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# Secondary School Students' Opinions on Teaching the Structure of the Atom with Augmented Reality Application


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## Abstract

This study is aimed at developing an achievement test on quadrilaterals for seventh-grade students. The concept of the atom can be visualized in different ways in the mind due to its structure, which the naked eye cannot see. Augmented reality (AR) is one of the applications that can be used to teach such concepts. This study aimed to investigate students' views on the use of AR applications in teaching. Phenomenological design, one of the qualitative research designs, was used in the study. The study group consisted of 26 -graders in a public secondary school. AR application was organized to teach the structure of the atom. Within the scope of the study, an interview form consisting of four open-ended questions prepared by the researchers and submitted to expert opinion for content validity was used as a data collection tool. When the students' answers to the questions were examined, it was determined that they had positive opinions that AR application could be used in other courses and different subjects, that this application was more instructive because it concretized the subject, that it caused a better understanding of the subject it was used in, and that it increased participation in the lesson due to the possibilities of providing three-dimensional images. Suggestions were made based on the results.


***Keywords:*** Augmented reality, atomic structure, secondary school students, student views.

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# Arttırılmış Gerçeklik Uygulaması ile İlgili Atomun Yapısının Öğretimine İlişkin Ortaokul Öğrencilerinin Görüşleri


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## Öz

Atom kavramı çıplak gözle görülemeyen yapısı nedeni ile zihinlerde farklı şekillerde canlandırılabilmektedir. Artırılmış gerçeklik (AR) uygulaması ise bu tür kavramların öğretiminde kullanılabilecek uygulamalardan biridir. Bu çalışmada AR uygulamasının öğretimde kullanılmasına ilişkin öğrenci görüşlerinin araştırılması amaçlanmıştır. Araştırmada nitel araştırma desenlerinden fenomoloji deseni kullanılmıştır. Çalışma grubunu bir devlet ortaokulunda öğrenim gören 26 yedinci sınıf öğrencisi oluşturmaktadır. Atomun yapısının öğretimi için AR uygulaması düzenlenmiştir. Araştırma kapsamında, veri toplama aracı olarak araştırmacılar tarafından hazırlanan ve kapsam geçerliği için uzman görüşüne sunulan dört açık uçlu sorudan oluşan görüşme formu kullanılmıştır. Öğrencilerin sorulara verdikleri cevapları incelendiğinde; AR uygulamasının diğer derslerde ve farklı konularda da kullanılabileceği, bu uygulamanın konuyu somutlaştırdığından dolayı daha öğretici olduğu, kullanıldığı konunun daha iyi kavranabilmesine sebep olduğu ve üç boyutlu görüntü sağlama olanaklarından dolayı derse katılımı da artırdığı yönünde olumlu görüşlere sahip oldukları belirlenmiştir. Ortaya çıkan sonuçlardan hareketle önerilerde bulunulmuştur.

***Anahtar Sözcükler:*** Arttırılmış gerçeklik, atomum yapısı, ortaokul öğrencileri, öğrenci görüşleri.

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## Introduction

In proportion to the rapid developments in science, there are also rapid technological developments. Developing technology is used in the field of education as in every field. The use of technology has become an indispensable part of distance education. In the world, there have recently been cases where teaching cannot continue in classrooms and can only be carried out technologically (Bostan Sarıoğlan, Şen, & Altaş, 2021). Countries with infrastructure in the use of technology in education have organized their educational environments in this process, and the importance of using technology in education has once again emerged. The effects of integrating technology into the teaching process on teaching have been the subject of many studies and it has been stated that the use of various technology applications in education positively affects teaching (Agustina, Siregar, Husain, Asfahani, & Pahmi, 2023; Deng, & Yu, 2023; Fitria, 2023; Grassini, 2023; Lee, 2024; Raja, & Nagasubramani, 2018; Rangel-de Lazaro, & Duart, 2023; Strzelecki, 2023; Wijayanto, Thamrin, Haetami, Mustoip, & Oktiawati, 2023; Yu, 2023; Zhu, Sun, Luo, Li, & Wang, 2023). One of the smart technologies accepted as medium-term in integrating these technologies into learning and teaching environments is augmented reality (AR) application (Spector & Denton, 2016). As a result of the increasing use of technology, the use of AR applications in education has also increased.

