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The Effect of React Strategy in Augmented Reality-Based Applications on the Problem-Solving Skills of Teacher Candidates

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Abstract
The main purpose of this research is to determine the effect of the REACT strategy in augmented reality applications on the problem-solving skills of teacher candidates. A parallel mixed method, which converges from mixed research designs, was used in the research. The study group of the research consists of 50 teacher candidates studying at the Faculty of Education at Siirt University. The REACT strategy rubric was used as a data collection tool in the quantitative dimension, and a semi-structured interview form, the researcher's and participant's diaries were used in the qualitative dimension. Quantitative data were analyzed with a computer package program and qualitative data were subjected to content analysis with the MAXQDA program. In addition, excerpts were made from stories, researcher's and participant's diaries, and semi-structured interview forms through document analysis, thus diversifying the data. As a result of the research, the problem-solving and critical thinking skills of the participants improved in the REACT strategy used in AR applications. During the experiencing step of the REACT strategy, which consists of interrelated steps, participants encountered problems and received support from their friends to solve these problems.

Keywords: Augment reality, Problem, Problem solving skills, REACT strategy

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Introduction

Augmented reality and education

Augmented reality (AR) is a technology that allows the combination of 3D virtual objects and real-world entities and real-time interactions (Uysal & Özdemir, 2024), which is seen as a derivative (Erbaş & Demirer, 2015) and extension of virtual reality (Çiloğlu, Yılmaz, Yılmaz & Karaoğlan, 2021). As seen in Figure 1, AR transfers real-world events to a virtual environment and makes them available to the individual.

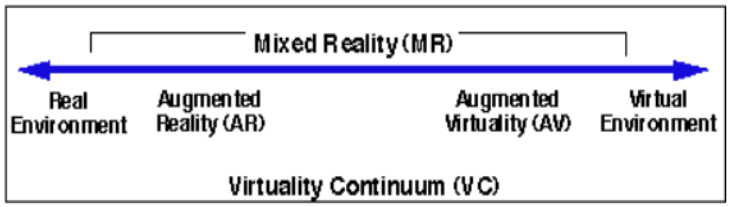


Figure 1. Simplified representation of a "virtuality continuum" (Milgram & Kishino, 1994:3)

The individual gains first-hand experience with augmented reality technology. The individual's interest in the subject increases. Learning by doing occurs (Tomi & Rambli, 2013). It makes the learning process fun. The individual's motivation for the lesson increases. Abstract concepts become concrete. The individual reaches his/her goals more easily with AR applications (Özeren & Top, 2023). The individual has the opportunity to see objects that he/she cannot see in real life and has difficulty reaching. A collaborative learning environment is created (Yoon, Anderson, Park, Elinich, & Lin, 2018). Thus, the individual adapts to real-life situations more easily with AR. All these features can be seen in studies on AR from past to present (Billinghurst and Henrysson, 2009) (See Figure 2).

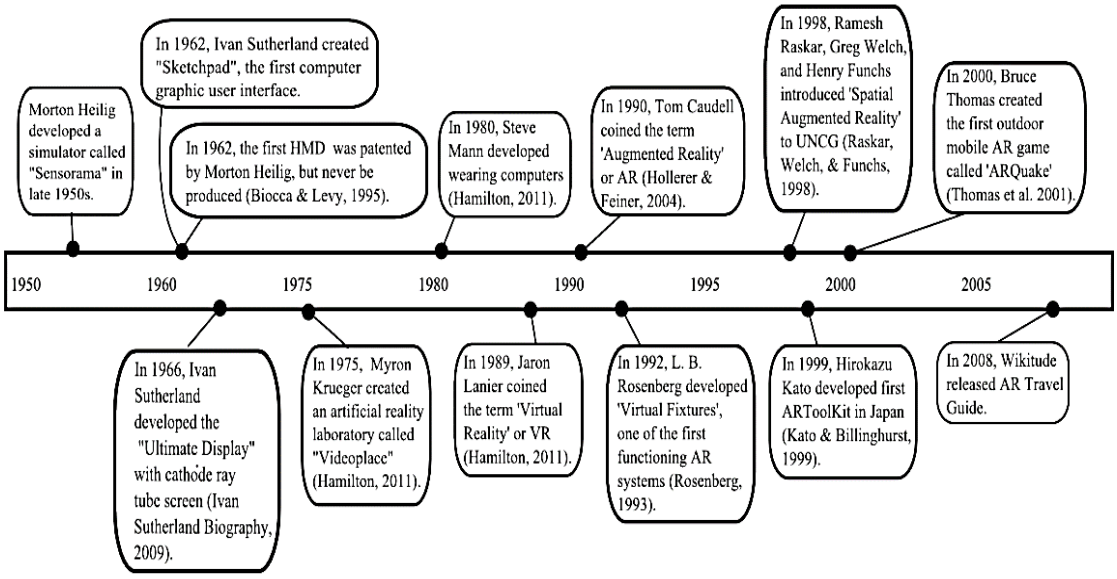


Figure 2. History of AR - a brief timeline (Yuen, Yaoyuneyong & Johnson, 2011:122)

In 1901, thoughts about AR were included in the book "The Master Key" by Frank Baum, author of The Wizard of Oz. Considering AR applications, cinematographer Morton Heilig invented Sensorama, a multi-sensory machine that stimulates the five senses, in 1957. In 1968, Ivan Sutherland designed the first head-mounted viewer, which he called the Sword of Damocles (Turhan, Metin & Ezberci Çevik, 2022). The term augmented reality was first coined by Tom Caudell, a Boeing researcher, in the early 1990s (Lee, 2012). In the mid-1990s, wearable computers were used for mobile AR applications in AR-related studies (Yuen, Yaoyuneyong & Johnson, 2011). In addition to the technologies used in these years, various projects related to AR have attracted attention. For example, Columbia Hardware's MARS project (Billinghurst and Henrysson, 2009) is important work for AR. Besides this, the Aumentaty project developed by the Labhuman laboratory, the BuildAR project developed by the Polytechnic University of Valencia in Spain and the HITLabNZ laboratory at the University of Canterbury in

New Zealand aim to integrate AR applications into the classroom. Similar applications are also found in European Union-funded research projects such as CONNECT (2005-2007), CREATE (2004) and ARiSE (2006-2008). Aurasma, known as an augmented reality platform, is a project called Science Center to Go, which offers a flexible learning environment to the individual (Martín-Gutiérrez, Mora, Añorbe-Díaz & González-Marrero, 2017). Magicbook (Billinghurst, Kato, & Poupyrev, 2001) applications, in which normal textbooks are used as the main interface, pictures are examined in the textbook, and readings are made, are seen as AR studies that attract attention in education.

REACT strategy

Basic skills such as literacy, critical thinking, creativity, and problem-solving are tried to be acquired by the individual in the 21st century with AR applications (Papanastasiou, Drigas, Skianis, Lytras & Papanastasiou, 2019). Individuals who use these skills increase their command of concepts in AR environments (Wibowo, 2023). Nowadays, when concept teaching is considered important, some strategies, such as REACT, are used in educational environments for the individual to explore the concept in depth. The REACT strategy, developed based on the context-based learning approach, was first described in the publication titled "Strategies for Mathematics: Teaching in Context" in the journal Educational Leadership and in two publications titled "Teaching Mathematics Contextually" and "Teaching Contextually" published within CORD (Arıkan, 2019). This strategy was introduced to the scientific world with the studies of Souders and Crawford (Ültay, 2014). REACT strategy, like AR applications, conveys scientific concepts to the student by associating them with daily life (Acar & Yaman, 2011).

The REACT strategy, introduced in the report prepared by Crawford (2001), consists of the steps of Relating, Experiencing, Applying, Cooperating and Transferring (Coştu, 2009). Crawford (2001) states that the first phase of REACT constitutes the heart of constructivism. When learning a new concept, individuals always associate the new concept with the concepts they are familiar with. In AR studies, the student always establishes a relationship between previous information while transferring his/her real-life information to the virtual environment (Özaltun & Kahraman, 2024). In other words, AR makes available virtual objects that are added to or associated with the real world, allowing the individual to see the real world (Azuma, 1997). In the second stage of REACT, there is learning by doing (Çatlıoğlu, 2010). Students come to class with some knowledge from their previous lives. Sometimes this makes the teacher's job difficult. Because while the teacher teaches new information, the student can benefit from past misconceptions. However, with the REACT strategy, the teacher observes the student at this stage and helps him/her make new discoveries with a sense of curiosity (Wahyuni, 2013). The teacher uses hands-on, manipulatives, problem-solving, and laboratory activities in classroom practices in this process, and student success is tried to be increased. For example, it was observed that student success in Mathematics and Science courses, where hands-on learning activities were used, increased by 70% in Mathematics and 40% in Science.

Manipulatives seem to be as effective as hands-on activities in increasing success. Manipulatives are tools used to concretize abstract concepts that are frequently used in mathematics lessons. Some computer programs, such as Geometer's Sketchpad and Cabri, can be given as examples of these tools. The student visualizes the concept, explores it, and answers questions about the concepts with these tools, which are mostly used in mathematics classes. He/she uses problem-solving skills while answering questions. For example, in mathematics class, the concept of ratio is explained by associating it with making fruit juice. Then the teacher asks the class, "How much concentrated fruit puree and water are needed to make fruit juice?" By using problem-solving skills, the student associates relevant information and suggests different solutions (Coştu, 2009). Similar applications and phases are also found in AR. In AR studies, students learn to discover knowledge by using problem-solving skills. Since 2009, The British Museum has been using AR to teach children about the Parthenon gallery. Using their tablets, children can play an augmented reality game called 'A Gift for Athena', which uses sculptures from the museum's collection. Again, AR technology is adapted to the classroom thanks to the Massive Open Online Course, allowing students and teachers to explore the water cycle (Bingöl, 2018).

