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Effect of technology-enriched learning environment on academic achievement of seventh-grade students in quadrilaterals*[3]

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- Effect of technology-enriched learning environment.
- Seventh-grade students in the quadrilaterals achievement.
- A pre-test/post-test matched control group quasi-experimental design.

Abstract
This research examined the effect of a technology-enriched classroom environment on achievement and retention in quadrilaterals of seventh graders. The quasi-experimental design of quantitative research with a pre-test/post-test matched control group was chosen as the research design. The research population consists of seventh-grade students of a city in the Central Anatolian Region. A middle school with nine branches at the seventh-grade level was determined, the equivalence test was applied to the students, and the equivalent classes were determined. After the classes were determined, these classes were randomly distributed to the groups. It was ensured that two mathematics teachers from the determined groups, one mathematics teacher in the experimental and control group, and another mathematics teacher in the other experimental and control group. The current seventh-grade quadrilateral program was applied to the control groups, and the learning environment program enriched with technology was applied to the experimental groups. Descriptive statistics of the scores obtained from the equalization, pre-test, post-test, and retention tests were calculated. Then, normality tests of these tests were performed. In the analysis, item analyses were used for the achievement test, one-way analysis of variance (ANOVA) for the equalization test, independent samples t-test, Mann-Whitney U Test, and paired samples t-test were used within the scope of research problems. As a result of the research, statistically significant mean differences between the experimental and control groups favored the experimental groups between post-test and persistence test scores. According to the technology-enriched learning environment program, teaching quadrilaterals increases students' achievement and permanent learning. In line with the results obtained, some suggestions were made.

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1. Introduction

Mathematics teaching emphasizes practices and learning approaches that help increase students' interest and understanding of mathematics rather than just transferring knowledge theoretically and logically. One of the approaches suitable for this is technology-enriched learning (TEL) which is defined as learning in which technology-based tools and applications support any learning environment, and learning is improved in this way (Wang & Hannafin, 2005). TEL provides a source of learning paradigms of the information society in terms of revealing innovative trends and evaluating research results (Goodyear & Retalis, 2010).

Technology transforms the learning process and provides advanced opportunities to gain knowledge and skills (Goodyear & Retalis, 2010). The rapid development of technology, increased access to technology, and diversification of communication methods have brought about the need for technological change and educational growth (NCTM, 2015). Research attempts to show how and to what extent learning occurs in interaction with technology. These positive and negative consequences by TEL can inspire educators and future instructional technologies in terms of how learning can be created more effectively (Coldwell-Neilson, 2018). Technology should be used to support individuals in the knowledge-creation process, considering the opportunities and risks it creates (Daniela, 2018).

TEL can be achieved through computers, tablets, interactive whiteboards, dynamic geometry software, visualization tools, spreadsheets, computer-supported interactive learning applications, simulations, holograms, educational games, digital learning content, and similar applications (Goodyear & Retalis, 2010). TEL can be arranged as digital, hybrid, or face-to-face classes, online learning environments, and online open learning environments where many students can participate (Duval et al., 2017). Self-learning, collaborative, or didactic learning can be used at these TEL. Students can analyze information, take responsibility for learning, and accept innovations (Daniela, 2018). In TEL, emphasis is placed on teaching practices, equipment, and the physical conditions of the environment where teaching will take place (Tondeur et al., 2015). Technology supports existing strategies in learning and teaching and creates opportunities to produce new strategies (Flavin, 2020). TEL increases academic motivation, encourages student participation (Xu et al., 2019), supports students' achievements (Sarıaslan & Küçük-Demir, 2020), and retention of learning with different learning styles (Gülbahar, 2005). Students can produce arguments based on scientific findings and create products based on them with TEL. In a TEL, learners develop skills such as critical thinking, expressing their ideas, sharing, and manipulating (Goodyear & Retalis, 2010).

National Council of Teachers of Mathematics (NCTM) describes one of the six key principles in mathematics teaching as the technology principle: "Technology is essential in teaching and learning mathematics; it affects teaching and enhances learning" (NCTM, 2020; p.11). NCTM supports the effective use of technology to enhance understanding and intuition and enrich mathematics teaching. Within the scope of the Fatih Project in Turkey aims to prepare and effectively use TEL equipped with interactive boards, supported by audio-visual materials, animations, simulations, videos, and other learning objects, to actively use information communication technologies (ICT) in the learning and teaching process in schools (MoNE, 2011). As an important part of learning environments, ICT allows for a structured and multidimensional learning environment and increases achievement (Erduran, 2020; Hıdıroğlu, 2012; Sarıaslan & Küçük-Demir, 2020).

Online learning technologies include collaborative learning environments, social networks, digital content, digital games, mobile devices, cloud technology, three-dimensional printing, virtual laboratories, holograms, tablets, and wearable technologies (Badia, 2015). These applications enable versatile and individualization of learning. Geometry 2.0 tools such as GeoGebra, Cabri 3D, and Geometers Sketched support collaboration and enable learning by discovery (Joglar Prieto et al., 2014). Digital transformation gained momentum with Industry 5.0, Society 5.0, and Education 5.0. The Internet of Things, cyber-physical systems, internet services, collection of big data, and artificial intelligence software have made technology an indispensable part of life (Xing & Marwala, 2017). Structuring learning environments in line with this transformation process can provide a more effective learning environment for today's digital natives.

Instructional technologies deeply affect the development of teachers and students, and the resulting product has a personal effect as much as the effect of the software, which gives students the chance to take responsibility for their learning. Its flexible use features promise responsible use and effective learning outside of school (Trouche & Drijvers, 2010). TEL enables students to make connections between algebraic and geometric representations that develop mathematical reasoning skills such as generalization, prediction, and proof (Zengin, 2021) and significantly increases achievement in sixth-grade angles compared to traditional teaching (Sarıaslan & Küçük-Demir, 2020). Dynamic geometry software significantly increases achievement compared to traditional tools (Ng et al., 2020). Using Geogebra increased student performance in analytical geometry (Saha et al., 2010). Technology-supported teaching differs significantly from traditional teaching based on geometry achievement and attitude (Deniz, 2019). The justifications and evidence skills in the argument structures of seventh-grade students differ depending on the use of technology (Sucu, 2021). To conclude, TEL can help students produce practical solutions and structure geometry that will contribute to their thinking and learning skills in the face of the abstract structure of geometry.

1.1. Use of Technology in Teaching Geometry

Along with the tools and applications, TEL aims to enhance learning and teaching. However, technology should not be used in isolation to develop a solution; instead, it should support mathematical logic and reasoning (Liang, 2016). Teachers are also expected to use instructional technologies at a certain level of proficiency. It is vital to recognize the features of these technologies and adapt them appropriately to TEL. Therefore, technology-enriched instruction must be carefully planned and designed with the right tools. Students' ability to generate ideas about geometry topics and test them through instructional technology enhances their higher-order thinking skills (Bozkurt & Ruthven, 2018). Instructional technologies are most effective when they help discover information through technology and evaluate its accuracy rather than simply presenting ready-made information (Bozkurt & Ruthven, 2018). There are various educational software that can be used to teach geometry. The most frequently encountered dynamic geometry software in the literature are GeoGebra, Cabri 3D, Geometer's Sketchpad, and Desmos. Teaching based on dynamic geometry software significantly positively affects students' achievement (Chan & Leung, 2014). Positive features of the use of dynamic geometry software have been determined, such as understanding concepts, preventing misconceptions, and providing ease of access to achievements and generalizations (Gürbüz & Gülburnu, 2013; Onal & Demir, 2013; Sarıaslan & Küçük-Demir, 2020). The use of dynamic geometry software increases interest in, and changes view towards mathematics positively and make the lessons more fun (Erdener & Gür, 2019; Özçakır-Sümen, 2022; Tuzer-Ünsal & Akay, 2020). On the other hand, it is recommended that instructional technologies be used to evaluate mathematics in a digital environment (Drijvers, 2018). The instructional technologies used in this study are briefly mentioned below.

GeoGebra, an open-source dynamic mathematics software, is a teaching tool for geometry and algebra calculations. Mathematical models, various activities, and simulations can be prepared and shared. GeoGebra has features that include both two- and three-dimensional drawing, a computer algebra system, process monitoring, recording, and sharing. Using GeoGebra transforms the student from a passive receiver into an active participant, supporting his creativity (Ljajko & Ibro, 2013). It meets the teaching objectives and can be adapted for students of different ages and levels (Zilinskiene & Demirbilek, 2015). It provides a rich learning process that directs students to use different strategies, approaches, and thinking skills (Hıdıroğlu & Bukova-Güzel, 2014). GeoGebra-supported teaching significantly increased achievement and retention of learning (Birgin & Topuz, 2021). GeoGebra has been used in this study for visualization and geometric drawing, primarily by teachers.

Desmos is a free online application designed to help everyone learn mathematics and express ideas mathematically. Desmos allows students to review their strategies, reflect on them, change them, and see how the changes affect the whole (Gulli, 2021). Desmos is a tool that helps students discover mathematical concepts (Koştur & Yılmaz, 2017). The activities carried out with Desmos are effective in conceptual and procedural learning (Özer, 2023). Desmos was used in this study for visualization purposes, and it was chosen because students can easily use it.

Coogle is used to create mind maps and support learning. Mind mapping is a note-taking technique developed by Tony Buzan, and its structure resembles that of a nerve cell. Mind maps hierarchically relate information and increase the ease of remembering and retaining knowledge by supporting it with visual elements. Mind maps enable students to discover relationships between concepts, encourage creative thinking (Davies, 2011), and support learning mathematical concepts (Agustiani et al., 2019). Coggle was used in this study to create mind maps.

Storyboardthat helps create digital stories that learners of all levels can use for learning, teaching, and communication. Its' drag-and-drop platform allows learners to create their own stories and characters. There are options for paid and free use. Scenes, characters, fonts, text boxes, and many other features can be customized flexibly. Teachers design in-class materials and create educational content (Muhammad et al., 2023). Students can use digital storyboards to prepare group studies and projects. These drafts can be shared and saved to prepare an electronic portfolio. Digital storytelling achieves conceptual learning at the desired level, and students are interested in digital stories (Dinçer & Yılmaz, 2019) and increase student motivation and participation (Özpınar, 2017). Digital story applications focus on supporting learning and teaching. They aim to convey ideas to other people in the best possible way. It is a way for individuals to express their understanding concretely. Digital stories enable commonalities or contradictions in understandings to emerge (Parola et al., 2022). A storyboard has been utilized in this study for problem formulation, classification, and definition. Plickers allow quick feedback from students who are defined to the program. Based on the answers given by the students, it is determined which students are correct, incorrect, or unable to answer the question, and necessary feedback is given.