Koumpouros (2024), in his research compiling augmented reality studies, stated that the studies on this subject doubled between 2016 and 2020. Hidayat and Wardat (2024) mentioned the commonly used types of augmented reality in their study, compiling the studies using AR applications in Science, Technology, Engineering and Mathematics education. AR application is an important technology that enhances learning experiences (Garzón, Pavón, & Baldiris, 2019). Using AR application in science education increases students' interest in the course (Ab Aziz, Ab Aziz, Avijit, Yusof, & Noor, 2012; Sumadio, & Rambli, 2010). It has been determined that teaching using AR applications in science lessons has positive and significant effects on students' academic achievement and various variables supporting science teaching (Anıl, & Batdi, 2023). From the perspective of students, interacting with materials produced with AR applications creates a fun environment for learning activities (İzgi Onbaşılı, 2018). With the decrease in the costs of AR technologies, the accessibility and usability of these technologies have increased, and their potential in teaching environments has increased (Somyürek, 2014). In particular, the increasing use of smartphones has increased the interest in AR applications (Kljun, Geroimenko, & Čopič Pucihar, 2020). Although the use of AR applications in education has advantages, technical problems and limitations arising from the equipment used in teaching are the most common problems (Koumpouros, 2024). In addition, the fact that students find using AR applications difficult is one of the other problems encountered (Akcayir & Akcayir, 2017).

When the literature is examined, it is understood that the features such as visualizing the subject and increasing comprehensibility, allowing students to experience events that are not possible in the real world, and concretizing abstract content are effective in the importance of augmented reality for science courses (Arvanitis et al., 2009; Klopfer, & Sheldon, 2010; Klopfer, & Squire, 2008). AR technologies also enable students to experience science experiments that may be risky to physically observe in the real world (Wu, Lee, Chang, & Liang, 2013). Students have various difficulties in learning abstract concepts in science courses. For example, there is a relationship between the representation of the structure of the atom in science books and students' misconceptions about the atom (Hejnová, & Kralik, 2019). In science education, human anatomy (Kurniawana, Suharjitoa, & Witjaksono, 2018), cell (Coşkun, & Özkaya, 2023; Özeren, & Top, 2023; Tarng, Lin, & Ou, 2021), atom (Cai, Wang, & Chiang, 2014; Ewais, & Troyer, 2019), periodic table (Alrige, Bitar, Al-Suraihi, Bawazeer, & Al-Hazmi, 2021; Olim, & Nisi, 2020) and the use of AR technology in teaching abstract concepts such as elements (Chen, & Liu, 2020) are effective in students' more accurate structuring of concepts.

This study aims to investigate students' views on using AR applications in teaching the subject of atoms at the secondary school level. It is important to understand the concepts in teaching, such as the atom, which students cannot observe and experiment with in daily life, and for these reasons, they have difficulty in understanding. It is stated in the studies that the atomic model that students form in their minds and the real atomic model are not compatible with each other (Harrison & Teragust, 1996; Kaya, 2023). The reason for this is the students' lack of knowledge and experience about the atomic model (Cokelez & Yalçın, 2012). In this context, there is a need for instructional content that will facilitate

students' understanding of the concept of the atom by concretizing it. Based on this situation, this study aimed to obtain students' opinions about the use of augmented reality applications in teaching the concept of atoms. Students' feedback on AR applications will facilitate understanding the strengths and weaknesses of using this application and shed light on future teaching applications. The research question of this study is as follows.

What are the students' opinions about using AR applications on the particulate structure of matter? The sub-questions determined based on the research question are given below.

1) What are the students' opinions about the contribution of the use of AR applications in courses to course success?
2) What are the students' opinions about the difficulties experienced while using the AR application?
3) What are the students' views on which subjects would be more effective if AR applications were used in science courses?
4) What are the students' opinions about the usage areas of AR applications in different courses?

## Method

### Research Design

Phenomenology design, one of the qualitative research designs, was used in this study. The study was conducted in the 2024-2025 academic year. Phenomenology is a qualitative research method that enables individuals to express their understandings, feelings, perspectives, and perceptions about a concept and is used to describe how they experience this concept (Rose, Beeby, & Parker, 1995).

### Study Group

The research group consisted of 26 students studying in the 7$^{th}$ grade of a public secondary school in a metropolitan center in the western region of Turkey. The school is a school with a medium achievement level in the city center. Convenient sampling method was used in the selection of the study group. The convenient sampling method is the method of identifying easily accessible individuals related to the problem (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz, & Demirel, 2010). Of the students participating in the study, 14 (53.8%) were female and 12 (46.2%) were male. The students' academic achievement in the science course's written exam was at a moderate level and the number of male and female students was close to each other.