In the third stage of the REACT strategy, the concepts to be used are introduced. In the application phase, students turn the concepts they have learned into practice through hands-on and problem-solving activities. The aim of the applications is to enable the student to learn the concept more deeply. For this reason, it is expected that their real situations are brought to the classroom environment as much as possible (Abebe, Tafari & Faris, 2024). The fourth phase of the REACT strategy is cooperation. Here, the student manages the process by sharing and communicating with others (Güneş, 2023). The last stage of the REACT strategy is using information outside the classroom (Akgürbüz, 2023). The REACT strategy embodies events/situations as in augmented reality. As Palancı and Turan (2021) state, communication channels are diversified by using virtual tools in augmented reality applications. Similarly, in the REACT strategy, the topics are conveyed by using tools and communication channels are made meaningful with these tools.

Importance of research

It appears that there are international and national studies on the REACT strategy. In these studies, the REACT strategy was associated with different variables. For example, Herlina and Ilmadi (2022) state in their study that the REACT strategy has a significant effect on high-level skills such as problem solving, critical thinking, and creative thinking. In addition, the topics of research associated with the concept of the REACT strategy are listed below:

Concept teaching (Rahayu, 2017; Junedi & Ayu, 2018; Anas & Fitriani, 2018), problem-solving skills (Durotulaila, Masykuri & Mulyani, 2014; Sari, Darhim & Rosjanuardi, 2018), critical thinking skills (Nisa, Lesmono & Bachtiar, 2017; Ihsani, Langitasari & Affifah, 2020), problem-solving, mathematics strategies, self-efficacy (Irjayanti & Heri, 2015; Putri & Santosa, 2015), scientific process skills (Tatlı, 2020),

Ways of reasoning in mathematics class (Pramata Sari & Darhim, 2020; Kurniawati, Andriani & Nendra, 2021), its effect on mathematics skills (Suryaningtyas & Halimah, 2017),

The effect of the GeoGebra-supported REACT Strategy on the understandability of Geometry Concepts (Jelatu & Ardana, 2018) and the effect of GeoGebra software supported REACT strategy on students' mathematical skills (Nurzannah, Muliana, Herizal, Fajriana, & Mursalin, 2021),

Evaluation of applications based on the REACT strategy (Demirtaş Şenel, 2023), investigation of the effect of activities developed according to the REACT strategy (Ültay, 2014),

When looking at the research in general, it can be seen that it is mostly focused on mathematics lessons. The studies consist of qualitative and mixed research. In experimental studies, certain variables have been tried to be revealed in the form of application. In particular, the technological variable was used in only one study. However, in today's 21st century, technological education is the feature that should be taken into consideration the most. The understanding that forms the general perspective of societies with education 5.0 supports this feature. Based on this, augmented reality applications were included in this research, and the participation of prospective teachers, who are the teachers of the future, in research with technological tools was tried to be supported. In the research, the REACT strategy was used in augmented reality application and the effect of the application process on the problem-solving skills of teacher candidates was tried to be determined. The fact that augmented reality application is not used in many studies on the REACT strategy makes this study unique. In other words, no national or international study has been found that uses and associates augmented reality with the REACT strategy.

Purpose of research

What is the effect of the REACT strategy on the problem-solving skills of teacher candidates in augmented reality-based applications?
1.What are the opinions of prospective teachers about AR-based applications?
2.What are the opinions of prospective teachers about the REACT strategy in AR-based applications?

Method

Research model

Convergent Mixed Methods Design was used in the research. In this design, the researcher collects qualitative and quantitative data together. These are analyzed separately, and in the findings section, qualitative and quantitative data support each other (Creswell & Creswell, 2018) (see Figure 3).

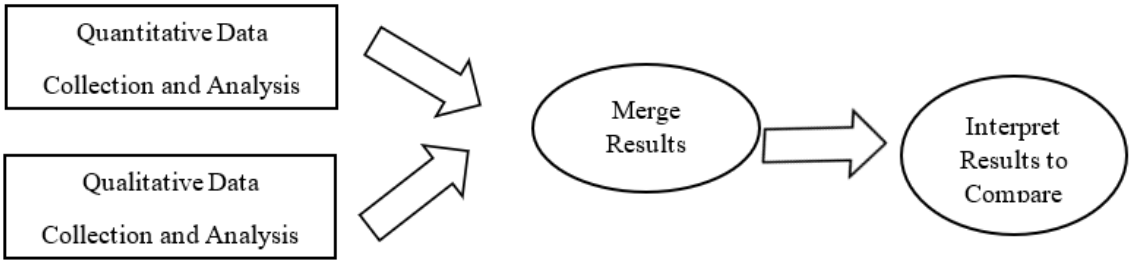


Figure 3. Convergent Mixed Methods Design (Creswell & Creswell, 2018)

If the researcher has limited time, has sufficient knowledge about collecting qualitative and quantitative data, and thinks that qualitative and quantitative data will be explained equally, he/she can use a convergent mixed method design in his/her research. For this reason, the convergent mixed design is seen as a strong design in which both types of data are considered together (Creswell & Plano Clark, 2018).
In the convergent mixed method design, data collection tools such as interviews, documents and observations are used. The qualitative and quantitative data obtained here are analyzed separately. Based on this information, three steps were followed in this research:

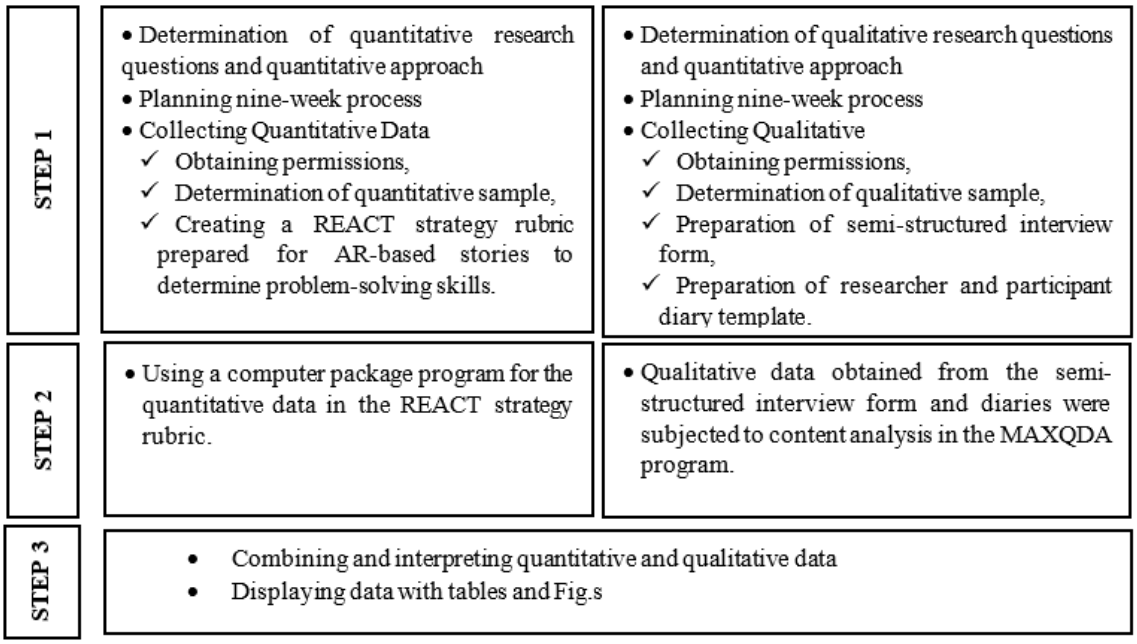


Figure 4. Research design flow chart according to convergent mixed methods design

Before collecting the data, the necessary official permissions were obtained in line with the Siirt University Ethics Committee Decision No. 795 dated 14.03.2024. Then, as seen in Figure 4, experimental procedures were started. 50 students were included in the experimental procedure. In this sample, the Single Group Pre-test - Post-test Design, one of the pre-experimental designs, was applied (see Figure 5).

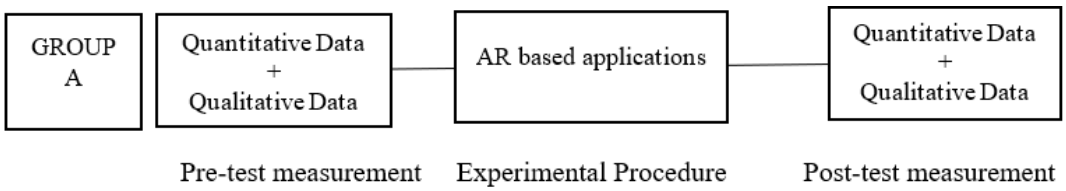


Figure 5. Experimental process suitable for mixed study

As seen in Figure 5, the REACT strategy rubric prepared for AR-based stories (pre-experiment A and post-experiment B form) to determine problem-solving skills in the quantitative dimension was used as pre-test and post-test. During the experimental process, researcher and student diaries and participant studies were included through document analysis. Participant studies consist of AR-based applications. After the experimental

procedure, a semi-structured interview form developed by the researcher was applied to the participants in the qualitative dimension. In these applications, some precautions were taken by the researcher for internal validity. First, the researcher randomly selected the participants. In this way, the distribution of participant characteristics is impartial. Since it was a single-group process, there was no separation of control and experimental groups. In external validity, the researcher limited his/her ideas about the study to the groups to which the results would be generalized. After all these processes, the data were combined and interpreted.