1.2. The Problem

TEL is interactive, dynamic, process-oriented, and analytical approaches open the doors to meaningful learning. Various instructional practices significantly contribute to teaching by revealing student creativity and potential. TEL transforms the traditional learning environments. It provides a dynamic, student-focused, highly interactive environment and emphasizes self-controlled learning. The opportunities provided by technology offer a wide range of tools to create unique representations and explore ideas and concepts (Saye & Brush, 2002). In addition to the radical effects of TEL on teaching methods, their goals and, therefore, their effects on the mathematical meaning formation and thinking skills in the learning process are also noted (Pea, 1987). Content-specific technologies in mathematics teaching include dynamic geometry software, interactive applications, manual calculators, data collection and analysis devices, and computer-based applications. Content-independent technologies include communication tools and Web-based digital media (NCTM, 2015). These technologies help students make sense of mathematical concepts and explore and define relationships.

The prevalence of tools that facilitate understanding concepts, such as modeling, graphics, and numerical calculation, enables the broader use of technology (Pea, 1987). TEL increases learning opportunities by reducing students' learning difficulties and increasing their interest and motivation (Demetgül & Baki, 2020). It contributes to developing metacognitive thinking and creative thinking skills (Gündüzalp, 2021). Using technology in the learning environment also enables the development of digital literacy skills (Grant, 2019). TEL affects achievement positively and significantly compared to traditional teaching (Hegedus et al., 2015; Kurvinen et al., 2020; Young, 2017) in sixth-grade subjects (Sarıaslan & Küçük-Demir, 2020). Sixth-grade students' misconceptions about height have been largely corrected at TEL (Senger, 2019), and their problem-solving skills have improved (Curaoğlu, 2012). In addition, students' positive opinions were recorded through TEL (Erduran, 2020).

TEL increases interest and motivation in mathematics, which is a reason for increased student achievement (Pari Condori et al., 2020; Wong & Wong, 2019). TEL enables the development of knowledge and skills by offering new ways of thinking about mathematics learning (Radović et al., 2019). TEL applied in geometry had a more positive effect than in mathematics (Çavuş & Deniz, 2022). Technologies such as GeoGebra, augmented reality, computer, animation, video, graphing calculator, and learning management systems are important components of geometry teaching (Sunzuma, 2023). Software such as Geogebra, which is used for technology enrichment, appeals to different sensory organs (Reisa, 2010). In this context, enriching with technology, in line with Gardner's Multiple Intelligence Theory, can appeal to different sensory organs and increase success by providing various methods and learning environments suitable for the student.

Activities prepared in accordance with the TEL make it easier for students to understand concepts, improve their problem-solving skills, make lessons more enjoyable, eliminate misconceptions, make it easier for them to understand the subjects, increase their achievement, improve their attitudes towards mathematics, support permanent learning and are more successful than traditional teaching (Aparı, 2019; Dikovic, 2009; Genç, 2010; Öz, 2015; Saha et al., 2010; Türkoğlu, 2014; Yılmaz, 2019). In addition, TEL contributes to students' skills such as reasoning, modeling, creative thinking, and inference (Çolakoğlu, 2018; Filiz, 2009). Inspired by these studies, TEL can increase the achievement of seventh-grade students in quadrilaterals and provide retention of earnings.

The widespread use of technology has prompted researchers to focus on the methods of utilizing and the effects of Technology-Enhanced Learning (TEL) in mathematics education. Şahin et al. (2024) highlighted the significance of technology-enhanced proof activities in establishing relationships, discovering insights, and generating hypotheses. Özkartal and Öçal (2021) demonstrated the positive impact of technology-enriched learning activities on the achievements and perceptions of fourth-grade students studying symmetry. Akyüz (2018) explored the roles of lecturers in creating content within geometry and in supporting mathematical thinking through argumentation-based technology. Sarıaslan and Küçük Demir (2020) noted that technology significantly influenced student achievement in the topic of angles in the sixth grade, compared to traditional teaching methods. This study aims to enrich the literature by presenting evidence supported by an experimental study on quadrilaterals in the seventh grade.

The research aims to investigate the impact of TEL on achievement and retention concerning seventh-grade quadrilaterals. TEL fosters an analytical approach to the subject, enabling students to grasp the concepts better. TEL positively affects achievements in quadrilaterals, which is part of the sub-learning areas of the polygons segment in the seventh-grade mathematics curriculum. Challenges arise in comprehending and applying the properties of quadrilaterals, environments, and area relations (Gülbağcı, 2009). Educational software and learning objects designed for this purpose can facilitate a more accurate understanding of quadrilaterals.

Understanding the place and significance of technology in the teaching and learning process is crucial, as effective TEL applications relate closely to student achievement (International Society for Technology in Education, 2008). In this context, the study is deemed important for revealing the effectiveness of TEL on seventh-grade achievements in quadrilaterals. It is vital to explore the impact of TEL in identifying solutions for assessing students' achievements in quadrilaterals. The problem this research addresses is: How does TEL affect seventh-grade achievement and retention regarding quadrilaterals? The sub-problems of this research are:

- Is there a statistically significant mean difference between the pre-test, post-test, and retention test of the students in the control and experimental groups caused by TEL?
- Is there a statistically significant mean difference between the pre-test and post-test achievement of the students in the control and experimental groups caused by TEL?
- In teaching the subject of quadrilaterals, is there a statistically significant mean difference between the post-test and retention test scores of the students in the control and experimental groups?

2. Method

2.1. Research Design

A pre-test/post-test matched control group quasi-experimental design, one of the quantitative research, was chosen as the research model. In this design, groups are matched based on certain criteria. Matched groups are randomly assigned to treatment groups (Büyüköztürk et al., 2018). The two random experimental and control groups were created by impartial assignment, in which certain procedures are performed before and after the experiment (Fraenkel & Wallen, 2009). The group subject to the TEL is the experimental group. In this design, a pre-test is performed to determine whether the experimental and control groups show similar characteristics before the experiment, and the pre and post-test results are examined to reveal the effect of the TEL on the groups (Karasar, 2018). The effect of a TEL on seventh-grade students' achievement and permanent learning about quadrilaterals was examined. This study's independent variable was the TEL curriculum, and the dependent variables were pre, post, and retention tests.

2.2. Population and Sample

The population consisted of seventh-grade students from a city in the Central Anatolia. A middle school was selected from the city to determine the sample. Before selecting this school, information was obtained about the number of seventh-grade classes and students in the city and the mathematics teachers teaching these classes. Teachers have similar characteristics, and their knowledge about mathematical software has been an important factor in choosing a school. Since this school was easily accessible by the researcher, it was selected by an appropriate sampling method; "Appropriate sampling method is the collection of data from a sample that the researcher can easily reach." (Büyüköztürk et al., 2018, p.95). The distribution of students in classes is shown in Table 1.

Table 1. Student distribution in classes

Class	f	%	Class	f	%
A	32	11.2	F	32	11.2
B	32	11.2	G	31	10.8
C	32	11.2	H	32	11.2
D	31	10.8	K	32	11.2
E	32	11.2	Total	286	100

The researcher interviewed three teachers who taught seventh-grade mathematics at the selected school and gave detailed information about the research. As a result of the interviews, teachers voluntarily participated in the research. As given in Table 1, there are nine classes and a total of 286 students at the seventh-grade level in the school. To determine whether classes are equivalent to each other, an equalization test was prepared by taking expert opinions. The equalization test is explained in detail in the next section. As a result of the equalization test, classes were equivalent. Classes 7B, 7E, 7F, and 7K were determined by random selection. Thus, the sample was a total of 128 students in classes. Elif taught the mathematics lesson for 7B and 7E, and Ayşe taught the mathematics lesson for 7F and 7K. With random selection among these classes, the experimental groups were 7B and 7K, and the control groups were 7E and 7F.

Table 2. Descriptives of teachers

Teacher	Type of Faculty Graduated from	Education Level	Professional Experience	Experience of 7th Grade	Does Teacher Use Mathematics Software?
Elif	Education	Masters	14 Years	8 Years	Yes
Ayşe	Education	Masters	17 Years	10 Years	Yes

As shown in Table 2, Elif and Ayşe displayed similar characteristics. In the interviews, both teachers demonstrated knowledge of mathematical software such as GeoGebra, Cabri, and SketchPad. Additionally, they completed courses on mathematical software during their undergraduate and graduate studies. Teachers possessing similar characteristics have played a significant role in teacher selection.

The researcher held meetings with the teachers before and after the treatment to exchange ideas. Elif and Ayşe implemented the treatment, with the researcher periodically supporting the teachers during interviews. In particular, the researcher informed the teachers about mathematical software and its usage. The researcher did not actively engage in the treatment process, significantly contributing to the results' objectivity. One mathematics teacher manages one experimental and control group, while the second mathematics teacher manages the other experimental and control group. The groups are organized to determine whether technology-enhanced learning (TEL) is effective on quadrilaterals. Managing the process with a teacher raises the question of whether students' achievement is influenced more by the teacher rather than by TEL. Conducting the implementation of the research with two mathematics teachers enhances the study's objectivity.

2.3. Examining the Equivalence of Classes and Determining Groups

The selected school has nine classes, and to determine whether these classes are equivalent, the researcher prepared an equalization test consisting of questions from the MoNE Scholarship Examination from previous years. During the preparation and finalization of this test, the opinions of four experts, including three mathematics teachers and one faculty member from the elementary mathematics education department, were taken. The questions in the equivalence test cover the students' quadrilateral knowledge. It was prepared to determine whether the classes were equivalent or not.

There was a total of 20 questions in the equivalence test. Questions 2, 3, 4, 7, 8, 9, and 20 of the test are from the 2021 7th Grade Scholarship Exam. Questions 5, 10, 14, and 15 are from the 2020 7th Grade Scholarship Exam. The 12th question is from the 2019 7th Grade Scholarship Exam. The 13th question is from the 2018 7th Grade Scholarship Exam. The 19th question is from the 2017 7th Grade Scholarship Examination. Questions 6, 1, and 11 are from the 2022 6th Grade Scholarship Exam. Questions 16, 17, and 18 are from the 2021 6th Grade Scholarship Exam. The equalization test was administered to 9 classes in the first week of the second semester of the 2022-2023 academic year. As a result of the equalization test, descriptive statistics of the classes are given in Table 3.

Table 3. Descriptive statistics results of equalization test

Class	N	$\bar{X}$	Mod	Median	ss	Kustosis	Skewness	Kolmogorov-Smirnov statistics	df	p
7A	32	51.88	50	50	23.44	-0.76	0.27	0.134	32	0.149
7B	32	50.31	45	45	20.12	0.39	0.37	0.135	32	0.143
7C	32	49.69	50	52.5	20	0.11	-0.05	0.147	32	0.077
7D	31	47.74	45	50	22.21	-0.94	0.1	0.143	31	0.109
7E	32	48.28	50	50	15.48	-0.48	-0.18	0.145	32	0.087
7F	32	51.1	50	50	19.04	-0.35	0.42	0.148	32	0.073
7G	31	49.03	45	50	23.32	-1.05	0.14	0.146	31	0.092
7H	32	48.91	45	45	21.91	0.13	0.9	0.143	32	0.093
7K	32	49.69	50	50	20.71	-0.14	-0.34	0.131	32	0.176

As given in Table 3, the mean, mode, and median values of the classes' equalization test scores are close. The kurtosis and skewness values of the classes' equalization test scores showed a normal distribution since they were between +1.5 and -1.5 (Tabachnick & Fidell, 2015). In addition, the normality test of the equalization test scores of the branches was conducted and the results are given in Table 3. The Kolmogorov-Smirnov test was performed since the number of students in the branches was $n>30$ (Bursal, 2017; Cevahir, 2020). According to the test results, it was seen that the p-value of each group was greater than 0.05. In light of these results, the equalization test scores of the branches showed a normal distribution.