### Research Instruments and Procedures

Within the scope of the research, 'Augmented Reality Opinion ' (AROF) was prepared by the researchers as a data collection tool to obtain the students' opinions about the use of AR applications in teaching the atom subject. The form consists of five open-ended questions in the first stage, and the opinions of two science education experts and two science teachers were taken to ensure content validity. As a result of expert opinions, one question was removed from the form in line with the opinion that it was ineffective in determining student ideas about augmented reality. The final version of the form included four open-ended questions. In the form, the following questions were asked: "What are your opinions about the contribution of AR application to course success, the difficulties experienced while using AR application, the subjects in which AR application would be more effective if it is used in science courses, and the usage areas of AR application in different courses?".

At the 7th grade level, the instruction in which AR application about the structure of the atom was used lasted four lesson hours. Inquiry-based learning approach was taken as a basis for teaching. Detailed information about teaching the structure of the atom is given below.

#### Inquiry Step

To direct the students to question, "Are there basic parts of the atom as there are basic parts of the cell?" and "What kind of structure do atoms have?" were asked. Then, the teacher tried to make the students observe that when he held a plastic comb to small pieces of paper, it did not attract the papers. Still, after rubbing the comb on his hair, the comb attracted the small pieces of paper and tried to intuit that some charges in the atom can move from one substance to another substance because they move very fast and that the atom consists of particles.

**Step of Revealing Existing Knowledge**

In this step, the teacher asked some questions for the students to recall the information they learned in the 6th grade. For example, "What kind of movements do particles make?" was asked.

**Forecasting**

In this step, students made predictions about the concept of an atom.

**Planning and Implementation Step**

In this section, the students were divided into 6 groups of 4. Students were made to watch videos about the concept of atoms. Then, the students were asked to open the AR application with the help of their smartphones, zoom in, examine the three-dimensional images of atoms of different elements, and compare them with the images in the video.

**Photo 1.** *Application phase*

**Photo 2.** *Application phase*

**Commenting and Presenting Results Step**

After watching the videos and examining the three-dimensional images of the element cards, the students realized that protons and neutrons are in the atom's nucleus. At the same time, electrons move very fast in the layers. They realized that protons are positively charged, neutrons are uncharged, and electrons are negatively charged. By comparing their predictions and observations, the students in the groups who made wrong predictions reached the correct conclusion by discussing among themselves.

**Evaluation Step**

At the end of the application, AROP was distributed to the students, and their opinions about augmented reality were taken into account.

**Data Analysis**

This study used the descriptive analysis method to analyze the qualitative data obtained from the open-ended questions in AROP. The answers given by each student to the AROP were analyzed separately by the researchers. Separate codes were created for the students' different answers. A science educator field expert re-examined the categories formed in each question to ensure reliability, and categories independent of the other researcher were formed. Then, the analyses of the two researchers were compared. The percentage of agreement between the two researchers was calculated as 92.4%. Inter-coder reliability above 70% indicates that the analysis results can be considered reliable (Miles, & Huberman, 1994), and it can be said that the data analysis in this study is reliable. The analyses continued on the answers, but the researchers could not reach a consensus until a consensus was reached between the two researchers. In the study, the participants' real names were kept confidential, and the participants were given codes as S1, S2, …….. S26 were given codes and used in direct quotations.

**Ethical Procedures**

The students included in this study volunteered to participate, and parental permissions were obtained. The student identities were kept confidential in the data obtained. Ethics committee approval was approved by the Balıkesir University Science and Engineering Sciences Ethics Committee in the meeting dated 16.12.2024 and numbered 2024/10.

## Results

The first sub-problem of the research is "What are the students' opinions about the contribution of the use of AR application in courses to course success?". The findings related to this research problem are presented in Table 1.

**Table 1**. *Student views on the contributions of the AR application to course success*

| Codes | Frequency |
|---|---|
| More memorable information | 3 |
| Better comprehension of the subject | 5 |
| Being more instructive by concretizing the subject | 5 |
| Learning the subject better because it is fun | 4 |
| More rational as it provides a three-dimensional image | 2 |
| Increased participation in the course | 7 |

When the codes in Table 1 were analyzed, it was determined that the students' opinions about the contributions of AR application to the success of the course were as follows: increasing participation in the lesson (f=7), being more instructive by concretizing the subject (f=5), comprehending the subject better (f=5), learning the subject better because it is fun (f=4), more memorable information (f=3) and being more permanent because it provides three-dimensional images (f=2).