Working group

The study group of the research consists of 50 (66% female and 34% male) teacher candidates studying at the Faculty of Education at Siirt University. 68% are 2nd grade students, 20% are 3rd grade students, and 12% are 4th grade students of the teacher candidates. These classes, 22% are studying in Classroom Teaching, 12% are studying in Elementary Mathematics Teaching, 12% are studying in Turkish Teaching, 8% are studying in Social Science Teaching, 12% are studying in Science Teaching, 12% are studying in English Teaching, and 22% are studying in Guidance and Psychological Counseling.
The activities were carried out in the Drama in Education course. The participants participated in the activities voluntarily and their approval for voluntary participation was obtained. Participants were determined using an easily accessible or convenient sampling method, one of the qualitative research sampling methods. According to Baltacı (2018), it is preferred by researchers as it does not require much cost and can be easily reached by participants. In this study, the researcher chose this sample because he/she used the REACT strategy in augmented reality-based applications in the courses he/she conducted, knew the participant group and could easily reach the participants.

Data collection tools

Quantitative data collection tool

In the research, the REACT strategy rubric prepared for AR-based stories was used to determine the problem-solving skills of the participants in the quantitative dimension. Firstly, two different stories were prepared for the pre-test and post-test. In form A and form B, the problem-solving skills of the participants were tried to be determined within the framework of the REACT strategy. The REACT strategy rubric developed by the researcher was used in the stories to determine both the AR-based applications and the participants' level of skills in the REACT strategy steps. The purpose of the Brookhart (2023) rubric is to determine the individual's performance. Sometimes a written article, sometimes oral communication, and sometimes structured objects are evaluated with this data collection tool. Rubrics are divided into two: analytical and holistic. An analytical rubric was used in this research. The reasons for this are listed below:

✓ Detailed scoring of the Relating, Experiencing, Implementing, Cooperating and Transferring steps of the REACT strategy,
✓ REACT strategy steps are multi-dimensional,
✓ Performance dimensions and levels are observable,
✓ Sufficient time to be used to evaluate performance,
✓ Obtaining more reliable results than holistic,
✓ Being process-oriented,
✓ Determining the participants' weaknesses and strengths

In the study, the steps suggested by Goodrich (2000) were used while developing the REACT strategy rubric. These are as follows: 1) The best and worst performances were determined 2) participant studies were used 3) performance criteria were listed 4) mutually inclusive criteria were not included in the scope of the research. Thus, content validity was tried to be ensured. 5) Performance levels were determined and appropriate scoring was made (such as writing = 3, not writing = 0, giving an example = 5, not being able to give an example = 0, etc.). 6) Applying draft rubric to 15 students who were not included in the main application. The aim here is to determine the suitability of the language and expression for the participant group. 7) Expert opinion was taken. To determine the suitability of the performance criteria for the participant group and the research purpose, the opinions of two experts in the field of Curriculum and Instruction and two Turkish teachers were consulted.

Qualitative data collection tools

As a qualitative data collection tool, a semi-structured interview form developed by the researcher and researcher and participant diaries through document analysis were used. While preparing the semi-structured interview form, the purpose of the research was first taken into consideration. Then a question pool was created. Six questions were prepared for the pilot application. Expert opinion was taken to ensure the suitability of the questions to the participant group and the scope of the research (Curriculum and Instruction Department, Turkish Teacher). After expert opinions, the number of questions was reduced to four as two questions covered the other questions. The final form was applied to a group of 20 participants who participated voluntarily.

Participant and researcher diaries about the process were included throughout the experimental procedure. As it is known, diaries are used in qualitative research. According to Ersoy (2015), diaries are data collection tools used to convey an individual's feelings and thoughts. The individual conveys his/her indecisiveness, observations, feelings and thoughts through diaries. In this study, diaries were used to support quantitative and qualitative data. Direct quotations were made in the diaries using the code "K" for the participant and the code "A" for the researcher.

Analysis of data

A computer package program was used for the data obtained from the REACT strategy rubric prepared for the stories used in the pre-test and post-test. A normality test was performed when analyzing quantitative data. As a result of the normality test (skewness=2,764 and kurtosis=9,609), Wilcoxon Signed Ranks Test was used.
While analyzing qualitative data, the MAXQDA program was used and the data was subjected to content analysis. The following steps were taken into account when analyzing the data in Figure 6.

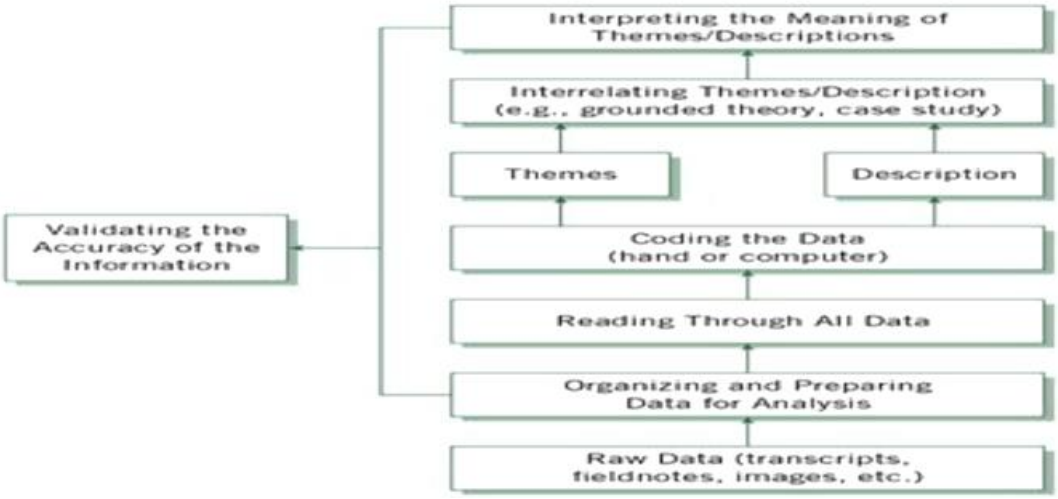


Figure 6. Data Analysis in Qualitative Research (Creswell & Creswell, 2018)

STEP 1: In this research, the data obtained in the semi-structured interview form and diaries were numbered from 1 to 20.
STEP 2: In this stage, data is prepared and organized for analysis. The researcher took the necessary notes within the framework of the general ideas of the participants.
STEP 3: The data in the interview form was read carefully by the researcher and the coding process started. A code list has been created for this. The coding process was first done manually and then transferred to the computer environment.
STEP 4: After the coding process, different and similar codes were classified and collected under certain themes.
STEP 5: Themes are visualized in the MAXQDA program and shown in the findings section.
STEP 6: Images are interpreted in the findings section.
In the nine-week research, the MyWebAR internet interface and the QR codes created on this site were used for AR applications. QR codes created on the internet interface are made available to students through QR code readers on students' phones.

Ensuring validity and reliability

First of all, each criterion was expressed clearly and understandably to ensure validity in the quantitative dimension. For example, the REACT strategy rubric consists of five performance dimensions: Relating,

Experiencing, Applying, Cooperating, and Transferring. In the Relating dimension, certain levels were determined to determine the criterion for feeling/realizing the problem in the story read (Writing three problems = 3 points, Writing two problems = 2 points, Writing one problem = 1, Writing no problems = 0). Secondly, care was taken to ensure that the general structure of each criterion was limited to its own purpose and did not interfere with other criteria for validity. For example, in the Experiencing dimension (writing a scenario with a main character, at least three supporting characters and a location in the story = 5 points) (Showing and explaining the scenarios on the interactive board = 5 points, adding a new main and three supporting characters to the scenario = 4 points, adding at least three objects to the scenario = 3 points, not doing any activity = 0 points). For validity, care was taken to include all characteristics to be measured in the scoring key. The scoring key includes five dimensions and 46 performances. These performances were scored separately throughout the process and AR applications and activities were carried out accordingly. For reliability, consistency was calculated by scoring 46 performances by two different raters (interrater reliability).

Different studies have been conducted on validity and reliability in the qualitative dimension. As Arslan (2022) stated, one of the ways to ensure validity is credibility (internal validity) and transferability (external validity). In the research, long-term interaction was established with the participants regarding credibility. The participant group was observed through diaries and their thoughts were written down. Triangulation was made using quantitative and qualitative data collection tools. Regarding transferability, the whole process was explained in detail and the process was detailed with researcher-student diaries. In reliability, consistency between coders was checked for consistency in the coding process. For this purpose, Miles and Huberman's reliability formula was used and was calculated as .96.

Ethics approval notification

Ethical permission (Date: 14.03.2024-Number: 795) was obtained from Siirt University Ethics Committee for this research.

Results and Discussion

The effect of the REACT strategy in augmented reality-based applications on the problem-solving skills of teacher candidates

The analysis performed to determine the effect of the REACT strategy with AR applications on the problem-solving skills of teacher candidates is included in Table 1.

