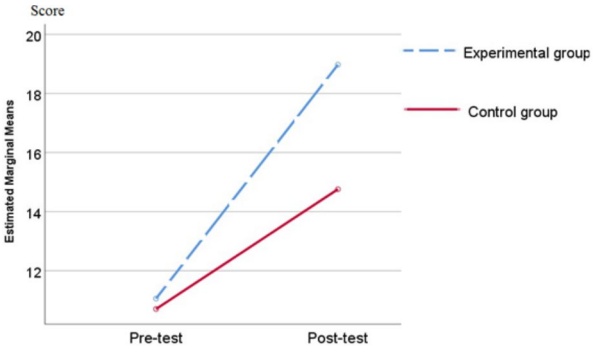


Fig. 7 Comparison of the AAT pre-test and post-test scores of the experimental and control group students

Table 4 Comparison of MMS post-test scores of experimental and control groups

Group	N	M	sd	df	t	*p*	*Cohen's d*
Experimental	36	4.32	0.39	71	2.754	0.007	0.633
Control	37	4.06	0.43				

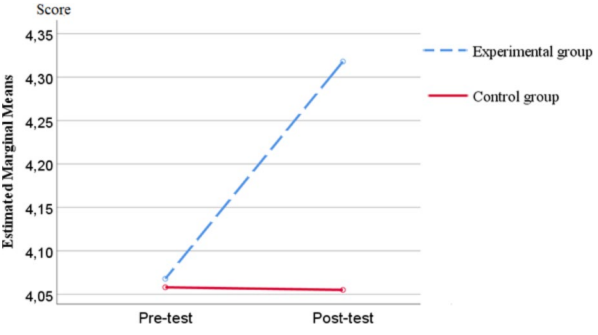


Fig. 8 Comparison of MMS pre-test and post-test scores of experimental and control group students

effect size calculated regarding the difference indicates a medium effect size (Cohen, 1988). According to these findings, it can be said that mobile-assisted seamless learning environments are effective in increasing student success.

5.2 Mathematics motivation

Independent samples t-test was used for determining whether there was a significant difference between the students' post-test test scores obtained from the mathematics motivation scale. Table 4 presents the test results regarding whether the MMS scores of students differ significantly according to the group variable, and Fig. 8 presents the pre-test and post-test results together.

According to Fig. 8, the MMS pre-test scores of both groups are close to each other. Although the control group students' post-test scores after the experimental process were the same, the experimental group students' motivation scores increased.

According to Table 4, the post-test mean scores of the experimental group students are 4.32, and the mean scores of the control group students are 4.06. When the mean scores are examined, the motivation values cumulate in the "strongly agree" category within the experimental group and in the "agree" category within the control group. MMS post-test scores in the students in the groups show a significant difference in favor of the experimental groups [$t(71)=2.754$, $p<.05$; $d=0.633$]. Cohen's d effect size calculated regarding the difference indicates a medium effect size (Cohen, 1988). According to these findings, it can be said that the mobile technology-assisted seamless learning environments are effective in increasing the mathematics motivation of students.

5.2.1 Intrinsic goal orientation

There was not a statistically significant difference regarding the intrinsic goal orientation sub-dimension between the experimental and control groups [$t(71)=0.452$, $p>.05$; $d=0.112$]. It was concluded that the mean scores of intrinsic goal orientation of the experimental group students ($M=4.44$, $SD=0.53$) were higher than the control group students ($M=4.38$, $SD=0.54$), as expected.

5.2.2 Extrinsic goal orientation

There was a statistically significant difference regarding the extrinsic goal orientation sub-dimension between the experimental and control groups [$t(71)=2.097$, $p<.05$; $d=0.498$]. It was concluded that the mean scores of extrinsic goal orientation of the experimental group students ($M=4.75$, $SD=0.33$) were higher than the control group students ($M=4.53$, $SD=0.53$), as expected.

5.2.3 Task value

There was a statistically significant difference regarding the task value sub-dimension between the experimental and control groups [$t(71)=2.016$, $p<.05$; $d=0.462$]. It was concluded that the mean scores of task value of the experimental group stu-

dents (M=4.51, SD=0.44) were higher than the control group students (M=4.28, SD=0.55), as expected.