Some examples of student views are given below:

*S7: Since we could see the three-dimensional version of the subject, we could analyze it better and understand the subject better.*

*S12: Augmented reality cards increase participation in the lesson because they make the lessons more fun.*

*S17: It affects our success positively. Because what is done and explained in the lesson is temporary. Augmented reality is more realistic and more permanent.*

The second sub-research problem of the study is "What are the students' opinions about the difficulties experienced while using the AR application?". The findings related to the research question are presented in Table 2.

**Table 2.** *Student opinions about the difficulties experienced during the use of the AR application*

| Codes | Frequency |
|---|---|
| No, I had no difficulty | 12 |
| The application does not open immediately | 8 |
| Some element cards are not read by the phone | 1 |
| Small phone screen | 2 |
| Internet problem | 3 |

When the codes in Table 2 were analyzed, it was seen that twelve students stated that they had no difficulty, eight students stated that the application did not open immediately, three students stated that they had internet connection problems, two students stated that the phone screen was small, and one student stated that the application that we downloaded to their phones did not read some element cards.

Some examples of student views are given below:

*S4: When the application is installed, it does not open immediately. It is necessary to enter the application and open it again.*

*S14: I did not. But the screen where we saw atoms was small. It would have been better to see it on the smart board.*

*S15: Some had internet problems. In some, it was not loaded.*

The third sub-problem of the research is "What are the students' views on which subjects would be more effective if AR application is used in the science course?". The findings related to the research question are presented in Table 3.

**Table 3.** *Opinions on the subjects in which AR applications can be more effective if they are used in science courses*

| Codes | Frequency |
|---|---|
| Basic parts of the cell | 10 |
| Space technology and celestial bodies | 6 |
| Phases of meiosis | 4 |
| Phases of mitosis | 4 |
| Mass and weight | 2 |

When the codes in Table 3 were analyzed, it was determined that ten students stated that the AR applications could be more effective if it was used in the science course in which subjects; ten students stated that it could be applied in the subjects of basic parts of the cell, six students in the subjects of space technology and celestial bodies, four students in the subjects of stages of meiosis, four students in the subjects of stages of mitosis, and two students in the subjects of mass and weight.

Some examples of student views are given below:

*S5: We could have used this application for animal and plant cells. When we read the cards on the phone, all of their keywords could have come out.*

*S7: We can observe meiosis and mitosis more carefully and have no difficulty understanding the subject.*

*S14: We can use it in the subject of space. Thus, it will be more fun and memorable. For example, augmented reality allows us to do experiments that we cannot do at school.*

The fourth sub-problem of the research is "What are the students' opinions about the usage areas of AR application in different courses?". The findings related to the research question are presented in Table 4.

**Tablo 4.** *Student opinions about the usage areas of AR applications in different courses*

| Codes | Frequency |
|---|---|
| Social Studies | 11 |
| Maths | 7 |
| Music | 3 |
| Technology-Design | 4 |
| English | 1 |

When the codes in Table 4 are analyzed, it is seen that 11 students stated that AR application could be used in social studies, seven students in mathematics, three students in music, four students in technologydesign, and one student in English courses.

Some examples of student views are given below:

*S17: I would like to do it in the social studies course. Because it allows us to feel the old structures, objects, etc. more closely and behave as if we were there.*

*S2: It would be very nice and fun in subjects such as geometry and shapes in maths lessons. S5: Yes, I would like to, for example, play an instrument in music.*

## Discussion, Conclusion and Recommendations

In this study, students were made to experience this technology with AR application on the structure of atom, and their opinions about AR application were investigated. Based on the results obtained in the research, it can be said that this technology has a positive effect on students because of the use of augmented reality in science lessons. Students stated that AR application would increase participation in the lesson by helping to comprehend the subject better, being more instructive because it concretizes the subject, and providing three-dimensional images. In addition, the students who stated that they generally had a positive opinion about the applications stated that they wanted to use these and similar applications in other courses and subjects. This situation can be explained by the positive effect of augmented reality applications on students' understanding. According to this result, it can be said that augmented reality applications are effective in understanding and concretizing concepts. When the literature is analyzed, results similar to those of this study are found. For example, Garzón and Acevedo (2019), in their research in which they compiled the studies on AR applications, stated that AR applications effectively increase students' achievement. In addition, Di Serio, Ibanez, and Kloos (2013) concluded in their study that using AR applications in lessons positively affects students' attitudes and motivation. A study by Rizov and Rizov (2015) revealed that students who used augmented reality applications as a learning tool in higher education courses increased their interest in the course and understood and internalized the learning content more easily.