Table 1. Wilcoxon Signed Rank Test results regarding the problem-solving skill scores of teacher candidates in the REACT strategy in augmented reality-based applications

MEASUREMENT		N	Mean Rank	Sum of Ranks	Z	p
Relating step	Negative Ranks	0	,00	,00	-6,195	0,00
Post-test	Positive Ranks	50	25,50	1275,00		
Pre-test	Ties	0				
	Total	50				
Experiencing step	Negative Ranks	0	,00	,00	-6,180	0,00
Post-test	Positive Ranks	50	25,50	1275,00		
Pre-test	Ties	0				
	Total	50				
Applying step	Negative Ranks	0	,00	,00	-5,860	0,00
Post-test	Positive Ranks	45	23,00	1035,00		
Pre-test	Ties	5				
	Total	50				
Cooperating step	Negative Ranks	0	,00	,00	-6,094	0,00
Post-test	Positive Ranks	48	24,50	1176,00		
Pre-test	Ties	2				
	Total	50				
Transferring step	Negative Ranks	0	,00	,00	-5,618	0,00
Post-test	Positive Ranks	40	20,50	820,00		
Pre-test	Ties	10				
	Total	50				

As seen in Table 1, there is a significant difference between the pre-test and post-test scores of the participants in the problem-solving skills in the REACT strategy steps in the activity studies conducted with AR applications ($p < 0.05$). It was observed that the participants' problem-solving skills scores increased in the relating, experiencing, applying, cooperating and transferring steps of the REACT strategy. In addition, it can be said that there was no increase in the problem-solving skills scores of 0 participants in relating and experiencing, 5 participants in applying, 2 participants in cooperating and 10 participants in transferring. As stated by Keskin and Çam (2018), individuals associate what they have learned with daily life with the REACT strategy. A similar opinion is valid for AR applications. In fact, in the participants' opinions about the AR application, it is stated that AR facilitates learning and concretizes the subject. For the individual, both AR and the REACT strategy provide a meaningful structuring of learning and the development of problem-solving skills. Guntur, Setyaningrum, Retnawati, and Marsigit (2020) touched upon the contributions of AR to problem-solving skills in their study. Although AR applications have positive aspects, their negative aspects were also mentioned in the study. The inadequacy of technological infrastructure in classes is seen as the biggest problem. In solving such problems, individuals again tried to solve them by using their problem-solving skills.

Opinions of teacher candidates on AR-based applications

The opinions that the participants wrote in their diaries on AR applications are shown in Figure 7.

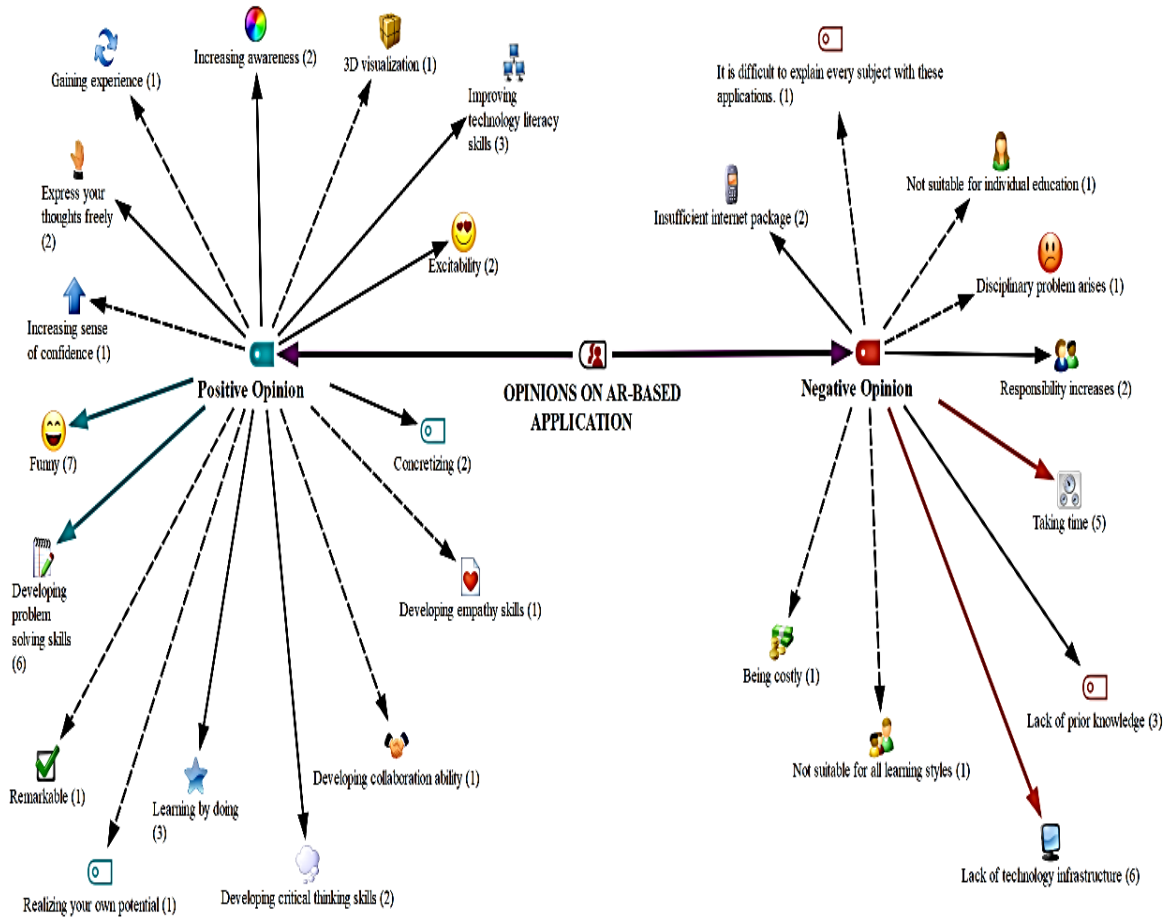


Figure 7. Opinions on AR-based application- Code-Theory Model

As seen in Figure 7, there are positive and negative opinions about the AR application in the diaries of 50 participants. Among the positive opinions, the most emphasized code is entertainment and improving problem-solving skills. Among the negative opinions, the most notable codes are taking time and the lack of technological infrastructure. Some quotes from the participants' positive and negative opinions about the AR application are given below in Figure 8, Figure 9 and Figure 10.

Today was very fun for me. I expressed my opinions for the solution of the problem in the story. I saw the three-dimensional shape of our drama class with the program that I liked the most. (K1-6.05.2024).

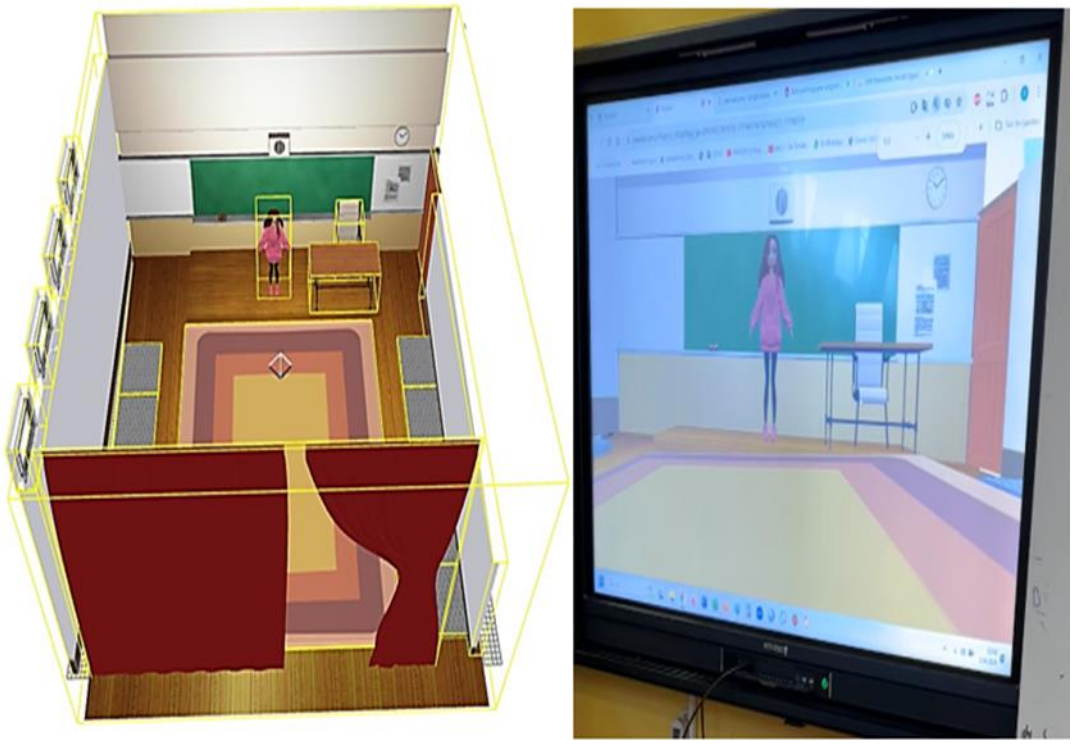


Figure 8. AR-based application

The fact that the lesson is fun and allows me to focus on the subject makes my learning easier. (K5-15.04.2024). .... I added objects in the AR program depending on the story. It was very fun. It was like I was playing a game at home... (K17-14.05.2024).