5.2.4 Learning belief

There was a statistically significant difference regarding the learning belief sub-dimension between the experimental and control groups [t(71)=2.250, $p<.05$; d=0.516]. It was concluded that the mean scores of learning beliefs of the experimental group students (M=4.32, SD=0.37) were higher than the control group students (M=4.09, SD=0.51), as expected.

5.2.5 Self-efficacy

There was a statistically significant difference regarding the self-efficacy sub-dimension between the experimental and control groups [t(71)=2.709, $p<.05$; d=0.627]. It was concluded that the mean scores of self-efficacies of the experimental group students (M=4.31, SD=0.65) were higher than the control group students (M=3.86, SD=0.78), as expected.

5.2.6 Test anxiety

There was not a statistically significant difference regarding the test anxiety sub-dimension between the experimental and control groups [t(71)=0.954, $p>.05$; d=0.228]. It was concluded that the mean scores of test anxiety sub-dimension of the experimental group students (M=3.56, SD=1.03) were higher than the control group students (M=3.31, SD=1.16).

5.3 Students' opinions

Semi-structured interviews were conducted with 12 students to identify student opinions on mobile-assisted seamless learning environments. Interviews were grouped under two categories: the advantages and limitations of AR and WhatsApp activities.

5.3.1 Positive reviews for the AR application

Useful, memorable, fun, visual effects, modeling, suitable for real life, easy learning opportunity, re-watch opportunity, memorable using three-dimensional shapes, interesting and intriguing were coded under the AR activities' advantages. Several positive student opinions on AR activities are presented below:

S1: "*The activities were good; we were able to see the modeling, not only the numbers. It is better in this way. I haven't used any AR application before. Videos were also good, and I grasped the subject better with examples. It was easier for me to understand when the topic was visualized*."

S2: "*We haven't used such a thing before. It was an interesting first use. I was amazed because it was three dimensional, and I was learning from it*."

S3: "*I think the application was good. It was easy to use. I liked the videos, and especially, they were memorable. AR affected me positively. It was different and more enjoyable compared to using a book.*"

S4: "*The activities are more memorable when they are three dimensional (...) For example, it is more memorable when an equation is modeled using scales instead of just writing it (...)*".

S6: "*I think the application is beneficial. We practiced more thanks to this application. I understood more easily since the solutions were adapted to real life."*

S7: "*It affected my daily life since it was memorable with its three-dimensional feature. I created solutions by visualizing them in class. The effects were outstanding.*"

S10: "*It helped me to reinforce the algebra which I learned before. Since it was also effective visually, it enabled the information to be memorable rather than just listening*."

S11: "*It was impressive. It was memorable, especially by visualization*."

S12: "*I think it was excellent. The activities and videos were enjoyable. I benefited from it*."

5.3.2 Reviews for the limitations of AR application

The difficulty of holding the tablet stable and lack of sound effects were coded under the AR application's limitations. Several negative student opinions regarding the negative properties of AR activities are presented below:

S1: "*(...) It was good to have lots of examples in the videos; however, it would have been better if it could be done without using paper.*"

S2: "*(...) The modeling could have had sound effects. It was also hard for me to watch and hold it at the same time.*"

5.3.3 Positive reviews for the WhatsApp

A platform for discussion, cooperation, being active, a warm environment, being together in an out-of-school environment, interpersonal tolerance, comparing solutions, learning different solutions, discussing questions, and defending one's ideas were coded under the advantages of WhatsApp. Several student opinions regarding the positive aspects of WhatsApp are presented below:

S1: "*We compared the parts we did incorrectly. We solved questions from time to time. We were solving questions together with our friends in an out-of-school environment*."

S2: "*I liked discussing with my friends in a social environment. We did not have such a group where we could discuss lessons before. (...) Discussing the questions with my teacher and my friends while solving the questions helped me learn the subject and easily figure out the solutions*."

S7: "*We cooperated nicely. We were informed about our mistakes immediately. We improved ourselves by explaining the subjects to others*."

S9: "*(...) It helped us since the questions that we do not think to ask or too shy to ask in class, are asked and discussed*."

S10: "*Both the students and the teacher established a sincere communication. Therefore, learning was easier and better in a pressure-free environment*."