Since the equalization test scores of the classes showed a normal distribution, a one-way analysis of variance (ANOVA) was run. First of all, the homogeneity test of the equalization test scores was performed based on classes, and the equalization scores showed a homogeneous distribution (F_{Levene} $(8, 277)= 1.239$; $p=0.276>0.05$). Then, ANOVA was performed to determine whether the classes were equivalent, and the results are shown in Table 4. There is no statistically significant mean difference between the equalization test scores of the classes ($F (8, 285) = 0.127$; $p=0.998>0.05$). The mathematics and geometry knowledge of the students in the classes are close to each other. After the equivalence of the classes was ensured, classes 7B, 7E as Elif's class, 7F, and 7K as Ayşe's class were determined by random selection. Then, again, random selection determined which classes were the experimental and control groups.

Table 4. ANOVA results on equalization test scores of classes

Source	Sum of Suares	df	Mean of Squares	F	p
Between gorups	441.517	8	55.190	0.127	0.998
Within groups	119944.934	277	433.014		
Total	120386.451	285			

2.4. Development of Achievement Test

The Mathematics Lesson Curriculum was examined before creating the achievement test to be prepared on quadrilaterals (MoNE, 2018). In the curriculum, quadrilaterals are included in the Geometry and Measurement learning area under the sub-heading of polygons. The researcher conducted a literature review and created a question pool consisting of 60 questions. This question pool was reduced to 25 questions by taking the opinions of five experts, including a Turkish teacher, three mathematics teachers, and a faculty member from the primary school mathematics teaching department. The first question among these is the 2022 7th Grade Scholarship Exam question. The third question is the question that appeared in the 2010 7th Grade SBS Exam. Question 17 is a question in the 2008 7th Grade SBS Exam. The 8th question is the question in the 2007 7th Scholarship Exam. The other questions were inspired by the scholarship exam questions and prepared by the researcher in line with expert opinions, using 7th-grade mathematics textbooks.

The first version of the achievement test, consisting of 25 questions, was administered to 300 8th-grade students in the same school as 7th-grade students at the beginning of the 2022-2023 academic year. The reason why the first version of the achievement test was administered to 8th graders was that 7th graders had recently learned the quadrilaterals. Questions in the achievement test should be multiple choice. Those who answered each question correctly in the achievement test were given one point, and those who answered incorrectly or left blank were given zero points. In this way, both question-based and total scores of 300 students were calculated. Students are ranked from highest to lowest according to their scores. Since 27% of the number 300 is 81, 81 students with high scores formed the upper group, 81 students with low scores formed the lower group, and the item analysis method with lower and upper groups was performed.

Kuder Richardson-20 (KR-20) value was calculated to determine the internal consistency coefficient of the achievement test. The KR-20 value of 25 questions in the quadrilateral achievement test, which was piloted, was calculated as 0.915. After removing eight questions with a low item discrimination index, the KR-20 value of the remaining 17 questions was calculated as 0.928. When the KR-20 value is 0.80 or above, the measurements obtained in the test are reliable (Secolsky & Denison, 2018). As a result of the item analysis and KR-20 analysis, it was concluded that the quadrilateral achievement test is a test of very good discrimination, high reliability, and medium difficulty.

2.5. Process of Preparing a TEL Program

The results obtained from the researcher's professional experience and interviews with colleagues determined that students had difficulty in learning quadrilaterals (Gülbağcı, 2009). Based on this, the researcher investigated what could be done to enrich the learning environment regarding quadrilaterals, and the idea of using various technological tools in mathematics lessons gained importance. In this context, applications such as Geogebra, Desmos Geometry Tool, Storyboardthat, and Coogle have gained importance by taking expert opinions. From these applications; Geogebra was used for visualization and geometric drawing. Desmos Geometry Tool was used for visualization purposes. Storyboardthat was used for problem posing, classification and definition purposes. Coogle was used for mind-mapping purposes.

The planning phase for lessons and activities incorporating the aforementioned practices on quadrilaterals has commenced. During this process, the researcher consulted the opinions of five experts, three mathematics teachers, and one faculty member from the mathematics teaching department while developing the program. He crafted the lesson plan and activities based on expert insights and information gathered from a literature review. The plans and activities were prepared in alignment with the 7th-grade quadrilateral goals outlined in the "Mathematics Lesson Curriculum," and expert opinions were sought once again. Based on expert feedback, the importance of obtaining rapid feedback from students at the end of each achievement and swiftly addressing any learning deficiencies that might arise became evident. Consequently, it was decided to integrate the "Plickers" application into the lesson plans and activities, which facilitates quick feedback to students.

The researcher conducted the pilot study of the developed lesson plan and activities over approximately three weeks in January during the 2022-2023 academic year. Following the pilot study, it was determined that one key area needing improvement was introducing the features of the applications to the students. Another identified area for enhancement was the determination that it would be beneficial to show short videos on the topic at the beginning of the lesson to capture students' attention. These deficiencies were discussed with the experts, and in response to their feedback, the application features were introduced and incorporated into the first lesson plan. To address the other deficiency, "Khan Academy videos" were used to engage students and added to the lesson plan. A revised pilot study reflecting these adjustments was conducted, and no negative effects were observed. This updated pilot study commenced in another 7th-grade class during the last week of February and continued for 12 lesson hours (approximately three weeks).

2.6. Courses Conducted within the Scope of Research

The courses carried out within the scope of the research started to be implemented as of the last week of March in the second semester of the 2022-2023 academic year. The experimental and control groups started two different programs at the same time. Twelve-course hours (approximately three weeks) are allocated to both programs. The mathematics teachers who taught the experimental and control groups paid due attention to the objectives and lesson hours. Experimental and control groups started and finished their respective programs simultaneously. During this process, the researcher and the mathematics teachers who implemented the programs constantly communicated.

2.6.1. Lessons Conducted in Control Groups

The lessons in the control groups of Teachers Elif and Ayşe were carried out in the classroom environment for twelve lesson hours in accordance with the achievements in the Mathematics Lesson Curriculum. Activities are included to increase students' academic achievement. The activities were carried out with the students in the classroom environment. The lessons conducted in the control groups were conducted based on the mathematics textbook distributed to students by the Ministry of Education. In addition, the warnings about quadrilaterals in the Mathematics Curriculum were also considered. The researcher and practitioner teachers prepared lesson plans and activities to be applied to the control groups, paying attention to the outcomes and the mathematics textbook.

The lesson plan applied to the control groups is presented in detail in Appendix 4. When this plan was examined, previously prepared square, rectangle, rhombus, trapezoid, and parallelogram shapes were distributed to the students for the first learning outcome on 7th-grade quadrilaterals. Students examined the side, angle, and diagonal properties of these quadrilateral types with the help of a ruler and protractor and filled in the relevant table given in the activities. Then, the practitioner teachers explained what was necessary, and the students took notes. Additionally, sample questions regarding the relevant quadrilateral type have been solved. Each type of quadrilateral was examined separately, and an evaluation study was carried out at the end of the objectives. In the second objective process, activities were carried out to determine the area relations of rhombuses and trapezoids. Again, practitioner teachers provided the necessary explanations for field relations. Sample questions have been solved for this achievement. In the third objective, area problems related to quadrilaterals were solved.

2.6.2. Lessons Conducted in Experimental Groups

The lessons for the experimental group were conducted using a technology-enhanced learning environment program aligned with the Mathematics Lesson Curriculum focusing on quadrilaterals. The mathematical software mentioned in the previous section was installed on the interactive classroom whiteboards in this setting. Initially, students in the experimental groups were informed about the features of these mathematical tools and how to use them. Next, the different types of quadrilaterals in the first objective were discussed separately, and their angle, side, and diagonal properties were explored with active student participation using Desmos and GeoGebra. After completing the activities on the characteristics of quadrilateral types, the students created mind maps illustrating the relationships among quadrilaterals.

In the second objective, the area relationships of rhombuses and trapezoids were developed through mathematical software according to the lesson plans and activities prepared for the classroom environment. The third objective involved activities to calculate the area of quadrilaterals, following the lesson plan. Additionally, Khan Academy videos were occasionally used to engage students' attention at the beginning of the course.

At the end of the lesson, questions were posed using the Plickers application to evaluate the students. This application provided rapid feedback from all students, allowing for the quick identification and correction of any learning deficiencies. Furthermore, this application reinforced students' correct understanding.

2.7. Pre-Test, Post-Test, and Retention Test

Before the two mathematics teachers began working with one another and conducting their application with the experimental and control groups, the finalized achievement test was administered to assess whether there was a significant difference between the groups. The pre-test comprised 17 questions, with a maximum possible score of 100 points; the first 16 questions were worth 6 points each, while the final question was valued at 4 points. The pre-test, designed to meet the objectives of the quadrilateral subject, included 17 questions: 11 were related to the first learning outcome, 3 to the second, and 3 to the third. The emphasis on the first learning outcome stems from its comprehensive coverage of the characteristics of different quadrilateral types and their interrelationships. In the lesson plans prepared for the experimental and control groups, more class time was devoted to the first outcome than the other outcomes.

After the technology-enriched learning environment program was applied to the experimental groups and the current 7th-grade mathematics program was applied to the control groups, a post-test was applied to all groups. To prevent students from remembering the questions in the pre-test, the locations of some questions, the options of some questions, and the numerical values in some questions were changed. In the final test, the first 16 questions receive 6 points, and the last question receives 4 points. The highest score that can be obtained from the final test is 100 points. A retention test was applied to the experimental and control groups six weeks after the post-test. The retention test was prepared by changing the places of some questions in the final test and the options of some questions.

2.8. Data Collection Process

Before starting the research data collection process, equalization and achievement tests, daily plans, and activities for implementation were developed by taking expert opinions. Pilot studies of the developed tests and daily plans were carried out, and consulting experts made necessary adjustments again. Before the treatment, necessary permissions were obtained from both the university and the Provincial Directorate of National Education.

First, a pretest was applied to the experimental and control groups. Then, the current program was applied to the control groups, and the TEL program was applied to the experimental groups. Immediately after the relevant program was applied to the experimental and control groups, a post-test was applied to the experimental and control groups. Six weeks after the last test, a retention test was applied to the experimental and control groups. The data collection process of this research is briefly shown in Table 5.