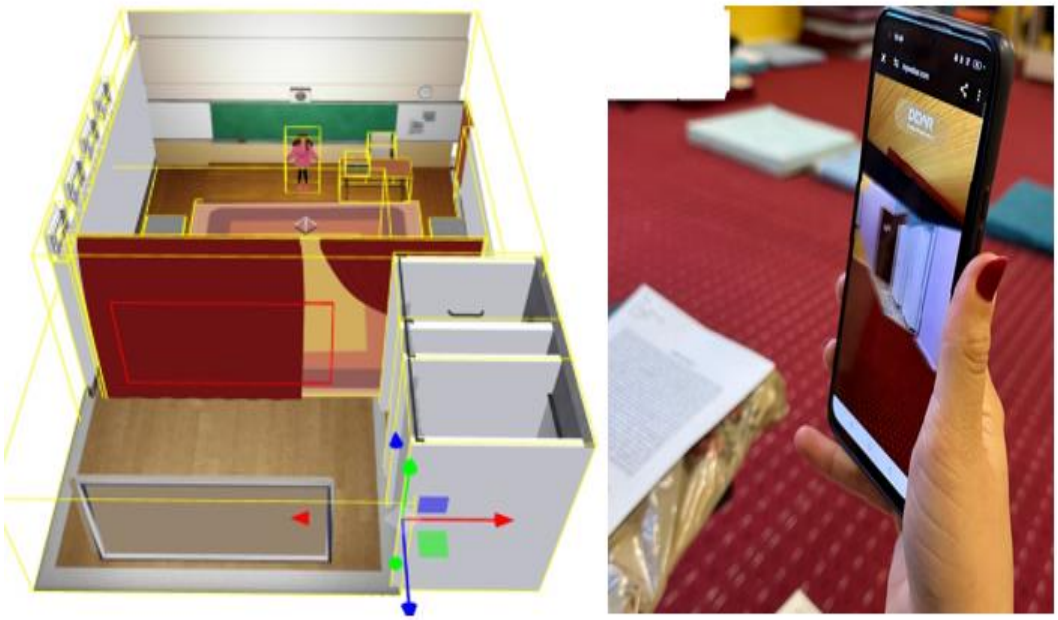


Figure 9. AR-based student application

The contributions of these activities to me are as follows: First, the lesson is fun... (K10-22.05.2024).

.... I suggested a solution related to the place. It takes a lot of time and I think it is a burden for people... (K3-27.05.2024).

The only problem is that it takes time. You need to be very well prepared for these applications. (K13-29.05.2024).
.... You experience problems when you do not have a technological infrastructure. (K19-20.05.2024).

Figure 10. Activity class

The only problem is the lack of technological infrastructure... Our classes are not sufficient in terms of technological infrastructure. (K50-24.04.2024).

In addition to the participants' diaries, quotes were also made from the researcher's diaries.
In the first weeks, students did not have any information about the AR application. Today, I gave general information about the AR application. (A-18.03.2024). Today, I saw that a few students were interested in this concept. They said they had heard about this concept on the internet before. (A-19.03.2024). The students' approaches excited me. I think that participation will increase as their knowledge about what to do increases. (A-20.03.2024). Having a technologically supported lesson for the students increased their motivation for the lesson. This is our second week. However, I noticed that some students were introverted. (A-1.04.2024). Again, on a different day, the application that the students enjoyed the most was the role-playing phase. After the story was read, they performed role-plays based on the story. They even brought their friends from other classes. (A-20.05.2024). (A-20.05.2024) The point that students complain about most is the insufficient technological infrastructure of the classroom. In order to minimize this situation, emphasis was placed on group work. (A-24.05.2024).

Opinions of teacher candidates on AR-based applications

Among the opinions of teacher candidates on the REACT strategy in AR-based applications, the first one is the definition of the REACT strategy. Participants' opinions on the definition are given in Figure 11.

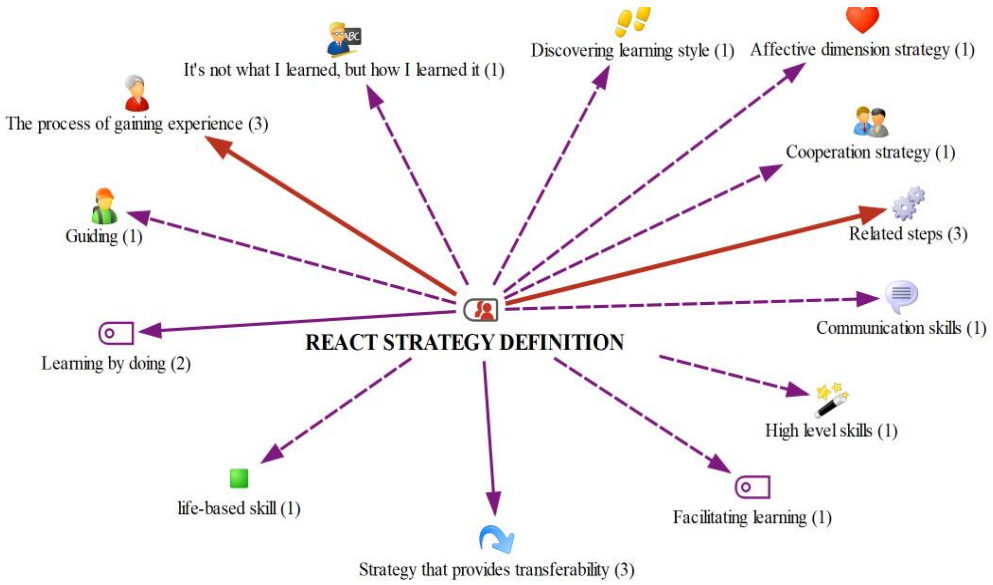


Figure 11. REACT strategy definition- Code-Theory Model

As seen in Figure 11, when defining the REACT strategy, participants mostly emphasized that it is a process consisting of interrelated steps and providing experience to the individual. Some of the participants' opinions are given below.

I think it's like the links of a chain. Each link completes the other (K1).

When it comes to REACT strategy, the first thing that comes to my mind is the interrelated steps (K5).

It's an application that gives people life experience. (K2).

It's a strategy that gives me a lot of experience, and these experiences create meaningful knowledge. (K3).

Herlina and Ilmadi (2022) and Jelatu and Ardana (2018) state in their studies that REACT consists of various steps and that these steps are interconnected. The individual's problem-solving skills develop at each step (Durotulaila, Masykuri & Mulyani, 2014; Keleş, 2019; Suryaningtyas & Halimah, 2017). In addition to problem-solving skills, 21st century skills such as critical thinking are also used (Nisa, Lesmono & Bachtiar, 2017; Ihsani, Langitasari & Affifah, 2020). These skills are used at every step and sometimes higher-level skills are more prominent at certain steps. For example, in the research, participants encountered more problems at the experiencing step Considering the general characteristics of this step, the individual learns by doing and learns various concepts (Durotulaila, Masykuri & Mulyani, 2014; Beştaş, 2022). What is important is for the individual to use their problem-solving skills in solving the REACT stages and the problems encountered in the stages. In this research, participants solved their problems by working collaboratively and getting support from their closed circle.

The second opinion of teacher candidates on the REACT strategy in AR-based applications is the skills developed with AR. Participants' opinions on skills are shown in Figure 12.

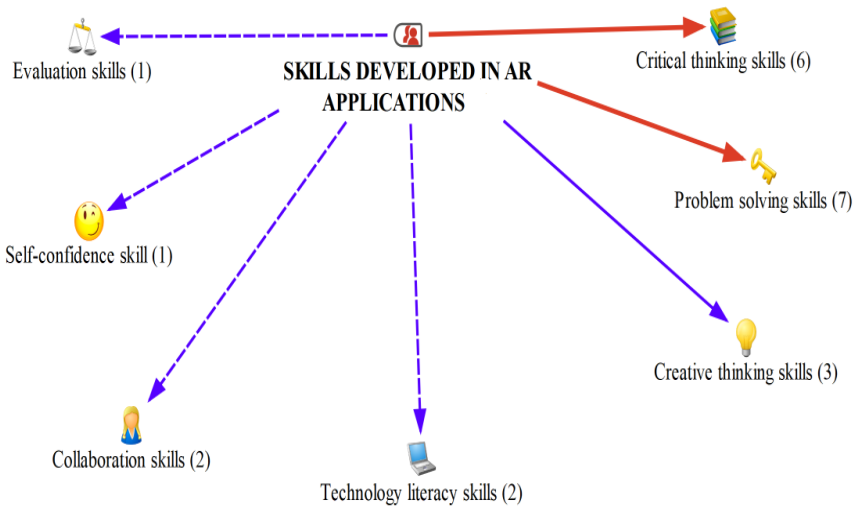
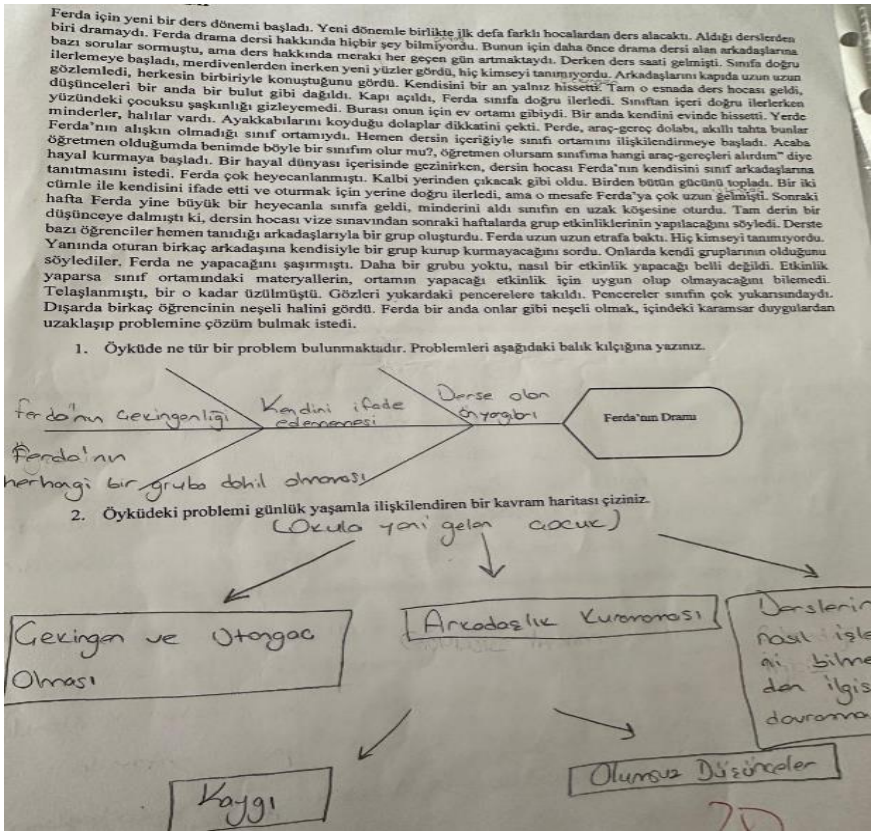


Figure 12. Skills developed in AR application- Code-Theory Model

As seen in Figure 12, the participants' critical thinking and problem-solving skills improved the most with AR applications. Participants' opinions on these two skills are given below Figure 13 and Figure 14.
My critical thinking skills improved the most in discussion groups (K4).