When the ' opinions were analyzed, the students who stated they had no difficulty using the AR application were encountered most frequently. The fact that the application did not open immediately and the internet were the most common problems encountered in the AR application. Since AR

applications are applications of technology, the problems experienced will affect the opinions about this application. Similarly, Koumpouros (2024), in his study compiling the results of the AR application, mentions that he encountered technical problems most frequently.

In their opinions, the students stated that AR applications would be most appropriate in teaching the cell subject, a concept we cannot see with our eyes. In addition, students stated that teaching the organelles of the cell and cell divisions with AR applications teaching the organelles of the cell and cell divisions with AR application would be better. This situation can be explained by the fact that the use of AR applications in learning micro-level concepts such as atom and cell and macro-level concepts such as universe and space, which students cannot see with their eyes, provides a chance to observe the concept concretely and affects better understanding. Coşkun and Özkaya (2023), Özeren and Top (2023), Tarng, Lin, and Ou (2021) stated in their studies that using AR application in teaching the cell subject was effective in helping students learn the subject better. Students also think it would be appropriate to use AR applications for space technologies and celestial bodies, which, unlike the concept of the atom, is not a very suitable subject for experimentation in science lessons and is taught through various activities. Chen, Chen, and Wang (2022) concluded that astronomy teaching using AR applications had a positive effect on students' academic achievement and motivation. Fleck and Simon (2013) stated that using AR applications in astronomy teaching was effective in onusing AR applications in astronomy teaching andin students' motivation. Supporting this result, Beltozar-Clemente, Sierra-Liñan, Zapata-Paulini, and Cabanillas-Carbonell (2022) found that the AR application significantly affected the astronomy learning of 4th and 6th-grade students in their study.

Another study result is that the students think  in social studies and mathematics courses. Students also stated that AR applications could be used in courses such as music and English. Students assume that using these applications to teach abstract concepts in these courses will positively affect their learning.

This study's biggest problem was bringing students' smartphones to the classroom environment. Smartphones were used only for AR applications in the science lesson and were controlled by the teacher during the lesson to prevent them from being used for different purposes. In this study, while obtaining the consent form from the parents, the students were asked to bring their smartphones to the classroom. However, not every student may have a smartphone, and smartphones are prohibited in some schools. Technology-supported devices must be present in the classroom to use the AR application. Therefore, it is important to establish technologies to support such applications in the classroom environment.

Based on the results of this study, the following suggestions were made by the researchers who will research this subject:

In future research, firstly, studies can be conducted to investigate the effects of using augmented reality applications in teaching micro and macro-level science subjects. At the same time, long-term experimental studies can be conducted to investigate the effects of augmented reality applications on students' cognitive and affective factors. Just as in the science course, it can be suggested that AR applications be used in subjects of other courses that contain abstract concepts and are difficult for students to understand.

## References

Ab Aziz, N., Ab Aziz, K., Avijit, P., Yusof, A. M., & Noor, N. S. M. (2012). Providing augmented reality based education for students with attention defcit hyperactive disorder via cloud computing: Its advantages. Advanced communication technology (ICACT), 2012 14th International Conference on Advanced Communication Technology (ICAAT) (pp. 577–581). IEEE. PyeongChang, South Korea. https://ieeexplore.ieee.org/xpl/conhome/6170041/proceeding

Agustina, I., Siregar, L. A., Husain, D. L., Asfahani, A., & Pahmi, P. (2023). Utilization of Digital Technology in Children's Education to Enhance Creative and Interactive Learning. *At-Tarbawi: Jurnal Pendidikan, Sosial Dan Kebudayaan, 10*(2), 276-283.

Akcayir, M., & Akcayir, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic literature review. *Educ. Res. Rev. 20,* 1–11.