Table 5. Data collection process

Teacher	Group	Pre-test	Application	Post-test
Elif	Experiment	Equivalence test Pre-test	TEL program	Post-test Retention test
	Control	Equivalence test Pre-test	Current program	Post-test Retention test
Ayşe	Experiment	Equivalence test Pre-test	TEL program	Post-test Retention test
	Control	Equivalence test Pre-test	Current program	Post-test Retention test

2.9. Data Analysis

A statistical program was used to analyze the data. Descriptive statistics of the equalization, pre-test, post-test, and retention tests were calculated. Then, normality tests of them were run. First, ANOVA was conducted to determine whether the nine classes were equivalent to each other based on the data obtained from the equivalence test. After the equivalent classes were determined, random assignment was made to the experimental and control groups.

Pre-test, post-test, and retention tests were applied to the experimental and control groups, respectively, and normal distribution was satisfied. An independent samples t-test was conducted to reveal whether there was a significant mean difference between the pre-test, post-test and retention test of each teacher between the experimental and control groups. An independent samples t-test was conducted to reveal whether the pre, post, and retention test of the control and experimental groups of Elif and Ayşe, who were the research implementers, differed significantly for each teacher. First, an independent samples t-test was conducted to see whether there was a significant mean difference between the pre-test of the students in the experimental groups of Elif and Ayşe. However, since the variances of the groups were not equal, the Mann-Whitney U Test, which is the non-parametric equivalent of the independent samples t-test, was used only in this analysis. A paired samples t-test was run to determine whether there was a mean difference between the pre and post-test of the experimental and control groups. Similarly, a paired samples t-test was conducted to see whether there was a statistically significant mean difference between the experimental and control groups' post and retention test mean.

3. Results

Descriptive statistics and normality of pre, post, and retention test scores of Elif and Ayşe's experimental and control groups are given in Table 6. The kurtosis and skewness values of the pre, post, and retention test scores of the experimental and control groups of Elif and Ayşe were normally distributed since they were between +1.5 and -1.5 (Tabachnick & Fidell, 2015). The number of students in the experimental and control groups was $n>30$; the Kolmogorov-Smirnov test was run (Bursal, 2017; Cevahir, 2020). As given in Table 6, the pre, post, and retention test scores showed a normal distribution.

3.1. Experimental and Control Groups of Elif

Independent samples t-test results are shown in Table 7 to see whether there is a significant mean difference between the pre, post, and retention test scores of the students in the control and experimental groups of Elif about quadrilaterals. The variances of the pre-test ($p=0.783>0.05$), post-test ($p=0.055>0.05$), and retention test ($p=0.061>0.05$) groups are distributed homogeneously. There is no statistically significant difference between the pre-test mean scores of the students in the experimental and control groups of Elif. Although the pre-test mean scores of the experimental group were slightly higher than the control group, there was no significant mean difference ($t(62) = 0.148$, $p = 0.883>0.05$). Cohen's d value is widely used in effect size calculations for the independent groups t-test, in which the mean difference of two groups is compared, and the paired samples t-test, in which the means of two measurements belonging to a group are compared (Özsoy & Özsoy, 2013). Cohen's d value is small, such as 0.20; values such as 0.50 are considered medium and values such as 0.80 are considered large effect sizes (Can, 2019; Cohen, 1988; Green & Salkind, 2005). The calculated effect value size (d = 0.037) showed that the mean difference in the pre-test scores of the experimental and control groups was very small. Elif's experimental and control group students' knowledge of quadrilaterals was close to each other before the treatment.

Table 6. Descriptive statistics results and normality of pre, post and retention test scores of experimental and control group of Elif and Ayşe

Teacher	Group-Test	N	$\bar{X}$	Median	sd	Skewness	Kurtosis	Kolmogorov-Smirnov Statistics	p
Elif	Experiment-pre	32	18.94	18	8.64	-0.54	0.11	0.133	0.162
	Experiment-post	32	56.19	53	21.6	-0.76	0.57	0.151	0.063
	Experiment-retention	32	55.44	52	21.31	-0.75	0.62	0.152	0.058
	Control- pre	32	18.63	18	8.25	-0.41	0.28	0.133	0.161
	Control- post	32	45.63	42	16.31	0.42	0.81	0.15	0.063
	Control-retention	32	38.88	36	15.82	-0.01	0.66	0.135	0.149
Ayşe	Experiment-pre	32	17.88	20	12.27	-1.27	-0.06	0.132	0.171
	Experiment-post	32	58.88	59	21.21	-0.88	0.40	0.134	0.154
	Experiment-retention	32	56.69	52	19.97	-1.06	0.54	0.144	0.9
	Control- pre	32	17.5	16	9.92	-0.27	0.42	0.148	0.073
	Control- Post	32	46	42	16.34	0.32	0.76	0.139	0.121
	Control-retention	32	39.31	36	16.43	1.22	0.97	0.142	0.98

Table 7. Independent samples t-test results regarding pre, post, and retention test scores of Elif's experimental and control group

Test	Group	$\bar{X}$	sd	Levene F	p	t	p
Pre	Experiment	18.94	8.64	0.076	0.783	0.148	0.883
	Control	18.63	8.25				
Post	Experiment	56.19	21.6	3.816	0.055	2.207	0.031
	Control	45.63	16.31				
Retention	Experiment	55.44	21.31	3.635	0.061	3.53	0.001
	Control	38.88	15.82				

There is a statistically significant mean difference between the students' post and retention test scores in the experimental and control groups of Elif. The post-test mean score of the experimental group was higher than that of the control group, creating a significant mean difference in favor of the experimental group (t (62) = 2.207, p=0.031<0.05). The effect size value was calculated as d=0.551. The fact that the retention test mean scores of the experimental group were higher than those of the control group created a significant mean difference in favor of the experimental group (t (62) = 3.53; p=0.001<0.05). The calculated effect value size (d = 0.882) showed that the mean difference in retention test scores of the experimental and control groups was high. These results showed that Elif's technology-enriched learning environment program to the experimental group on quadrilaterals increased the students' academic achievement and contributed to their permanent learning.

A paired samples t-test is performed to determine whether there is a significant mean difference between the two repeated measurements of a group (Cevahir, 2020; Pallant, 2017). The assumptions of this test are the same as the independent samples t-test (Büyüköztürk, 2011). Table 6 shows Elif's pre-test, post-test, and retention test of the experimental and control groups show a normal distribution. Since the pretest and posttest scores and posttest and retention test scores of the experimental and control groups show normal distribution, the paired samples t-test results are shown in Table 8.

As given in Table 8, there is a statistically significant mean difference between the pre and post-test of the students in the experimental and control groups of Elif. The post-test mean of the experimental group was higher than the pre-test mean, creating a significant mean difference (t (31) = -13.582; p=0.000<0.05). The effect size (d = 2.264) was large. The post-test mean of the control group was higher than the pre-test mean, creating a significant difference (t (31) = -8.566; p=0.000<0.05). The effect size was large (d= 2.089). Teaching the quadrilaterals by the TEL program increased the achievement of the experimental group in favor of the post-test. The achievement in the control group was also increased in the lessons conducted in the control group.

Table 8. Paired samples t-test results of Elif's pre test-post test and post test-retention test scores of the experimental and control group

Group	Test	$\bar{X}$	sd	t	df	p
Experiment	Pre	18.94	8.64	-13.582	31	0.000
	Post	56.19	21.6			
	Post	56.19	21.6	0.953	31	0.348
	Retention	55.44	21.31			
Control	Pre	18.63	8.25	-8.566	31	0.000
	Post	45.63	16.31			
	Post	45.63	16.31	1.926	31	0.063
	Retention	38.88	15.82			

There is no statistically significant mean difference between the posttest and retention test of the students in Elif's experimental and control groups. The fact that the post-test mean of the experimental group was higher than the retention test mean scores did not create a significant mean difference (t (31) = 0.953; p = 0.348>0.05). The effect size (d = 0.035) was very small. In the control group, the post-test mean was 6.75 points higher than the retention test mean, which did not create a significant mean difference (t (31) = 1.926; p=0.063>0.05). The effect size was small (d = 0.42). Since teaching quadrilaterals through the TEL program by Elif contributed to the meaningful learning of the students in the experimental group, there was no significant decrease in the retention test and the effect size was very small. The lessons conducted in the control group did not create a statistically significant difference in the retention test of Elif's control group.

3.2. Experimental and Control Groups of Ayşe

Pre, post, and retention test scores of the students in Ayşe's control and experimental groups showed a normal distribution. An independent samples t-test was conducted to see whether there was a significant mean difference between the pre, post, and retention test scores of the students in the control and experimental groups of Ayşe, as shown in Table 9.

Table 9. Independent samples t-test results of Ayşe's pre, post, and retention test scores of the experimental and control group

Test	Groups	$\bar{X}$	sd	Levene F	Levene p	t	df	p
Pre	Experimental	17.88	12.27	3.057	0.085	0.134	62	0.893
	Control	17.50	9.92					
Post	Experimental	58.88	21.21	2.409	0.126	2.72	62	0.008
	Control	46	16.34					
Retention	Experimental	56.69	19.97	3.043	0.086	3.801	62	0.000
	Control	39.31	16.43					

The variances of the pre (p=0.085>0.05), post (p=0.126>0.05), and retention (p=0.086>0.05) test groups are distributed homogeneously. There is no statistically significant difference between the pre-test mean of the students in the experimental and control groups of Ayşe. Although the pre-test mean of the experimental group was slightly higher than the control group, this did not create a significant mean difference (t (62) = 0.134, p=0.893>0.05). The effect size (d = 0.035) in the pre-test of the experimental and control groups was very small. This result showed that the knowledge of Ayşe's students in the experimental and control groups about quadrilaterals was close to each other before the treatment.

There is a statistically significant difference between Ayşe's post and retention test mean of the students in the experimental and control groups. The post-test mean of the experimental group was higher than that of the control group, creating a significant difference in favor of the experimental group (t (62) = 2.72; p=0.008<0.05). The effect size was calculated as d=0.68. The fact that the retention test mean of the experimental group was higher than that of the control group created a significant difference in favor of the experimental group (t (62) = 3.043, p=0.000<0.05). The effect size (d = 0.95) retention test scores between the experimental and control groups were high. These results show that the technology-enriched learning environment program that Ayşe applied to the experimental group about quadrilaterals increased the students' academic achievement and contributed to their permanent learning. Since the experimental group's pre-post and post-retention test scores showed normal distribution, paired-sample t-test results are shown in Table 10.