Ferda için yeni bir ders dönemi başladı. Yeni dönemle birlikte ilk defa farklı hocalardan ders alacaktı. Aldığı derslerden biri dramaydı. Ferda drama dersi hakkında hiçbir şey bilmiyordu. Bunun için daha önce drama dersi alan arkadaşlarına bazı sorular sormuştu, ama ders hakkında merakı her geçen gün artmaktaydı. Derken ders saati gelmişti. Sınıfa doğru ilerlemeye başladı, merdivenlerden inerken yeni yüzler gördü, hiç kimseyi tanımıyordu. Arkadaşlarını kapıda uzun uzun gözlemledi, herkesin birbiriyle konuştuğunu gördü. Kendisini bir an yalnız hissetti. Tam o esnada ders hocası geldi, düşünceleri bir anda bir bulut gibi dağıldı. Kapı açıldı, Ferda sınıfa doğru ilerledi. Sınıftan içeri doğru ilerlerken yüzündeki çocuksu şaşkınlığı gizleyemedi. Burası onun için ev ortamı gibiydi. Bir anda kendini evinde hissetti. Yerde minderler, halılar vardı. Ayakkabılarını koyduğu dolaplar dikkatini çekti. Perde, araç-gereç dolabı, akıllı tahta bunlar Ferda'nın alışkın olmadığı sınıf ortamıydı. Hemen dersin içeriğiyle sınıfı ortamını ilişkilendirmeye başladı. Acaba öğretmen olduğumda benimde böyle bir sınıfım olur mu?, öğretmen olursam sınıfıma hangi araç-gereçleri alırdım" diye hayal kurmaya başladı. Bir hayal dünyası içerisinde gezinirken, dersin hocası Ferda'nın kendisini sınıf arkadaşlarına tanıtmasını istedi. Ferda çok heyecanlanmıştı. Kalbi yerinden çıkacak gibi oldu. Birden bütün gücünü topladı. Bir iki cümle ile kendisini ifade etti ve oturmak için yerine doğru ilerledi, ama o mesafe Ferda'ya çok uzun gelmişti. Sonraki hafta Ferda yine büyük bir heyecanla sınıfa geldi, minderini aldı sınıfın en uzak köşesine oturdu. Tam derin bir düşünceye dalmıştı ki, dersin hocası vize sınavından sonraki haftalarda grup etkinliklerinin yapılacağını söyledi. Derste bazı öğrenciler hemen tanıdığı arkadaşlarıyla bir grup oluşturdu. Ferda uzun uzun etrafa baktı. Hiç kimseyi tanımıyordu. Yanında oturan birkaç arkadaşına kendisiyle bir grup kurup kurmayacağını sordu. Onlarda kendi gruplarının olduğunu söylediler. Ferda ne yapacağını şaşırmıştı. Daha bir grubu yoktu, nasıl bir etkinlik yapacağı belli değildi. Etkinlik yaparsa sınıf ortamındaki materyallerin, ortamın yapacağı etkinlik için uygun olup olmayacağını bilemedi. Telaşlanmıştı, bir o kadar üzülmüştü. Gözleri yukardaki pencerelere takıldı. Pencereler sınıfın çok yukarısındaydı. Dışarda birkaç öğrencinin neşeli halini gördü. Ferda bir anda onlar gibi neşeli olmak, içindeki karamsar duygulardan uzaklaşıp problemine çözüm bulmak istedi.

1. Öyküde ne tür bir problem bulunmaktadır. Problemleri aşağıdaki balık kılçığına yazınız.

2. Öyküdeki problemi günlük yaşamla ilişkilendiren bir kavram haritası çiziniz.

Figure 13. Student scenario

I used my critical thinking skills a lot while expressing positive and negative opinions about the subject (K10).
My critical thinking skills improved. This skill of yours improves because you are constantly expressing your opinions about the stories. (K17).

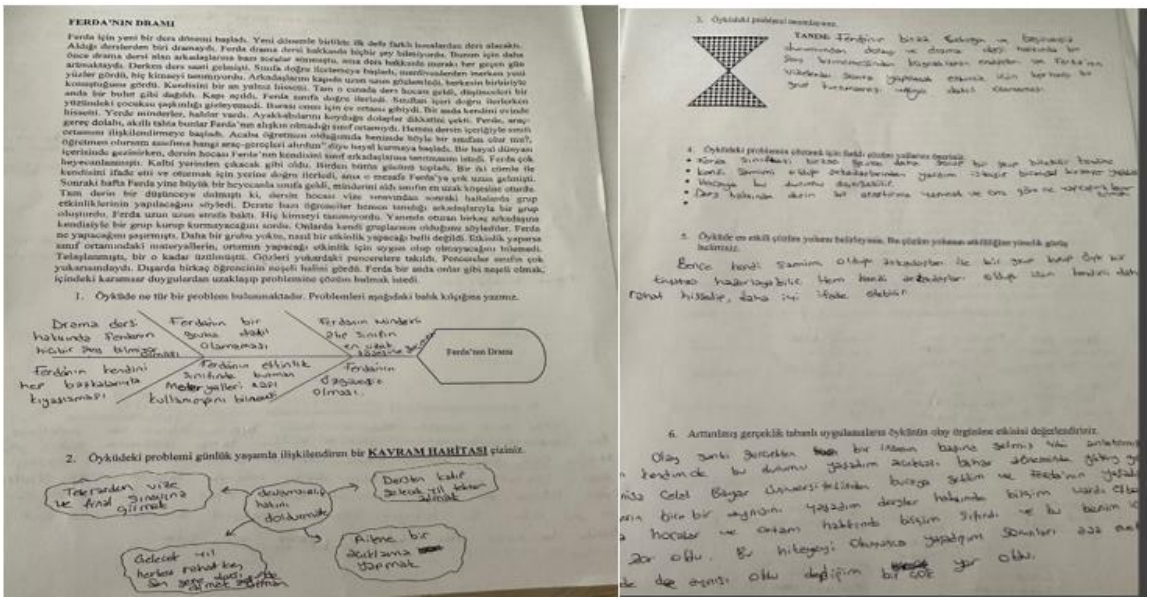


Figure 14. Student scenario

Problems arose at many stages of forming groups and writing scenarios. For this reason, my problem-solving skills improved (K3).

My problem-solving skills improved. Because when we acted without planning, we encountered many problems. You inevitably find solutions to the problems (K14).

I can say this directly. My problem-solving skills improved a lot. Subjects encourage people to learn. There is a problem in every new subject you learn and you use your problem-solving skills to solve this problem (K19).

The third step among the opinions of prospective teachers on the REACT strategy in AR-based applications is the step in which they have the most problems with the REACT strategy. Participants' opinions on the steps are given in Figure 15.

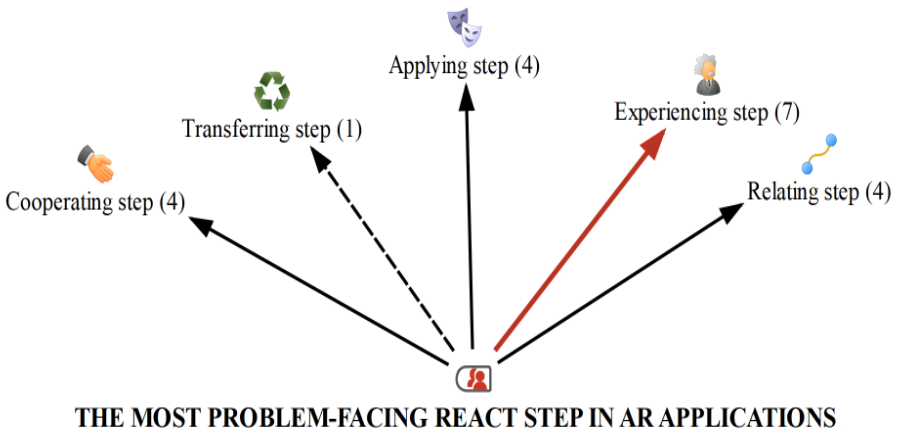


Figure 15. The most problem-facing REACT step in AR applications- Code-Theory Model

As seen in Figure 15, participants experienced more problems in the experiencing step of the REACT strategy. Participants' opinions on these problems are given below.
In the experience phase, I had disagreements with my group mates while writing new scenarios based on the story (K6).

