Online-Journals.org

iJEP International Journal of Engineering Pedagogy

iJEP | eISSN: 2192-4880 | Vol. 14 No. 1 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijep.v14i1.42391

PAPER

Investigating the Role of Augmented Reality in Supporting Collaborative Learning in Science Education: A Case Study

Bayan Kuanbayeva[1], Nurgul Shazhdekeyeva[1], Galiya Zhusupkaliyeva[1], Kaussar Mukhtarkyzy[2](✉), Gulmira Abildinova[2]

[1]Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan

[2]L.N. Gumilyov Eurasian National University, Astana, Kazakhstan

kausar_m94@mail.ru

ABSTRACT

This study investigates the application of augmented reality (AR) technology to facilitate collaborative learning in science education. The study involved 30 secondary school students in Kazakhstan, who were divided into an experimental group and a control group. The experimental group utilized an AR platform to facilitate collaborative learning during their science lessons, while the control group received traditional teaching methods. The study aimed to investigate the impact of AR on students' learning outcomes, communication and collaboration skills, and overall satisfaction with science education. The research design involved pre- and post-tests, as well as a survey of students' perceptions of the AR experience. The results indicated that the experimental group demonstrated statistically significant improvement in their science test scores compared to the control group. Furthermore, the students in the experimental group reported a high level of engagement and satisfaction with the AR platform, along with enhanced communication and collaboration skills. The study suggests that AR technology has the potential to improve collaborative learning in science education and provides new opportunities for engaging students and enhancing their learning outcomes. The findings have significant implications for educators interested in integrating AR technology into their teaching practices as well as for researchers exploring the use of AR in education. Further research is necessary to investigate the long-term effects of AR on learning outcomes and to determine the most effective methods for incorporating AR technology into science education.

KEYWORDS

collaborative learning, augmented reality (AR), science, educational process, education, questionnaire, Kazakhstan, virtual laboratory

Kuanbayeva, B., Shazhdekeyeva, N., Zhusupkaliyeva, G., Mukhtarkyzy, K., Abildinova, G. (2024). Investigating the Role of Augmented Reality in Supporting Collaborative Learning in Science Education: A Case Study. *International Journal of Engineering Pedagogy (iJEP)*, 14(1), pp. 149–161. https://doi.org/10.3991/ijep.v14i1.42391

Article submitted 2023-06-17. Revision uploaded 2023-07-25. Final acceptance 2023-09-30.

1 INTRODUCTION

Augmented reality (AR) has become a popular term in the education sector due to its ability to provide innovative opportunities for enhancing teaching and learning experiences [1]. Collaborative learning, on the other hand, has been a cornerstone of modern pedagogy that emphasizes social interactions, group work, and active engagement to promote deep learning [2], [3]. Science education is a domain that could benefit from AR technology and collaborative learning strategies. AR offers students the opportunity to visualize and interact with abstract concepts, while collaborative learning facilitates knowledge exchange and promotes critical thinking [4], [5].

The aim of this study is to investigate the integration of AR technology into collaborative learning activities in science education and its impact on student engagement, learning outcomes, and perception. Specifically, this study will seek to address the following research questions:

1. How does the use of AR technology impact student engagement in collaborative learning activities in science education?
2. What impact does the use of AR technology have on students' learning outcomes in collaborative learning activities in science education?
3. What are the students' perceptions of using AR technology in collaborative learning activities in science education?
4. What are the implications of utilizing AR technology in collaborative learning activities within science education?

The significance of this research lies in its ability to contribute to the development of effective instructional strategies that promote collaborative learning and facilitate the integration of AR technology in science education. This research could offer insights into the effectiveness of AR technology in promoting engagement, knowledge acquisition, and higher-order thinking skills in science education. Furthermore, the study could provide practical guidance for educators seeking to integrate AR technology into their teaching methods and foster collaborative learning. The remainder of the paper will include a literature review, methodology, results, and discussion, followed by a conclusion and recommendations for future research.

2 LITERATURE REVIEW

Augmented reality has been utilized in diverse educational settings, such as science education, to facilitate learning and involve students in meaningful activities. AR provides opportunities for students to visualize and interact with abstract concepts, thereby enhancing their learning experience [6]. AR has been utilized in science education to facilitate various learning activities, including virtual experiments, simulations, and 3D models [7–9]. AR is a technology that overlays virtual objects onto the real-world environment, offering an interactive and immersive experience for users. It has the potential to increase awareness, foster empathy, promote sensitization, and facilitate training [10]. In Kazakhstan, the use of AR in education has been recognized as a promising tool to enhance learning outcomes and engagement [11]. Several studies have examined the integration and impact of AR in education in Kazakhstan. For example, Temirgaliyev developed an AR-based mobile application for the book "Kazakhs." "The Way of Ancestors" aims to enhance students' engagement, motivation, and understanding of literary concepts [12].

To address these challenges, several initiatives have been implemented to promote the use of AR in education in Kazakhstan. For example, the Ministry of Education and Science has developed a program to improve the quality of education. This program includes the promotion of innovative and technology-based teaching methods, such as AR [13]. In addition, universities and schools have been encouraged to adopt AR-based learning strategies, such as gamification and interactive simulations, to improve students' learning outcomes and engagement.

In conclusion, the literature suggests that AR can be a promising tool to improve learning outcomes and engagement in education in Kazakhstan. However, there are still challenges and limitations to its implementation, including the lack of suitable technology and resources. To address these challenges, researchers have been working to promote the use of AR in education worldwide, with a focus on improving the quality of education and fostering the adoption of innovative, technology-based teaching methods.