Table 10. Paired samples t-test results of Ayşe's pre test-post test and post test-retention test of the experimental and control group

Groups	Test	$\bar{X}$	sd	t	df	p
Experimental	Pre	17.88	12.27	-10.146	31	0.000
	Post	58.88	21.21			
	Post	58.88	21.21	1.135	31	0.265
	Retention	56.69	19.97			
Control	Pre	17.5	9.92	-8.082	31	0.000
	Post	46	164			
	Post	46	16.34	1.901	31	0.67
	Retention	39.31	16.43			

Table 10 shows a statistically significant mean difference between the pre and post-test of the experimental and control groups of Ayşe. The post-test mean of the experimental group was higher than the pre-test means, creating a significant mean difference (t (31) = -10.146; p=0.000<0.05)). The effect size (d = 2.266) was large. The post-test mean of the control group was higher than the pre-test mean, creating a significant difference (t (31) = -8.082; p=0.000<0.05). The effect size was large (d= 2.108). Teaching quadrilaterals, carried out by the TEL program, increased the achievement of the experimental group in favor of the post-test. The achievement in the control group was also increased in the lessons conducted in the control group.

There is no statistically significant mean difference between the posttest and retention test of the students in Ayşe's experimental and control groups. The fact that the post-test mean of the experimental group was higher than the retention test mean did not create a significant mean difference (t (31) = 1.135; p=0.265>0.05). The effect size (d = 0.109) was very small. In the control group, the post-test mean was 6.69 points higher than the retention test mean, which did not create a significant mean difference (t (31) = 1.901; p=0.67>0.05). The effect size was small (d = 0.408). Since teaching quadrilaterals through the TEL program by Ayşe contributed to the meaningful learning of the students in the experimental group, there was no significant decrease in the retention test and the effect size was very small. The lessons conducted in the control group did not create a statistically significant difference in the retention test of Ayşe's control group.

3.3. Comparison of Elif and Ayşe's Experimental and Control Groups

The control and experimental groups of Elif and Ayşe were compared. In this context, "Is there a statistically significant mean difference between pre, post, and retention test scores of students in the control and experimental groups of Elif and Ayşe regarding quadrilaterals?". The independent samples t-test results are shown in Table 11.

Table 11. Independent samples t-test results regarding pre-test, post-test and retention-test scores of Elif and Ayşe's control group

Test	Teacher	$\bar{X}$	sd	Levene F	Levene p	t	df	p
Pre	Elif	18.63	8.25	0.936	0.337	0.493	62	0.623
	Ayşe	17.50	9.92					
Post	Elif	45.63	16.31	0.001	0.975	-0.092	62	0.927
	Ayşe	46	16.34					
Retention	Elif	38.88	15.82	0.002	0.962	-0.109	62	0.914
	Ayşe	39.31	16.43					

The variances of Elif and Ayşe's pre (p=0.337>0.05), post (p=0.975>0.05), and retention scores (p=0.962>0.05) of the control groups are distributed homogeneously. There is no statistically significant mean difference between the pre and post-test mean scores of the students in the control groups of Elif and Ayşe. Although the pre-test mean scores of Elif's control group were slightly higher than those of

Ayşe's control group, there is no significant difference (t (62) = 0.493; p=0.623>0.05). The posttest mean scores of Ayşe's control group are slightly higher than those of Elif's control group. But this did not create a statistically significant difference (t (62) = -0.092; p=0.927>0.05). The effect size was d = 0.124 in the pre-test and d = 0.022 in the post-test. The effect size in the control groups of Elif and Ayşe showed that these differences were very small. The knowledge of Elif and Ayşe's students in the control group on quadrilaterals before and after the treatment was close to each other.

There is no statistically significant difference between the retention test mean scores of the students in the control groups of Elif and Ayşe. Although the retention test mean scores of Ayşe's control group were slightly higher than Elif's control group, this did not create a statistically significant mean difference (t (62) = -0.109; p=0.914>0.05). The effect size (d = 0.026) was very small. In the retention test applied after six weeks, the retention of knowledge about quadrilaterals of the students in the control groups with two teachers did not differ significantly.

As given in Table 6, the students' pre-test scores in the experimental groups of Elif and Ayşe showed a normal distribution. An independent samples t-test was conducted to see whether there was a significant mean difference between the students' pre-test scores in the Elif and Ayşe experimental groups. However, since the variances of the groups were not distributed homogeneously (p=0.013<0.05), the Mann-Whitney U Test, which is the non-parametric equivalent of the independent samples t-test, was used to determine whether there was a significant mean difference between groups in cases where one of the assumptions of the independent samples t-test is not met (Bursal, 2017; Cevahir, 2020). The results of the Mann-Whitney U Test are shown in Table 12.

Table 12. Mann Whitney U test on pre-test scores of Elif and Ayşe's experimental group

Test	Teacher	N	Mean Rank	U	p
Pre	Elif	32	33.19	490	0.766
	Ayşe	32	31.81		

There is no statistically significant difference between the pre-test mean of the students in the experimental groups of Elif and Ayşe. Although the mean rank of pre-test scores of Elif's control group was slightly higher than that of Ayşe's experimental group, this did not create a significant difference (p=0.766>0.05). The effect value size (d=0.1) was small. This result showed that the knowledge of Elif and Ayşe's students in the experimental group on quadrilaterals was close to each other before the treatment. To see whether there is a significant mean difference between the post and retention test of the students in the experimental groups of Elif and Ayşe, independent samples t-test results are shown in Table 13.

Table 13. Independent samples t-test results regarding the post-test and retention test of Elif and Ayşe's experimental group

				Levene				
Test	**Teacher**	$\bar{X}$	**sd**	**F**	**p**	**t**	**df**	**p**
Post	Elif	56,19	21,60	0,106	0,746	-0,502	62	0,617
	Ayşe	58,88	21,21					
Retention	Elif	55,44	21,31	0,037	0,848	-0,242	62	0,809
	Ayşe	56,69	19,97					

The variances of the post-test (p=0.746>0.05) and retention test (p=0.848>0.05) according to the teachers are distributed homogeneously. No statistically significant mean difference exists between the students' post and retention test in the Elif and Ayşe experimental groups. Ayşe's post-test mean (t (62) = -0.502; p=0.617) and retention test ($t_{(62)}$ = -0.242; p= 0.809) mean of Elif's experimental group. It is slightly higher than the experimental group. However, this did not create a statistically significant mean difference. Effect size values were as d = 0.126 in the post-test and d = 0.061 in the retention test. The effect sizes in Elif and Ayşe's experimental groups were very small. Elif and Ayşe applied a TEL program to the experimental groups. After the treatment, knowledge about quadrilaterals acquired by the students in the experimental groups with both teachers did not differ at a statistically significant level. In the retention test applied after six weeks, the retention of the knowledge about quadrilaterals acquired by the students in the experimental groups with both teachers did not differ significantly.

3.4. The Effect of TEL Program on The Learning of Quadrilaterals

ANCOVA was used to examine whether there was a significant difference between the post-test when the pre-test was controlled between the experiment in which the TEL program was applied and the control groups in which the current program was applied. Two assumptions of ANCOVA, homogeneity of variances and homogeneity of regression, were examined (Karagöz, 2017). Firstly, the homogeneity of variances of Ayşe and Elif's experimental and control groups is $F_{Ayşe}(1,62)=2.028$, $p=0.16>0.05$, and $F_{Elif}(1,62)=0.111$, $p=0.740>0.05$ was ensured. When the regression homogeneity assumption is examined in Table 14, Ayşe's control and experimental group $F_{Ayşe}(1) = 0.912$, $p=0.343 > 0.05$, the homogeneity of the regression is ensured. Thus, both assumptions of ANCOVA were met (Karagöz, 2017). $F(1)= 17.870$, $p=0.000<0.05$ in Elif's control group and experimental group, the homogeneity of the regression was not ensured. ANCOVA is a powerful analysis method, and when the number of students in the groups is low, the assumption of homogeneity of the regression can be considered as satisfied (Tabachnick & Fidell, 2015).

Table 14. ANCOVA assumption for Ayşe and Elif's groups (dependent variable: post-test)

Teacher	Source	Tip III Sum of Squares	df	Mean Squares	F	p
Ayşe	Corrected Model	3048,241[a]	3	1016,080	2,792	,048
	Intercept	45954,253	1	45954,253	126,274	,000
	Group	123,784	1	123,784	,340	,562
	Pre-test	16,139	1	16,139	,044	,834
	Gorup * Pre test	331,813	1	331,813	,912	,343
	Error	21835,509	60	363,925		
	Total	200864,000	64			
	Corrected Total	24883,750	63			
	a. R^2= ,122 (Adjusted R^2 = ,079)					
Elif	Corrected Model	11201,594[a]	3	3733,865	16,842	,000
	Intercept	9873,292	1	9873,292	44,535	,000
	Group	1684,396	1	1684,396	7,598	,008
	Pre-test	5022,121	1	5022,121	22,653	,000
	Gorup * Pre test	3961,717	1	3961,717	17,870	,000
	Error	13301,843	60	221,697		
	Total	190356,000	64			
	Corrected Total	24503,438	63			
	a. R^2= ,457 (Adjusted R^2 = ,430)					

Table 15. ANCOVA of Ayşe and Elif's groups

Teacher	Source	Tip III Sum of Squares	df	Mean Squares	F	p	Eta square
Ayşe	Corrected Model	2716.428a	2	1358.214	3.738	029	.109
	intercept	45967.034	1	45967.034	126.492	000	.675
	Group	64.178	1	64.178	.177	676	.003
	Pre-test	2637.405	1	2637.405	7.258	009	.106
	Group * Pre-test	22167.322	61	363.399			
	Error	200864.000	64				
	Total	24883.750	63				
	a. R^2 = .109 (Adjusted R^2 = .08)						
Elif	Corrected Model	7239.877	2	3619.939	12.791	.000	.295
	intercept	9455.419	1	9455.419	33.410	.000	.354
	Group	5454.815	1	5454.815	19.274	.000	.240
	Pre-test	1669.053	1	1669.053	5.898	.018	.088
	Group * Pre-test	17263.560	61	283.009			
	Error	190356.000	64				
	Total	24503.438	63				
	a. R^2 = .295 (Adjusted R^2 = .272)						

As given in Table 15, the mean difference between the post-test (pre-test corrected) means is statistically significant, as $p_{Ayşe}=0.009<0.05$ and $p_{Elif}=0.018<0.05$. The TEL program applied by Ayşe and Elif to the experimental group made a difference in the learning of the 7th-grade quadrilaterals and affected the students' achievements in quadrilaterals. Since the p-value of the pre-test of the quadrilateral achievement test is p = 0.000<0.05, the effect of the quadrilateral achievement pre-test on the quadrilateral achievement post-test is significant. The impact value is 23%.

4. Conclusion, Discussion and Recommendations

The teaching prepared to determine the effect of the TEL on learning the quadrilaterals was evaluated based on pre-test, post-test, and retention tests. Two different practitioner teachers researched one experimental and control group. The findings regarding the experimental and control groups of both practitioners followed a parallel course and did not create a significant difference. For this reason, the findings obtained in the applications are discussed together based on the literature.