5.3.4 Reviews for the limitations of WhatsApp

Time constraints, a low number of people, a lack of participation, and sharing questions in a virtual environment were coded under WhatsApp's limitations. Several student opinions regarding the negative aspects of WhatsApp are presented below:

S3: "*There could have been more people in the group. However, my interest in the subject increased in the group*."

S8: "*It would have been more effective if we had more time to share more questions. I mean, if we had more time to discuss the questions, it would have been better*."

6 Discussion

The post-test scores of the students who used the AR application for the activities were higher than the control group students, and the difference between the scores was statistically significant. The core of a seamless learning concept is connecting the in-class learning with out-of-class learning environments by planning and establishing an uninterrupted connection. The modeling within the algebra learning area is important, and connecting the algebra unit with real life is essential. The reasons for the study results could be the properties such as modeling in the AR application, the visualization impact created within the students, being able to re-watch, and embody the abstract concepts increasing student success. In addition, the uninterrupted continuation of in-class learning in out-of-class learning environments can be another factor that increases student success. Besides, discussing questions in WhatsApp groups enabled information exchange between peers during the application period, and individual learning was supported by social learning. The students may have overcome their deficiencies in the algebra learning area via their peers in group discussions. This situation was observed in the student interviews as well. The students were socially involved in the learning process via the WhatsApp groups, and they also showed an increased interest. There are similar studies in the literature that have similar results (Chen, 2019; Fabian et al., 2018; Gecu-Parmaksiz & Delialioglu, 2019; Özdemir & Özçakır, 2019). The study of Fößl et al. (2016) examined the effects of the mathematics seamless learning process on student success, concluding that the experimental group students showing better learning performances, and new learning and teaching environments were indicated as the reasons. Al Khateeb (2019) highlighted the flexibility of time and space provided by mobile applications to students and stated that students are more successful in mathematics when used in mobile applications. Kalloo & Mohan (2012) stated in their study that the MobileMath application positively affected the algebra performance of secondary school students who learned algebra before but did not result in a statistically significant difference for the students who took this lesson for the first time. The researchers stated that the students found the game-based teaching using mobile devices enjoyable and highlighted the need to produce content to support academic development. Support-

ing environments outside the classroom with mobile technologies can increase students' success in focusing on digital relations (McMullen et al., 2019). In addition, augmented reality applications can help understand abstract concepts by converting abstract information into concrete objects or visualizing phenomena that are not suitable for students to access (Bujak et al., 2013). The use of teaching models in teaching processes makes learning more effective and contributes to the learning of skills and concepts that cannot be learned with traditional teaching styles (Altun, 2015). At this point, integrating augmented reality applications into the educational environment is considered important, and it is stated that this integration enhances the potential to provide better learning opportunities to students with its contribution to the teaching and learning processes (Dalim et al., 2017).

The mathematics motivation post-test scores of the students who followed the activities using AR activities were higher than those of the control group. The difference between the scores was statistically significant. The reason for this result may be that the mobile technologies used in teaching increase the interest in learning. In other words, the students may have shown more interest due to AR activities. This interest may have increased the will; hence, the motivation of students to learn. In addition, visual stimuli and technological opportunities may have eased learning processes as a result of AR activities. The students may have dismissed the failure feeling and were motivated. There may have been a motivation increase to correctly solve the questions due to WhatsApp groups' competitive environment and enabling students to compare the solutions in those groups. In literature, it is possible to come across studies stating that using mobile technologies positively affects student motivation (e.g., Cahyono & Ludwig, 2018; Cahyono et al., 2020; Chen, 2019; Estapa & Nadolny, 2015). Cahyono and Ludwig (2018) stated that learning mathematics by discovering it in out-of-school environments using mobile applications supports positive motivations of students. Similarly, various reasons such as mobile applications being interesting to students (Nasir & Nirfayanti, 2019), enabling collaborative learning (Lee et al., 2019), being more fun than normal teaching applications, and making the lesson interactive (Drigas & Pappas, 2015) can have positive effects on motivation.