Experience phase. While we were thinking of creating small groups, we created large groups. We wrote a very broad scenario (K12).

Fourth, the participants' opinions on solving the problems they encountered in the REACT strategy steps are shown in Figure 16.

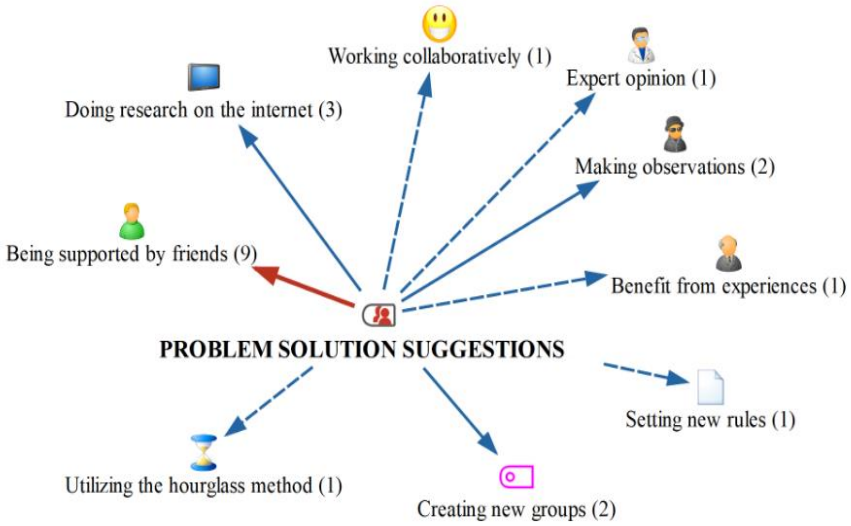


Figure 16. Problem solution suggestions - Code-Theory Model

As seen in Figure 16, the most emphasized solution suggestions for the problems encountered in the REACT strategy steps include the participants getting support from their friends. Participants' opinions on this support are presented below in the form of quotes in Figure 17.

…. I exchanged information with my group mates (K2).

…I got help from my friends outside the class (K5).

Figure 17. Student's group activity

…. Then my friend helped me. Thanks to this help, different events came to my mind (K20).

Conclusion

AR applications were included in the research and the problem-solving skills of the participants were tried to be determined with the REACT strategy used in these applications. As a result of the research, it was seen that the participants defined the problems in the given stories. They related the problems to daily life. Later, in group activities, they wrote new scenarios based on the story. They added new characters and objects to the scenarios that were read. The groups shared their opinions about these characters and objects. They suggested solutions to the existing problems in the opinions. In addition, they tried to find an effective solution by determining their own rules. They worked collaboratively to visualize the effective solutions they found. Finally, they discussed their positive and negative opinions about the plot using the aquarium technique and problem-solving technique. Thus,

the five steps of the REACT strategy were used in AR applications with the activities carried out and the problem-solving skills of the participants were tried to be determined step by step.
In the study, participants define the REACT strategy as a process in which experiences are used and a cycle of interrelated steps. It is seen that AR applications, in which technologies are used extensively within the concept of contemporary education, and the REACT strategy used in these applications make significant contributions to the student's academic development and ability to use technology. In the globalizing world, individuals mostly use problem-solving skills with AR technology, which is used extensively, especially in the field of education. Thus, one of the common points of intersection of AR and REACT strategies is "problem-solving skills". Many studies are needed for this skill to be used more in today's education. Therefore, more studies are needed on the use of both AR and REACT in other courses and which skills students develop. This study focuses on problem solving skills and other studies can be conducted on the development of different skills.

Recommendations

In the study, it was tried to determine the effect of the REACT strategy on the problem-solving skills of teacher candidates in augmented reality applications. Hybrid studies can be carried out for the use of the REACT strategy in different education levels and courses. In these studies, AR applications can be considered and different high-level skills of the participants can be determined.

Author (s) Contribution Rate

There is one sole author (100%), who produced, reviewed and approved the final manuscript.

Ethical Approval

Ethical permission (Date: 14.03.2024-Number: 795) was obtained from Siirt University Ethics Committee for this research.

References

Abebe, W.K., Tafari, H.W. & Faris,S.B. (2024). Effect of context based REACT strategy on students' conceptual understanding of heredity. *Cogent Education, 11*(1), 2290104, https://doi.org/10.1080/2331186X.2023.2290104

Acar, B. & Yaman, M. (2011). Bağlam temelli öğrenmenin öğrencilerin ilgi ve bilgi düzeylerine etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 40, 1-10.

Akgürbüz, M. (2023). *Sınıf dışı etkinliklerle bağlam temelli yaklaşımı REACT stratejisinin başarı ve kalıcılığa etkisi: Vücudumuzdaki sistemler*. (Yayınlanmamış Yüksek Lisans Tezi). Ondokuz Mayıs Üniversitesi, Lisansüstü Eğitim Enstitüsü, Samsun.

Anas, A. & Fitriani, A. (2018). Penerapan Model Pembelajaran REACT dalam Peningkatan Pemahaman Konsep Siswa. *AlKhwarizmi: Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam, 6*(2), 157–166. https://doi.org/10.24256/jpmipa.v6i2.338

Arıkan, A. (2019). *Sosyal bilgiler dersinde REACT stratejisine dayalı etkinliklerin öğrencilerin akademik başarılarına, sosyal bilgiler dersine yönelik tutumlarına ve öğrenmenin kalıcılığına etkisi.* (Yayınlanmamış Yüksek Lisans Tezi). Aydın Adnan Menderes Üniversitesi, Sosyal Bilimler Enstitüsü, Aydın.

Arslan, E. (2022). Nitel araştırmalarda geçerlilik ve güvenilirlik. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 2022 Sayı 51: Özel sayı 1, 395-407.

Azuma, R. T. (1997). A Survey of Augmented Reality. *Presence, 6*(4). 355–385.

Baltacı, A. (2018). Nitel araştırmalarda örnekleme yöntemleri ve örnek hacmi sorunsalı üzerine kavramsal bir inceleme. *BEÜ SBE Derg., 7*(1), 231-274.

Beştaş, B. (2022). *REACT stratejisinin 6. sınıf öğrencilerinin akademik başarılarına etkisi ve görüşlerinin incelenmesi*. (Yayınlanmamış Yüksek Lisans Tezi). Siirt Üniversitesi, Fen Bilimleri Enstitüsü, Siirt.

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). *The MagicBook: a transitional AR inteface. Computers & Graphics, 25*(5), 745-753.

Billinghurst, M., & Henrysson, A. (2009). *Mobile architectural augmented reality*. (X. Wang, & M. Schnabel, Eds.) Mixed Reality in Architecture, Design and Construction, 3, 93-104.

Bingöl, B. (2018). Yeni bir yaşam biçimi: Artırılmış Gerçeklik (AG). *Etkileşim* (1), 44-55. https://doi.org/10.32739/etkilesim.2018.1.8

Brookhart, S.M. (2023). *Dereceli puanlama anahtarlarının hazırlanması ve uygulanması* (Çev:İ. Karakaya & F.N. Fişne). Ankara: Pegem Akademi.

Coştu, S. (2009). *Matematik öğretiminde bağlamsal öğrenme ve öğretme yaklaşımına göre tasarlanan öğrenme ortamlarında öğretmen deneyimleri*. (Yayınlanmamış Yüksek Lisans Tezi). Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Trabzon.

Crawford M.L. (2001). *Teaching contextually:research, rationale, and techniques for ımproving student motivation and achievement in mathematics and science*. CCI Publishing, Waco, Texas.

Creswell, J.W. & Creswell, J.D. (2018). *Research design qualitative, quantitative, and mixed methods approaches* (Fifth Edition). SAGE Publications, Inc.

Creswell, J.W. & Plano Clark, V.L. (2018). *Designing and conducting mixed methods research* (Third Edition). SAGE Publications, Inc.

Çatlıoğlu, H. (2010). *Matematik öğretmeni adaylarıyla bağlamsal öğrenme ve öğretme deneyiminin değerlendirilmesi*. (Yayınlanmamış Yüksek Lisans Tezi). Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Trabzon.

Çiloğlu, T., Yılmaz, Ö., Yılmaz, A., & Karaoğlan, F. (2021). Eğitimde artırılmış gerçeklik konulu makalelerin incelenmesi. *Ahmet Keleşoğlu Eğitim Fakültesi Dergisi, 3*(2), 147-158.

Demirtaş Şenel, G. (2023). *Bağlam temelli öğrenme kapsamında ilkokul üçüncü sınıf hayat bilgisi dersinde REACT stratejisine dayalı uygulamaların değerlendirilmesi*. (Yayınlanmamış Doktora Tezi). Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Durotulaila, A.H., Masykuri, M. & Mulyani, D.B. (2014). Pengaruh Model Pembelajaran REACT (Relating Experiencing Applying, Cooperating, Transfering) Dengan Metode Eksperimen Dan Penyelesaian Masalah Terhadap Prestasi Belajar DitinjauDari Kemampuan Analisis Siswa. *Jurnal Pendidikan Kimia, 3* (4), 66-74–74.

Erbaş, Ç., & Demirer, V. (2015). Eğitimde Artırılmış Gerçeklik Uygulamaları: Google Glass Örneği. *Journal of Instructional Technologies and Teacher Education, 3*(2), 8-16.