Alrige, M., Bitar, H., Al-Suraihi, W., Bawazeer, K., & Al-Hazmi, E. (2021). MicroWorld: An Augmented-Reality Arabian App to Learn Atomic Space. Technologies, 9(3), 53. https://doi.org/10.3390/technologies9030053.

Anıl, Ö., & Batdi, V. (2023). Use of augmented reality in science education: A mixed-methods research with the multi-complementary approach. *Education and Information Technologies, 28*:5147–5185 https://doi.org/10.1007/s10639-022-11398-6.

Arvanitis, T. N., Petrou, A., Knight, J. F., Savas, S., Sotiriou, S., Gargalakos, M., & Gialouri, E. (2009). Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. *Personal and ubiquitous computing, 13*(3), 243-250.

Beltozar-Clemente, S., Sierra-Liñan, F., Zapata-Paulini, J., & Cabanillas-Carbonell, M. (2022). Augmented reality mobile application to improve the astronomy teaching-learning process. *Advances in Mobile Learning Educational Research, 2*(2), 464-474.

Bostan Sarıoğlan, A., Şen, R., & Altaş, R. (2021). What do secondary school students think about experimental practices in science lessons taught in distance education?. *Journal of Educational Technology and Online Learning, 4*(2), 193-214.

Büyüköztürk, Ş., Kılıç-Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2010). *Bilimsel araştırma yöntemleri* (6. ed.). Ankara: Pegem A Publishing.

Cai, S., Wang, X., & Chiang, F. K. (2014). A case study of Augmented Reality simulation system application in a chemistry course. Computers in human behavior, 37, 31-40. https://doi.org/10.1016/j.chb.2014.04.018.

Chen, C. C., Chen, H. R., & Wang, T. Y. (2022). Creative situated augmented reality learning for astronomy curricula. *Educational Technology & Society, 25*(2), 148-162.

Chen, S. Y., & Liu, S. Y. (2020). Using augmented reality to experiment with elements in a chemistry course. *Computers in Human Behavior, 111,* 106418. https://doi.org/10.1016/j.chb.2020.106418.

Cokelez, A., & Yalçın, S. (2012). Investigation of mental models of elementary 7th grade students about atom concept. *Elementeary Education Online, 11*(2) 452-471.

Coşkun, H., & Özkaya, A. (2023). The Effect of 7th Grade "Cell and Divisions" Unit Teaching with Augmented Reality Technology on Students' Academic Achievement. *Journal of Teacher Education and Lifelong Learning, 5*(2), 538-554.

Deng, X., & Yu, Z. (2023). A meta-analysis and systematic review of the effect of chatbot technology use in sustainable education. *Sustainability, 15*(4), 2940.

Di Serio, A., Ibanez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education, 68*, 586- 596.

Ewais, A., & Troyer, O. D. (2019). A usability and acceptance evaluation of the use of augmented reality for learning atoms and moleculers reaction by primary school female students in Palestine. *Journal of Educational Computing Research, 57*(7), 1643-1670.

Fitria, T. N. (2023). Augmented reality (AR) and virtual reality (VR) technology in education: Media of teaching and learning: A review. *International Journal of Computer and Information System (IJCIS), 4*(1), 14-25.

Fleck, S., & Simon, G. (2013, November). An augmented reality environment for astronomy learning in elementary grades: an exploratory study. In Proceedings of the 25th Conference on l'Interaction Homme-Machine (pp. 14-22).

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. *Educational Research Review,* 27, 244-260. https://doi.org/10.1016/j.edurev.2019.04.001.

Garzón, J., Pavón, & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality, 23:*447–459 https://doi.org/10.1007/s10055-019-00379-9.

Grassini, S. (2023). Shaping the future of education: exploring the potential and consequences of AI and ChatGPT in educational settings. *Education Sciences, 13*(7), 692.

Harrison, A. G., & Treagust, D. F. (1996). Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. *Science Education, 80*(5), 509-534.

Hejnová, E., & Králík, J. (2019, September). Images of atoms in physics textbooks for lower secondary schools vs. misconceptions of pupils about atoms. In AIP Conference Proceedings (Vol. 2152, No. 1). AIP Publishing.

Hidayat, R., & Wardat, Y. (2024). A systematic review of augmented reality in science, technology, engineering and mathematics education. *Education and Information Technologies, 29*(8), 9257-9282.

İzgi Onbaşılı, Ü. (2018). Artırılmış gerçeklik uygulamalarının ilkokul öğrencilerinin artırılmış gerçeklik uygulamalarına yönelik tutumlarına ve fen motivasyonlarına etkisi. *Ege Journal of Education, 19*(1), 320-337.