The students within the study's scope stated positive opinions on AR activities, such as being beneficial, enabling memorability, being enjoyable, the created visual impact, compatibleness with real life, and including modeling. On the other hand, two students who expressed positive opinions about the application also stated technical problems such as not holding the tablet still and lack of sound effects in animations. All students expressed that the application enabled easy learning, enhanced memorability using 3D shapes, enabled re-watching, contributed to fast learning, helped visualize using modeling, made learning enjoyable, and developed a sense of curiosity. The students expressed positive opinions such as being able to remember the activities while solving the questions, benefiting from similar questions, being able to re-watch in case there is a part that they did not understand, reinforcing the subject and the activities being detailed, regarding how the activities helped while solving the problems. All students expressed that AR activities positively affected their interest and will to learn the subject. Students stated that including the technology in learning, using the application for the first time, the application being interest-

ing and enhancing the sense of curiosity and that it is different, and the application being adaptable to real life as the reasons for this. Students expressed positive opinions about WhatsApp regarding the feature to discuss the questions and being able to convene out-of-school. Two students also stated negative opinions regarding sharing questions in a virtual environment and a lack of participation in the groups. Eight students expressed positive opinions on group communication in WhatsApp groups regarding cooperation, everybody being active, a warm environment, and interpersonal tolerance. In contrast, four students stated that group meetings' duration was short, and there should have been more students in the group. Besides, all students expressed positive opinions on cooperation between students and being able to compare solutions. The students stated positive opinions on defending one's ideas, concentrating on the question together, and learning different solutions when asked a question within the motivation theme's scope. It was determined that students did not have any experience using AR activities and participating in WhatsApp groups. Therefore, participating in such a seamless learning environment for the first time may explain the positive opinions in general. There are similar studies in the literature that have similar results. For example, Fabian et al. (2018) stated that students have positive opinions on using mobile technologies since these technologies make the lesson interesting, enjoyable, and beneficial. Baya'a & Daher (2009) stated that students have positive opinions on using mobile phones in mathematics lessons about the fact that being able to learn independently, learning, and visualizing mathematics due to teamwork and collaboration. Çetinkaya (2019) expressed that student stated positive opinions on using the instant messaging application WhatsApp, using mobile technology, and that WhatsApp is a correct approach, and students would like similar applications and technologies to be used for other lessons as well.

7 Limitations and future directions

The study is limited to the achievements in the 7th-grade algebra learning field and the activities related to these achievements. It is recommended that future studies be conducted on different subjects and at different grade levels to examine the effects of mobile applications. In addition, the study was carried out with 73 students. Different experimental studies can be carried out with students selected from wider audiences to be able to generalize the research. As in this study, a literature review revealed that mobile technology applications are used in out-of-school learning environments (e.g., Cahyono & Ludwig, 2018; McMullen et al., 2019). In this context, to increase the prevalence of augmented reality applications, projects in which mathematics exhibitions or activities in which this technology takes place can be prepared and its effect in the context of seamless learning can be studied. In addition, WhatsApp groups were created to support social learning within the seamless learning in the study. Positive effects of WhatsApp groups on students were observed; the utility as an essential social learning tool in increasing mathematics achievement and mathematics motivation was tested. Hence, by creating common groups for different learning areas, students' socialization, success, motivation, or other learning variables can be examined more broadly.

8 Conclusions

The study concluded that mobile technology-supported learning environments enabled statistically significant increases in students' academic achievement and motivation levels. In the motivation sub-dimensions, a statistically significant difference was found between the experimental and control groups regarding external goal orientation, subject value, learning belief, and self-efficacy levels. However, there was no significant difference in the internal goal orientation and test anxiety sub-dimensions. According to the results obtained from the interviews, the students stated that the application is interesting, fun, supports cooperative learning, and facilitates learning. On the other hand, some students expressed the physical problems they experienced while using the tablets.

Among the difficulties experienced in learning mathematics, the existence of abstract concepts was pointed out, and the necessity of using materials in a way that would reduce the abstractness of the concept to be explained was stated (Tatar & Dikici, 2008). For this purpose, developments in technology offer new prospects to increase students' comprehension levels in the teaching process (Açıkgül & Aslaner, 2020). In this regard, presenting the models supported by augmented reality applications in terms of embodying abstract concepts with visual elements is important for middle school students who switch from arithmetic to algebra. We also think that it is important to take individual and social learning into consideration together. In this context, mobile technologies offer many opportunities for both individual and social learning.

The recent Covid-19 pandemic and technology developments have revealed the importance of out-of-school learning environments. In this context, we think that mobile-assisted learning studies that will bridge formal learning and informal learning are valuable, and this is an area that needs to be studied further.

Declarations

Conflict of Interest None.

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