The first result is that the means of the experimental and control groups of both practicing teachers did not differ based on their pre-tests. On the other hand, the experimental and control groups' post-test and retention-test means differed significantly in favor of the experimental group. This indicates that TEL of seventh-grade quadrilaterals positively and significantly affects achievement. Similarly, the experimental groups were more successful than the control group (Sarı, 2021).

Another result was that the pre-post averages of both experimental groups of practicing teachers differed significantly in favor of the post-test. There was no significant mean difference between the post and retention tests of the experimental groups. This situation was interpreted as the applied teaching positively affecting learning retention. Similarly, Geogebra-supported mathematics courses positively affect achievement and knowledge retention (Sevgi & Soylu, 2022). Moreover, the pre and post-test means of both control groups of practicing teachers differed significantly in favor of the post-test. This indicates that traditional teaching on quadrilaterals also has a positive effect. The mean difference between students' pre-test and post-test scores is an expected result, generally observed in the literature and indicates that new learning has occurred (Çilingir & Artut, 2016; Usta et al., 2018). In addition, no significant mean difference was detected between the post and retention tests of the control groups.

The fact that the mean scores of the experimental groups in the post-test were significantly different from the mean scores of the control groups is likely due to the advantages of the technology-enriched learning environment in the teaching process. These results demonstrate that technology-enriched teaching effectively teaches abstract mathematical concepts such as quadrilaterals, the properties of quadrilateral types, and area. Technology-enriched teaching allowed seventh-grade students to classify quadrilaterals, understand the relationships between them and grasp the properties of quadrilaterals. In this way, teaching helped students comprehend quadrilateral types and the area concept more concretely. The fact that these research results align with studies such as Altın (2012), Cengiz (2017), Dikovic (2009), Öner (2013), and Sarıaslan and Küçük-Demir (2020) contributes to the relevant literature on the effectiveness of technology-enriched teaching.

The mean retention test scores of the experimental groups significantly differ from those of the control groups. The finding of a significant difference favoring the experimental groups indicates that TEL activities help students retain the information they have learned more permanently compared to the current seventh-grade curriculum. This situation suggests that TEL positively impacts the understanding and learning of quadrilateral concepts and the retention of the applied teaching methods. Studies in the literature indicate that TEL is effective in enhancing the permanence of the information students acquire. Notable examples include Topuz (2017) on circles; Genç (2010) on polygons and quadrilaterals; Vasquez (2015) on transformation geometry; Acar (2015) on exponential and logarithmic functions; and Öz (2015) on geometric objects, all reaching similar conclusions about TEL's role in increasing student achievement and knowledge retention.

To evaluate the impact of practitioner teachers on practice, the means of the experimental groups of various practitioners and the control groups of different practitioners were compared. The teacher factor significantly affects students' achievement (Yenilmez & Duman, 2008). Research on teachers' use of technology in teaching identifies factors such as technology perception, self-confidence, planning, physical conditions, teaching plans, application, and the ability to use materials, which are also influential

(Kaleli-Yılmaz, 2015). In this study, the means of pre-tests, post-tests, and retention tests for the control groups comprising different practitioners did not demonstrate significant differences. Similarly, the pre-test, post-test, and retention test means of the experimental groups composed of various practitioners were compared, revealing no significant mean differences. Therefore, no differentiation arose from practitioners.

Math teachers can use interactive math software such as Geogebra and Desmos in their classes to help students explore quadrilaterals. They can increase student motivation by organizing in-class competitions and online games. They can help students better connect to topics by presenting math problems in a story format with applications such as Storyboardthat. They can appeal to different learning styles by sharing educational videos and interactive e-books about quadrilaterals. They can help students visually organize mathematical concepts and relationships with applications like Coogle and make complex topics more understandable. They can give students instant feedback with online quizzes and interactive applications such as Plickers. These suggestions show that technology-enriched learning environments can effectively increase students' academic achievement and learning retention on quadrilaterals.

In conclusion, the effects of a curriculum based on the TEL on the achievement and retention of students at different grade levels or in different mathematics subjects can be examined. Students' affective perceptions, such as motivation and anxiety, and student opinions can be added to similar research. Similar research can be conducted using the mixed research method.

The mathematics curriculum prepared following the TEL increases the achievement of seventh-grade students about quadrilaterals and ensures permanent learning. In this context, classroom environments should be enriched in terms of technology. It is recommended that necessary studies be carried out to enrich digital content and introduce this content to teachers and students.

Statement of Researchers

Researchers' contribution rate statement:
Both authors contributed equally to all chapters.

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The authors declare that they have no conflict of interest.

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The data supporting this study's findings are available from the corresponding author upon reasonable request.
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Sevim Sevgi completed my PhD studies in October 2015 in the Secondary School Science and Mathematics Department, specializing in Mathematics Education, at Middle East Technical University (METU) in Ankara, Turkey, under the supervision of Prof. Dr. Giray Berberoğlu. I work as an assistant professor and doctor in the Mathematics and Science Education Department, focusing on the elementary mathematics teaching program at Erciyes University in Kayseri, Turkey. I served as a visiting assistant professor from February 2020 to February 2021 in the Department of Teaching and Learning, specializing in the mathematics teaching program at Peabody College of Education, Vanderbilt University. The website is www.pm2.org. The project focuses on implementing instructional improvement strategies in school districts and other educational organizations, targeting the core of mathematics teaching and learning, which is incredibly challenging. I have guided master's and PhD students at Erciyes University, with 11 master's students graduating. They specifically become middle school mathematics teachers for grades 5 to 8. I have been serving as an associate professor since 2021 at Erciyes University.

6. References

Acar, H. (2015). *Üstel ve logaritmik fonksiyonlar konusunun dinamik geometri yazılımı Geogebra ile öğretiminin öğrenci başarısına etkisi* [*The effects of teaching with dynamic geometry software geogebra on 11th grade students' achievement in exponential and logarithmic functions*]. [Unpublished master's thesis]. Uşak University, Türkiye.

Agustiani, D., Johar, R., & Bahrun, B. (2019). Students' conceptual understanding in learning mathematics through scientific approach with mind mapping. *Beta: Jurnal Tadris Matematika*, *12*(2), 144-156. https://doi.org/10.20414/betajtm.v12i2.256

Akyüz, D. (2018). Geometri'nin argümantasyona dayalı bir teknoloji kullanımı ile öğretilmesi [Teaching geometry using argumentation-based technology]. https://hdl.handle.net/11511/59797

Altın, S. (2012). *Bilgisayar destekli dönüşüm geometrisi öğretiminin 8. sınıf öğrencilerinin başarısına ve matematik dersine yönelik tutumuna etkisi [The effect of computer aided transformation geometry instruction on 8th grade students mathematics succes and attitude*]. [Unpublished master's thesis]. Eskişehir Osmangazi University, Türkiye.

Aparı, B. (2019). *Geogebra destekli problem kurma temelli öğrenme sürecinin öğrencilerin problem kurma becerisine ve özyeterlik inancına etkisi [The effect of GeoGebra supported problem posing based learning process on students' problem posing skills and self-efficacy belief*]. [Unpublished master's thesis]. Dicle University, Türkiye.

Badia, A. (2015). Research trends in technology-enhanced learning/Tendencias de la investigación en el aprendizaje favorecido por la tecnología. *Infancia y Aprendizaje*, *38*(2), 253-278. https://doi.org/10.1080/02103702.2015.1016744

Birgin, O., & Topuz, F. (2021). Effect of the GeoGebra software-supported collaborative learning environment on seventh grade students' geometry achievement, retention and attitudes. *The Journal of Educational Research*, *114*(5), 474-494. https://doi.org/10.1080/00220671.2021.1983505

Bozkurt, G., & Ruthven, K. (2017). Classroom-based professional expertise: a mathematics teacher's practice with technology. *Educational Studies in Mathematics*, *94*(3), 309-328. https://doi.org/10.1007/s10649-016-9732-5

Bursal, M. (2017). *SPSS ile temel veri analizi [Basic data analysis with SPSS]*. Anı Yayıncılık.

Büyüköztürk, Ş. (2011). *Sosyal bilimler için veri analizi el kitabı* [*Handbook of data analysis for the social sciences*]. Pegem.

Büyüköztürk, Ş., Çakmak, E. K., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2018). *Bilimsel araştırma yöntemleri [Scientific research methods]*. Pegem Akademi. https://doi.org/10.14527/9789944919289

Can, A. (2019). *Spss ile bilimsel araştırma sürecinde nicel veri analizi [Quantitative data analysis in scientific research process with SPSS]*. Pegem

Cengiz, N. (2017). *Teknoloji destekli matematik öğretiminin öğrencilerin matematik başarısına ve matematik kaygısına etkisi* [*The effects of technology-supported mathematic on students' success and math anxiety]. [Unpublished master's thesis*]. Gaziantep University,

Cevahir, E. (2020). *SPSS ile nicel veri analizi rehberi [Guide to quantitative data analysis with SPSS]*. Kibele Yayınları.

Chan, K. K., & Leung, S. W. (2014). Dynamic geometry software improves mathematical achievement: Systematic review and meta-analysis. *Journal of Educational Computing Research*, *51*(3), 311-325. https://doi.org/10.2190/EC.51.3.c

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Coldwell-Neilson, J. (2018). Digital literacy expectations in higher education. In Open oceans: Learning without borders: ASCILITE 2018 Conference Proceedings (pp. 103-112). ASCILITE. https://doi.org/10.14742/apubs.2018.1922

Curaoğlu, O. (2012). *Teknoloji ile zenginleştirilmiş öğretimin altıncı sınıf öğrencilerinin matematik dersine karşı tutumlarına ve matematik dersindeki problem çözme becerilerine etkisi* [*The effects of technology enriched instruction on 6th grade public school students' attitudes and problem solving skills in mathematics*]. [Unpublished doctoral dissertation]. Orta Doğu Teknik University, Türkiye.

Çavuş, H., & Deniz, S. (2022). The effect of technology assisted teaching on success in mathematics and geometry: A meta-analysis study. *Participatory Educational Research*, *9*(2), 358-397. https://doi.org/10.17275/per.22.45.9.2

Çilingir, E., & Artut, P. D. (2016). *Gerçekçi matematik eğitimi yaklaşımının ilkokul öğrencilerinin başarılarına, görsel matematik okuryazarlığı özyeterlik algılarına ve problem çözme tutumlarına etkisi [Effect of realistic mathematics education approach on visual mathematics literacy perceptions and problem solving attitude of students*]. Turkish *Journal of Computer and Mathematics Education*, *7*(3), 578-600. https://doi.org/10.16949/turkbilmat.277872

Çolakoğlu, S. (2018). *Çember konusunun geogebra yazılımıyla öğretiminin 7.sınıf öğrencilerinin yaratıcı düşünme becerilerine etkisi* [*The effects of teaching circle subject with geogebra software on creative thinking skills of 7th grade students*]. [Unpublished master's thesis]. Bayburt University, Türkiye.