Ersoy, A. (2015). Doktora öğrencilerinin ilk nitel araştırma deneyimlerinin günlükler aracılığıyla incelenmesi. *Pegem Eğitim ve Öğretim Dergisi, 5*(5), 549-568, http://dx.doi.org/10.14527/pegegog.2015.030

Guntur, M I S, Setyaningrum, S. Retnawati, H., & Marsigit (2020). Can augmented reality improve problem-solving and spatial skill? Journal of Physics: Conference Series, Volume 1581, *The 3rd International*

Seminar on Innovation in Mathematics and Mathematics Education (ISIMMED 2019) 3-4 October 2019, Yogyakarta, Indonesia

Goodrich, A. H. (2000). Using rubrics to promote thinking and learning. *Educational Leadership*, 57 (5), 13–18.

Güneş, L. (2023). *Altıncı sınıf elektriğin iletimi ünitesinin REACT stratejisi ile öğrencilerin akademik başarısına ve tutumuna etkisinin incelenmesi*. (Yayınlanmamış Yüksek Lisans Tezi). Sakarya Üniversitesi, Eğitim Bilimleri Enstitüsü, Sakarya.

Herlina, E. ve Ilmadi I. (2022). The Implementation of REACT Strategy in Training Students' Higher Order Thinking Skills (HOTS). *Ta'dib Journal, 25*(1), 47-57. https://doi.org/10.31958/jt.v25i1.5049

Ihsani, A. Z., Langitasari, I., & Affifah, I. (2020). Penerapan model pembelajaran REACT terhadap keterampilan berpikir kritis siswa pada konsep kelarutan dan hasil kali kelarutan. *Jurnal Inovasi Pendidikan Kimia, 14*(1), 2498–2511.

Irjayanti, R., & Heri, R. (2015). Keefektifan strategi REACT ditinjau Dari Presatasi Belajar, Kemampuan Penyelesaian Masalah, Koneksi Matematis, *Self Efficacy*. *Jurnal Riset Pendidikan Matematika, 2*(2), 262–272.

Jelatu, S. & Ardana, I. (2018). Effect of GeoGebra-Aided REACT strategy on understanding of geometry concepts. *International journal of instruction, 11*(4), 325-336.

Junedi, B., & Ayu, D. M. (2018). Penerapan Strategi Relating, Exsperiencing, Applying, Cooperating and Transfering (REACT) Terhadap Pemahaman Konsep Matematika Siswa Kelas Viii. MES: *Journal of Mathematics Education and Science, 3*(2), 125–132. https://doi.org/10.30743/mes.v3i2.502

Kaya, S. (2020). *11. sınıf öğrencilerine 'sindirim sistemi' konusunun REACT Stratejisi ile öğretimi.* (Yayınlanmamış Doktora Tezi). Atatürk Üniversitesi, Eğitim Bilimleri Enstitüsü, Erzurum.

Keleş, İ.H. (2019). *7. sınıf fen bilimleri dersi "saf maddeler, karışımlar ve karışımların ayrılması" konularının REACT stratejisiyle öğretimi.* (Yayınlanmamış Yüksek Lisans Tezi). Kilis 7 Aralık Üniversitesi, Fen Bilimleri Enstitüsü, Kilis.

Keskin, F., & Çam, A. (2019). Yaşam temelli REACT stratejisinin altıncı sınıf öğrencilerinin akademik başarısına ve fen okuryazarlığına etkisi. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi* (49), 38-59.

Kurniawati, R., Andriani, S., & Nendra, F. (2021). Dampak strategi relating, experiencing, applying, coorperating dan tranfering (REACT) pada kemampuan penaralan matematis di tinjau dari minat belajar. *Edu Sains: Jurnal Pendidikan Sains Dan Matematika, 9*(1), 33–39.

Lee, K. (2012). Augmented reality in education and training. *Techtrends, 56*(2), 13–21. https://doi.org/10.1007/s11528-012-0559-3

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual technologies trends in education. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(2), 469-486.

Miles, M, B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded Sourcebook*. (2nded). Thousand Oaks, CA: Sage.

Milgram, P. & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information Systems, 77*(12). Retrieved July 24, 2010 from http:// etclab.mie.utoronto.ca/people/paul_dir/IEICE94/ieice.html.

Nisa, F.C., Lesmono, A. D. & Bachtiar, R.W. (2017). Model Pembelajaran Kontekstual Relating, Experiencing, Applying, Cooperating, and Transferring (REACT) dengan Simulasi Virtual dalam Pembelajaran Fisika di SMA (Materi Momentum, Impuls dan Tumbukan Kelas X SMAN 2 Jember) 1). *Jurnal Pembelajaran Fisika*, 7, 8–14.

Nurzannah, Muliana, Herizal, Fajriana & Mursalin (2021). The effect of REACT strategy assisted by GeoGebra software on students' mathematical representation ability. *Malikussaleh Journal of Mathematics Learning (MJML), 4* (2), 90-97.

Özaltun, G., & Kahraman, M. E. (2024). Artırılmış gerçeklik (AG) teknolojisinin tasarım eğitiminde etkileşimli öğrenmeye katkısı. *Art-E Sanat Dergisi, 16*(32), 669-700. https://doi.org/10.21602/sduarte.1367153

Özeren, S & Top, E. (2023). The effects of augmented reality applications on the academic achievement and motivation of secondary school students. *Malaysian Online Journal of Educational Technology, 11*(1), 25-40. http://dx.doi.org/10.52380/mojet.2023.11.1.425

Palancı, A., & Turan, Z. (2021). How does the use of the augmented reality technology in mathematics education affect learning processes? *A systematic review. International Journal of Curriculum and Instructional Studies, 11*(1), 89-11.

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality, 23*(4), 425-436. https://doi.org/10.1007/s10055-018-0363-2

Pramata Sari, D. & Darhim (2020). Implementation of REACT strategy to develop mathematical representation, reasoning, and disposition ability. *Journal on Mathematics Education, 11* (1), 145-156.

Putri, R.I. & Santosa, R.H. 2015). Keefektifan strategi REACT ditinjau darı prestası belajar, kemampuan penyelesaıan masalah, koneksı matematıs, self efficacy. *Jurnal Rıset Pendıdıkan Matematıka*, 2, Nomor 2, November 2015, 262–272. Available online at JRPM Website: http://journal.uny.ac.id/index.php/jrpm/index

Rahayu N.R. (2017). *Pengaruh Model Pembelajaran REACT dan guided discovery learning terhadap pemahaman konsep matematika siswa*. Skripsi, Universitas Muhammadiyah Ponorogo.

Sari, D. P., Darhim, & Rosjanuardi, R. (2018). Errors of students learning with REACT strategy in solving the problems of mathematical representation ability. *Journal on Mathematics Education, 9*(1), 121-128. http://dx.doi.org/10.22342/jme.9.1.4301.121-128

Suryaningtyas, B. ve Halimah, L. (2017). Pengaruh strategi REACT terhadap kemampuan koneksi matematis siswa kelas v sd. *Jurnal Khazanah Sekolah Dasar, 5*(1), 90-98.

Tatlı, A. (2020). *REACT Stratejisinin ortaokul öğrencilerinin kavramsal anlama, bilimsel süreç ve yaşam becerileri üzerine etkisi.* (Yayınlanmamış Yüksek Lisans Tezi). Düzce Üniversitesi, Fen Bilimleri Enstitüsü, Düzce.

Tomi, A., & Rambli, D. R. A. (2013). An interactive mobile augmented reality magical playbook: Learning number with the thirsty crow. *Procedia Computer Science*, 25, 123–130. https://doi.org/10.1016/j.procs.2013.11.015

Turhan, M. A.; Metin, M. & Ezberci Çevik, E., (2022). A Content Analysis of Studies Published in the Field of Augmented Reality in Education. *Journal of Educational Technology & Online Learning, 5*(1), 243-262.

Uysal, F. & Özdemir, D. (2024). İlkokul 3. sınıf öğrencilerine yönelik artırılmış gerçeklik teknolojisi ile ingilizce eğitimi için mobil oyun uygulaması. *Journal of Estudam Information, 5* (1): 12–18, 2024, https://doi.org/10.53608/Estudambilisim.1307619

Ültay, E. (2014). *İtme, momentum ve çarpışmalar konusuyla ilgili bağlam temelli öğrenme yaklaşımına dayalı açıklama destekli REACT stratejisine göre geliştirilen etkinliklerin etkisinin araştırılması.* (Yayınlanmamış Doktora Tezi). Karadeniz Teknik Üniversitesi, Eğitim Bilimleri Enstitüsü, Trabzon.

Wahyuni, E.S. (2013). *The application of contextual teaching learning using REACT in speaking practices for business english class. Magister Scientiae* - ISSN: 0852-078X 145 Edisi No. 34 - Oktober 2013. https://core.ac.uk/download/pdf/294854902.pdf

Wibowo, F.C. (2023). Effects of Augmented Reality Integration (ARI) based Model Physics Independent Learning (MPIL) for facilitating 21st-Century Skills (21-CS). *Journal of Technology and Science Education, 13*(1), 178-192. https://doi.org/10.3926/jotse.1800.

Yoon, S. A., Anderson, E., Park, M., Elinich, K., & Lin, J. (2018). How augmented reality, textual, and collaborative scaffolds work synergistically to improve learning in a science museum. *Research in Science & Technological Education, 36*(3), 261-281. https://doi.org/10.1080/02635143.2017.1386645

Yuen, S. C.-Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange, 4*(1), 119–140. https://doi.org/10.18785/jetde.0401.10