Kaya, A. (2023). Addressing student misconceptions about atoms and examining instructor strategies for overcoming them. *Journal of Pedagogical Research, 7*(4), 251-262.

Kljun, M., Geroimenko, V., & Čopič Pucihar, K. (2020). *Augmented Reality in Education: Current Status and Advancement of the Field*. In: Geroimenko, V. (eds) Augmented Reality in Education. Springer Series on Cultural Computing. Springer, Cham. https://doi.org/10.1007/978-3-030-42156-4_1.

Klopfer, E., & Sheldon, J. (2010). Augmenting your own reality: Student authoring of science-based augmented reality games. *New directions for youth development, 128,* 85-94.

Klopfer, E., & Squire, K. (2008). Environmental detectives—the development of an augmented reality platform for environmental simulations. *Educational Technology Research and Development, 56*(2), 203-228.

Koumpouros, Y. (2024). Revealing the true potential and prospects of augmented reality in education. *Smart Learning Environments, 11*:2 https://doi.org/10.1186/s40561-023-00288-0.

Kurniawana, M. H., Suharjitoa, D., & Witjaksono, G. (2018). Human Anatomy Learning Systems Using Augmented Reality on Mobile Application. *Procedia Computer Science, Volume 135*, Pages 80-88.

Lee, H. (2024). The rise of ChatGPT: Exploring its potential in medical education. *Anatomical Sciences Education, 17*(5), 926-931.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. (2nd Education). Calif.: SAGE Publications.

Olim, S. C., & Nisi, V. (2020). Augmented reality towards facilitating abstract concepts learning. In Entertainment Computing–ICEC 2020: 19th IFIP TC 14 International Conference, ICEC 2020, Xi'an, China, November 10–13, 2020, Proceedings 19 (pp. 188-204). Springer International Publishing.

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.

Raja, R., & Nagasubramani, P. C. (2018). Impact of modern technology in education. *Journal of Applied and Advanced Research, 3*(1), 33-35.

Rangel-de Lazaro, G., & Duart, J. M. (2023). You can handle, you can teach it: Systematic review on the use of extended reality and artificial intelligence technologies for online higher education. *Sustainability, 15*(4), 3507.

Rizov, T., & Rizova, E. D. (2015). Augmented reality as a teaching tool in higher education. International Journal of Cognitive Research in Science, Engineering and Education:(IJCRSEE), 3(1), 7-15.

Rose, P., Beeby, J. & Parker, D. (1995). Academic rigour in the lived experience of researchers using phenomenological methods in nursing. *Journal of Advanced Nursing, 21*(6), 2648.1995.21061123.x

Somyürek, S. (2014). Öğrenme sürecinde z kuşağının dikkatini çekme: Artırılmış gerçeklik. *Eğitim Teknolojisi Kuram ve Uygulama 4*(1), 63-80.

Spector, J. M., & Denton, T. X. (2016, March). Smart learning environments: Concepts and issues. Society for Information Technology & Teacher Education International Conference, Savannah, GA

Strzelecki, A. (2023). To use or not to use ChatGPT in higher education? A study of students' acceptance and use of technology. *Interactive Learning Environments,* 1-14.

Sumadio, D. D., & Rambli, D. R. A. (2010). Preliminary evaluation on user acceptance of the augmented reality use for education. Proceedings of Second İnternational Conference on Computer Engineering and Applications (pp. 461–465).

Tarng, W., Lin, Y. J., & Ou, K. L. (2021). A virtual experiment for learning the principle of Daniell cell based on augmented reality. *Applied Sciences, 11*(2), 762. https://doi.org/10.3390/app11020762.

Wijayanto, P. W., Thamrin, H. M., Haetami, A., Mustoip, S., & Oktiawati, U. Y. (2023). The potential of metaverse technology in education as a transformation of learning media in Indonesia. Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran, 9(2), 396-407.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education, 62,* 41-49.

Yu, Z. (2023). A meta-analysis of the effect of virtual reality technology in education. *Interactive Learning Environments, 31*(8), 4956-4976.

Zhu, C., Sun, M., Luo, J., Li, T., & Wang, M. (2023). How to Harness the Potential of ChatGPT in Education?. Knowledge Management & E-Learning, 15(2), 133-152.