Daniela, L. (2018). *Didactics of smart pedagogy: Smart pedagogy for technology enhanced learning*. Springer. https://doi.org/10.1007/978-3-030-01551-0

Davies, M. (2011). Concept mapping, mind mapping and argument mapping: What are the differences and do they matter? *Higher Education*, *62*, 279-301. https://doi.org/10.1007/s10734-010-9387-6

Demetgül, Z. & Baki, A. (2020). *Teknoloji donanımlı bir sınıfta mutlak değer ve eşitsizlikler konusunun öğretiminden yansımalar: bir aksiyon araştırması* [*Reflections on Instruction of Inequality And Absolute Value In A Technology-Equipped Classroom: An Action Research*]. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *11*(1), 91-127. https://doi.org/10.16949/turkbilmat.333662

Deniz, S. (2019). *Teknoloji destekli öğretimin matematik ve geometri alanlarında başarı ve tutuma etkisi üzerine bir meta analiz çalışması* [*A meta analysis study on the effect of technology- aided teaching on the academic achievement and attitude towards mathematics and geometry*]. [Unpublished master's thesis]. Van Yüzüncü Yıl University, Türkiye.

Dikovic, L. (2009). Implementing Dynamic Mathematics Resources with GeoGebra at the College Level. International *Journal of Emerging Technologies in Learning (IJET)*, *1*(3), 183 – 187. https://doi.org/10.3991/ijet.v4i3.784

Dinçer, B., & Yılmaz, S. (2019). *Matematik dersinde dijital hikaye anlatımının açıklık kavramı öğretimine etkisinin incelenmesine yönelik deneysel bir çalışma* [*An experimental study on the investigation of the effect of digital storytelling on teaching of the concept of range*]. *International Journal of New Trends in Arts, Sports & Science Education (IJTASE)*, *8*(2), 49-57.

Drijvers, P. (2018). Digital assessment of mathematics: Opportunities, issues and criteria. *Mesure et évaluation en éducation*, *41*(1), 41-66. I: https://doi.org/10.7202/1055896ar

Duval, E., Sharples, M., & Sutherland, R. (2017). *Technology-Enhanced Learning*. Springer. https://doi.org/10.1007/978-3-319-02600-8

Erdener, K., & Gür, H. (2019). *Ortaokul matematik derslerinde dinamik geometri yazılımı Geometer's Sketchpad kullanımı ile ilgili öğrenci görüşleri* [*Students' views towards using the dynamic software Geometer's Sketchpad in middle school mathematics classrooms*]. Balıkesir Üniversitesi *Fen Bilimleri Enstitüsü Dergisi*, *21*(1), 364-377. https://doi.org/10.25092/baunfbed.548536

Erduran, A. (2020). *Fonksiyon kavramının öğretiminde teknoloji ile zenginleştirilmiş öğrenme ortamının öğrenci başarısına etkisi* [*The effect of technology enriched learning environment on student achievement in teaching function concept*]. *Batı Anadolu Eğitim Bilimleri Dergisi*, *11*(1), 169-194.

Filiz, M. (2009). *Geogebra ve cabri geometri II dinamik geometri yazılımlarının web destekli ortamlarda kullanılmasının öğrenci başarısına etkisi* [*The effect of using geogebra and cabri geometry II dynamic geometry softwares in a web-based setting on students achievement*]. [Unpublished master's thesis]. Karadeniz Teknik University, Türkiye.

Flavin, M. (2020). *Re-imagining technology enhanced learning: Critical perspectives on disruptive innovation*. Springer Nature. https://doi.org/10.1007/978-3-030-55785-0

Fraenkel, J.R. & Wallen, N.E. (2009). *How to design and evaluate research in education*. McGraw-Hill.

Genç, G. (2010). *Dinamik geometri yazılımı ile 5. Sınıf çokgenler ve dörtgenler konularının kavratılması* [*Teaching 5th grade polygon and quadrangle subjects through dynamic geometry software*]. [Unpublished master's thesis]. Adnan Menderes University, Türkiye.

Grant, D. G. (2019). Predicting Web 2.0 use among US teens - Expanding the power of the skill, will and tool model. *British Journal of Educational Technology*, *50*(6), 3405-3419. https://doi.org/10.1111/bjet.12745

Green, S. B., Salkind, N. J. (2005). Using spss for windows and macintosh: Analyzing and understanding data. Pearson.

Goodyear P, Retalis S. (2010). Learning, technology and design. In: P. Goodyear, S. Retalis, (editors). Technology-enhanced learning: Design patterns and pattern languages. (pp.1–28). Sense Publishers. https://doi.org/10.3109/0142159X.2015.1009024

Gulli, C. (2021). Technology in Teaching Mathematics: Desmos. Proceedings of GREAT Day, 2020(1), 8. https://knightscholar.geneseo.edu/proceedings-of-great-day/vol2020/iss1/8

Gülbağcı, S. (2009*). İlköğretim 7. sınıf dörtgenler konusunun öğretiminde dinamik geometri yazılımlarının etkisi* [*The effect of dynamic geometry software on seventh grade students" understanding of quadrilaterals*]. [Unpublished master's thesis]. Ankara University, Türkiye.

Gülbahar, Y. (2005). Öğrenme stilleri ve teknoloji. *Eğitim ve Bilim*, *30*(138), 10-17.

Gündüzalp, C. (2021). *Web 2.0 araçları ile zenginleştirilmiş çevrimiçi öğrenmenin öğrencilerin üst bilişsel ve yaratıcı düşünme becerilerine etkisi* [*The effect of online learning enriched with web 2.0 tools on students' metacognitive and creative thinking skills*]. *Uluslararası Türkçe Edebiyat Kültür Eğitim (TEKE) Dergisi*, *10*(3), 1158-1177. https://dergipark.org.tr/en/pub/teke/issue/65 009/1000828

Gürbüz, R., & Gülburnu, M. (2013). *8. sınıf geometri öğretiminde kullanılan cabri 3D'nin kavramsal öğrenmeye etkisi* [*Effect of teaching geometry with use cabri 3d in eighth grade on conceptual learning*]. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *4*(3), 224-241. https://doi.org/10.16949/turcomat.60325

Hegedus, S. J., Dalton, S., & Tapper, J. R. (2015). The impact of technology-enhanced curriculum on learning advanced algebra in US high school classrooms. *Educational Technology Research and Development*, *63*, 203-228. https://doi.org/10.1007/s11423-015-9371-z

Hıdıroğlu, Ç. N. (2012). *Teknoloji destekli ortamda matematiksel modelleme problemlerinin çözüm süreçlerinin analiz edilmesi: Yaklaşım ve düşünme süreçleri üzerine bir açıklama* [*Analysing mathematical modelling problems solving processes in the technology-aided environment: An explanation on approaches and thought processes*]. [Unpublished doctoral dissertation]. Dokuz Eylül University, Türkiye.

Hıdıroğlu, Ç. N., & Bukova-Güzel, E. (2014). *Matematiksel modellemede GeoGebra kullanımı: Boy-ayak uzunluğu problemi* [*Using geogebra in mathematical modeling: the height-foot length problem*]. *Pamukkale Üniversitesi Eğitim Fakültesi Dergisi*, *36*(36), 29-44. https://doi.org/10.9779/PUJE607

International Society for Technology in Education. (2008). National educational technology standards for teachers. http://www.iste.org/standards/nets-for-teachers.aspx

Joglar Prieto, N., Sordo Juanena, J. M., & Star, J. R. (2014). Designing Geometry 2.0 learning environments: a preliminary study with primary school students. *International Journal of Mathematical Education in Science and Technology*, *45*(3), 396-416. https://doi.org/10.1080/0020739X.2013.837526

Kaleli-Yilmaz, G. (2015). The views of mathematics teachers on the factors affecting the integration of technology in mathematics courses. *Australian Journal of Teacher Education (Online)*, *40*(8), 132-148. https://doi.org/10.14221/ajte.2015v40n8.8

Karasar, N. (2018). *Bilimsel araştırma yöntemi* [*Scientific research method*]. Nobel Akademik Yayıncılık.

Koştur, M., & Yılmaz, A. (2017). Technology support for learning exponential and logarithmic functions. *Ihlara Eğitim Araştırmaları Dergisi*, *2*(2), 50-68.

Kurvinen, E., Kaila, E., Laakso, M. J., & Salakoski, T. (2020). Long term effects on technology enhanced learning: The use of weekly digital lessons in mathematics. *Informatics in Education. 19*(1), 51–75 https://doi.org/10.15388/infedu.2020.04

Liang, S. (2016). Teaching the concept of limit by using conceptual conflict strategy and Desmos graphing calculator. *International Journal of Research in Education and Science (IJRES)*, *2*(1), 35-48. https://doi.org/10.21890/ijres.62743

Ljajko, E., & Ibro, V. (2013). Development of ideas in a geogebra-aided mathematics instruction. *Online Submission*, *3*(3), 1-7. http://dx.doi.org/10.13054/mije.si.2013.01

Ministry of National Education (MoNE) (2018). Ortaokul matematik dersi (5, 6, 7 ve 8. Sınıflar) öğretim programı. MoNE.

Ministry of National Education (MoNE) (2011). Project Components. http://fatihprojesi.MoNE.gov.tr/tr/icerikincele.php?id =14/15.04.2023

Muhammad, I., Elmawati, E., Samosir, C. M., & Marchy, F. (2023). Bibliometric analysis: Research on articulate storylines in mathematics learning. EduMa: *Mathematics Education Learning And Teaching*, *12*(1), 77-87. http://dx.doi.org/10.24235/eduma.v12i1.12607

NCTM, (2000). Principles and Standards for School Mathematics. Reston, VA.

NCTM. (2015). Strategic use of technology in teaching and learning mathematics.

Ng, O. L., Shi, L., & Ting, F. (2020). Exploring differences in primary students' geometry learning outcomes in two technology-enhanced environments: dynamic geometry and 3D printing. *International Journal of STEM Education*, *7*(1), 1-13. https://doi.org/10.1186/s40594-020-00244-1

Onal, N., & Demir, C. G. (2013). *İlköğretim yedinci sınıfta bilgisayar destekli geometri öğretiminin öğrenci başarısına etkisi* [*The effect of computer assisted geometry instruction on seventh grade school students' achievement*]. *Turkish Journal of Education*, *2*(1), 19-28. https://doi.org/10.19128/turje.181051

Öner, A. (2013). *Bilgisayar destekli öğretimin ilköğretim matematik öğretmen adaylarının trigonometrik fonksiyonların periyotlarıyla ilgili kavram imajlarına etkisi* [*The effects of computer assisted instruction on preservice elementary mathematics teachers' concept images related to the trigonometric functions' periods*]. [Unpublished master's thesis]. Necmettin Erbakan University, Türkiye.

Öz, M. (2015). *Ortaokul 7. sınıf matematik dersi geometrik cisimler alt öğrenme alanının öğretiminde dinamik matematik yazılımı geogebra 5.0 kullanımının öğrenci başarısına etkisi* [*The effects of using a dynamic mathematics software geogebra 5.0 in teaching the subject of 'geometric object' in seventh grade math class in a primary school on students' achievement*]. [Unpublished master's thesis]. Gazi University, Türkiye.

Özçakir-Sümen, Ö. (2013). *GeoGebra yazılımı ile simetri konusunun öğretiminin matematik başarısı ve kaygısına etkisi* [*The effect of teaching symmetry subject by GeoGebra software to mathematics success and anxiety*]. [Unpublished master's thesis]. On Dokuz Mayıs University, Türkiye.

Özer, A., E. (2023). *Teknoloji destekli modelleme etkinlikleriyle üstel ve logaritmik fonksiyonların öğretimi* [*Teaching exponential and logarithmic functions with technology aided modelling activities*]. [Unpublished doctoral dissertation]. Dokuz Eylül University, Türkiye.

Özkartal, Ç., & Öçal, T. (2021). *Zenginleştirilmiş öğrenme etkinliklerinin simetri konusundaki başarıya ve algıya etkisi* [*The effect of enriched learning activities on achievement and perception regarding symmetry*]. *Bayburt Eğitim Fakültesi Dergisi*, *16*(31), 80-102. https://doi.org/10.35675/befdergi.738227

Özpınar, İ. (2017). *Matematik öğretmeni adaylarının dijital öyküleme süreci ve dijital öykülerin öğretim ortamlarında kullanımına yönelik görüşleri* [*Preservice mathematics teachers' opinions on the use of digital stories and ınstructional environments*]. *Bartin Üniversitesi Egitim Fakültesi Dergisi*, *6*(3), 1189-1210. https://doi.org/10.14686/buefad.340057

Özsoy, S., & Özsoy, G. (2013). *Eğitim araştırmalarında etki büyüklüğü raporlanması* [*The reporting of effect size in educational research*]. *İlköğretim Online*, *12*(2), 334-346.

Pari Condori, A., Mendoza Velazco, D. J., & Auccahuallpa Fernández, R. (2020). GeoGebra as a technological tool in the process of teaching and learning geometry. In Conference on Information and Communication Technologies of Ecuador (pp. 258-271). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-62833-8_20

Parola, A., Di Fuccio, R., Somma, F., & Miglino, O. (2022). Educational Digital Storytelling: Empowering Students to Shape Their Future. In International Conference on Psychology, Learning, Technology (pp. 119-129). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-15845-2_8

Pea, R. D. (1987). Cognitive technologies for mathematics education. Routledge.

Radović, S., Marić, M., & Passey, D. (2019). Technology enhancing mathematics learning behaviours: Shifting learning goals from "producing the right answer" to "understanding how to address current and future mathematical challenges". *Education and Information Technologies*, *24*, 103-126. https://doi.org/10.1007/s10639-018-9763-x

Reisa, Z. A. (2010). Computer supported mathematics with geogebra. *Procedia-Social and Behavioral Sciences*, *9*, 1449-1455. https://doi.org/10.1016/j.sbspro.2010.12.348

Saha, R. A., Ayub, A. F. M., & Tarmizi, R. A. (2010). The effects of GeoGebra on mathematics achievement: enlightening coordinate geometry learning. *Procedia-Social and Behavioral Sciences*, *8*, 686-693. https://doi.org/10.1016/j.sbspro.2010.12.095

Sarı, H. Y. (2021). *Dinamik geometri yazılımları kullanımının öğrencilerin başarısına ve öğrenmelerin kalıcılığına etkileri* [*The effects of the use of dynamic geometry software on the success of students and the permanent of learnings*]. *International Journal of Educational Studies in Mathematics*, *8*(2), 124-139. https://doi.org/10.17278/ijesim.879628

Sarıaslan, M. F., & Küçük-Demir, B. (2020). *Teknoloji ile zenginleştirilmiş ortamda geometri öğretiminin 6. sınıf öğrencilerinin açılar konusundaki başarısına etkisi* [*The effect of geometry teaching on 6th grade students' achievement about the topic of angle in the enriched technological environment*]. *Journal of Computer and Education Research*, *8*(16), 503-525. https://doi.org/10.18009/jcer.735671

Saye, J. W., & Brush, T. (2002). Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development*, *50*(3), 77 – 96. https://doi.org/10.1007/BF02505026

Secolsky, C., & Denison, D. B. (2018). Handbook on measurement, assessment, and evaluation in higher education (2nd Ed.). Routledge. https://doi.org/10.4324/9781315709307

Senger, E. (2019). *Sosyomatematiksel normlar ve teknoloji ile zenginleştirilmiş öğretimin 6. sınıf öğrencilerinin yükseklik kavramını anlamasına etkisi* [*The effect of sociomathematical norms and technology integrated instruction on 6th grade students' understanding of altitude*]. [Unpublished master's thesis]. Boğaziçi University, Türkiye.

Sevgi, S., & Soylu, Y. (2022). *Trigonometrik fonksiyonların grafiklerini yorumlama konusunun geogebra ile tasarlanmış etkinliklerle öğretiminin öğrencilerin akademik başarısına ve kalıcılığa etkisi* [*The effect of teaching the subject of interpretation of graphics of trigonometric functions with activities designed with geogebra activities on the success of students and permanence*]. *Journal of Academic Social Science Studies*, *15*(91). https://doi.org/10.29228/JASSS.63862

Sucu, H. (2021). *Teknoloji destekli bir öğrenme ortamında ortaokul öğrencilerinin argüman yapılarının toulmin modeline göre incelenmesi* [*Analysis of argument structures of secondary school students in a technology supported learning environment according to the Toulmin Model*]. [Unpublished master's thesis]. Eskişehir Anadolu University, Türkiye.

Sunzuma, G. (2023). Technology integration in geometry teaching and learning: A systematic review (2010–2022). *LUMAT: International Journal on Math, Science and Technology Education*, *11*(3), 1-18. https://doi.org/10.31129/LUMAT.11.3.1938

Şahin, M., Karakuş, F., Özsoy, M., Çınargil, T. (2024). *Dinamik geometri yazılımlarıyla zenginleştirilmiş ispat etkinliklerinin tasarlanması* [*Designing proof activities enriched with dynamic geometry software*]. *Uluslararası Bilim Ve Eğitim Dergisi*, *7*(2), 100-130. https://doi.org/10.47477/ubed.1513272

Tabachnick, B. G. and Fidell, L. S. (2015). Çok değişkenli istatistiklerin kullanımı. (Çeviren M. Baloğlu). Nobel Akademik Yayıncılık.

Tondeur, J., De Bruyne, E., Van den Driessche, M., McKenney, S., & Zandvliet, D. (2015). The physical placement of classroom technology and its influences on educational practices. *Cambridge journal of education*, *45*(4), 537-556. https://doi.org/10.1080/0305764X.2014.998624

Topuz, F. (2017). *Çember ve daire konusunun öğretiminde dinamik geometri yazılımı GeoGebra kullanımının yedinci sınıf öğrencilerinin başarılarına, geometriye yönelik tutumlarına ve öğrenmedeki kalıcılık düzeylerine etkisi* [*The effect of using dynamic geometry software geogebra for teaching of 'Circle and Disc' on the 7th grade students' achievement, attitudes towards geometry and retention level in learning*]. [Unpublished master's thesis]. Uşak University, Türkiye.

Trouche, L., & Drijvers, P. (2010). Handheld technology for mathematics education: Flashback into the future. *ZDM, 42*, 667-681. https://doi.org/10.1007/s11858-010-0269-2

Türkoğlu, H. (2014). *Dinamik geometri yazılımı kullanarak göz izleme yöntemi ile alan bağımsız bilişsel stile sahip matematik öğretmen adaylarınını problem çözme becerilerinin öğrenme stilleri açısından incelenmesi* [*Investigation of the field independent mathematic teacher candidates' problem solving skills with their learning style by using dynamic geometry software through eye tracking methodology*]. [Unpublished master's thesis]. Başkent University, Türkiye.

Usta, N., Işık, A. D., Taş, F., Gülay, G., Şahan, G., Genç, S., ... & Küçük, K. (2018). *Oyunlarla matematik öğretiminin ortaokul 7. sınıf öğrencilerinin matematik başarısına etkisi* [*The effect of teaching mathematics with games on the mathematics achievement of secondary school 7th grade students*]. *Elementary Education Online*, *17*(4), 1972-1987. https://doi.org/10.17051/ilko nline.2019.506917

Vasquez, D. (2015). Enhancing student achievement using geogebra in a technology rich environment. [Unpublished master's thesis]. California State Polytechnic University , ABD.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research & Development*, *53*(4), 5–23. https://doi.org/10.1007/BF02504682

Wong, S. L., & Wong, S. L. (2019). Relationship between interest and mathematics performance in a technology-enhanced learning context in Malaysia. *Research and Practice in Technology Enhanced Learning*, *14*(1), 1-13. https://doi.org/10.1186/s41039-019-0114-3

Xing, B., & Marwala, T. (2017). Implications of the fourth industrial age for higher education. The Thinker Issue 73 Third Quarter 2017. https://ssrn.com/abstract=3225331

Xu, Y., Chiu, C. K., & Ye, X. (2019). Understanding the use of technology-enhanced learning spaces in Hong Kong: an exploratory study. *Asia Pacific Journal of Education*, *39*(3), 290-309. https://doi.org/10.1080/02188791.2019.1598846

Yılmaz, H. Z. (2019). *Altıncı sınıf öğrencilerinin çokgenler ve dörtgenler konusundaki kavram yanılgılarının geogebra ile bilişsel çelişki oluşturarak giderilme sürecinin incelenmesi* [*The analysis of the process of removing misconceptions of 6th grade students about polygons tetragons by creating cognitive contradiction with geogebra*]. [Unpublished master's thesis]. Gazi University, Türkiye.

Yenilmez, K., & Duman, Ö. A. (2008). *İlköğretimde matematik başarısını etkileyen faktörlere ilişkin öğrenci görüşleri* [*Students' opinions about the factors which affect the mathematics success in elementary education*]. *Manas Üniversitesi Sosyal Bilimler Dergisi*, *10*(19), 251-268.

Young, J. (2017). Technology-enhanced mathematics instruction: A second-order meta-analysis of 30 years of research. *Educational Research Review*, *22*, 19-33. https://doi.org/10.1016/j.edurev.2017.07.001

Zengin, Y. (2021). Students' understanding of parametric equations in a collaborative technology-enhanced learning environment. *International Journal of Mathematical Education in Science and Technology*, *54*(1), 1-27. https://doi.org/10.1080/0020739X .2021.1966848

Zilinskiene, I., & Demirbilek, M. (2015). Use of GeoGebra in primary math education in Lithuania: an exploratory study from teachers' perspective. *Informatics in Education*, *14*(1), 127. https://doi.org/10.15388/infedu.2015.08