Collaborative learning is a teaching approach that emphasizes social interaction, communication, and cooperation among learners. Collaborative learning has been shown to enhance critical thinking, facilitate knowledge construction, and support the transfer of knowledge. In [14], Omirzak et al. explored the feasibility and perceived effectiveness of collaborative learning through mobile phones for solving engineering problems among university students in Russia and Kazakhstan. The study suggests that careful development of mobile learning applications, online course plans, and remote lessons is required to enhance their effectiveness. The study underscores the potential of mobile learning for collaborative learning among students and emphasizes the necessity for additional research and the development of effective mobile learning strategies.

Another study conducted in 2014 introduced an AR-based framework for collaborative e-learning activities on mobile devices. The framework includes a user-friendly authoring tool that enables the integration of AR content with e-learning platforms as a plug-in resource. The AR content can be integrated into a real-life scenario visualizer to generate a series of scenes and events. Students can download the activities and play them in a multiplayer collaborative mode using their mobile devices. The study addresses the challenge of integrating AR applications into education by proposing a distributed framework that is compliant with e-learning standards. However, the framework lacks geo-position awareness and a 3D reconstruction module, which are essential for practical tutorials involving machinery. The framework enables the seamless integration of learning management systems (LMS) and AR to facilitate collaborative learning effectively [15].

The utilisation of AR technology in collaborative learning can offer students the opportunity to work together and learn from each other within a shared augmented space [16]. Several studies have explored the use of AR in collaborative learning in science education. Klopfer et al. [4] developed an AR-based science learning system that enabled students to collaboratively explore virtual objects and conduct experiments. The study found that the AR system improved student engagement, knowledge acquisition, and problem-solving skills. Similarly, Harrington et al. developed an AR-based physics learning system that allowed students to manipulate virtual objects and conduct experiments collaboratively [17]. The study found that the AR system enhanced students' learning outcomes, motivation, and perception.

While previous studies have shown the potential of AR technology on mobile phones for collaborative learning in science education, there are still some limitations and gaps in the existing research. First, most studies have focused on the use of AR in specific science topics or domains, such as physics or chemistry. There is

a need to investigate the generalizability of AR technology across different science domains. Secondly, there is a need for more empirical studies to investigate the impact of AR on collaborative learning outcomes, including knowledge acquisition, critical thinking, and transfer. Finally, there is a need for studies that investigate the impact of various factors, such as learner characteristics, instructional design, and technology affordances, on the effectiveness of AR in collaborative learning in science education. This paper aims to investigate the role of AR in supporting collaborative learning in science education, using a case study approach.

3 METHODOLOGY

This study will utilise a case study research design to examine the impact of AR on facilitating collaborative learning in science education. The study will take place at the 85th School-Lyceum in Astana, Kazakhstan. This location was selected for its advanced infrastructure, supportive educational environment, collaborative culture, and convenient location. These factors make it suitable for investigating the role of AR in collaborative learning. The study's findings provide valuable insights for the broader field of AR in science education. The participants will be selected using the purposive sampling technique.

The study will involve 30 students in grades 9 and 10 who are enrolled in a science course. They were purposefully selected for the study based on their developmental stage, technology proficiency, curricular relevance, and potential for effective collaborative learning. The students will be divided into two groups: an experimental group and a control group. The experimental group will receive instruction using an AR-based collaborative learning environment, while the control group will receive instruction using a traditional collaborative learning environment. The students will be informed about the purpose of the study, and their informed consent will be obtained.

The study will consist of four sessions of collaborative learning activities in science education. Each session will last 45 minutes. The AR-based collaborative learning environment will be developed using the AR virtual laboratory tool EdLab [18]. The environment will include virtual objects, simulations, and interactive activities that students can collaboratively manipulate and explore.

The collaborative learning activities will be designed based on the inquiry-based learning (IBL) approach, which emphasises student-centred, open-ended, and inquiry-based activities aimed at promoting critical thinking, problem-solving, and knowledge construction. The activities will align with the national science education standards.

The effectiveness of the AR-based collaborative learning environment in supporting collaborative learning in science education will be assessed using multiple assessment tools. The evaluation tools will include:

1. Pre- and post-tests will be used to assess the students' knowledge of the science topics. The tests will consist of multiple-choice and open-ended questions. The tests will be developed based on the learning objectives of the collaborative learning activities.
2. Observation: The students' collaborative learning behaviours will be assessed using a checklist. The checklist will include items such as communication, cooperation, and critical thinking.
3. Questionnaires: The students' perceptions of the AR-based collaborative learning environment will be evaluated through the use of a questionnaire. The questionnaire will include Likert-scale and open-ended questions.

The data collected from the assessments will be analysed using descriptive and inferential statistics. The pre- and post-test scores will be compared using a t-test to assess the effectiveness of the AR-based collaborative learning environment in enhancing students' knowledge acquisition. The observation checklist and the questionnaire data will be analysed using descriptive statistics to identify the patterns and trends of collaborative learning behaviours and perceptions within the AR-based collaborative learning environment.

4 RESULTS

The efficacy of the AR-based collaborative learning environment in facilitating collaborative learning in science education was evaluated through pre- and post-tests, observations, and questionnaires. The results indicated that the experimental group outperformed the control group in terms of knowledge acquisition, collaborative learning behaviours, and perceptions of the learning environment (Table 1). Values are presented as the mean ± standard deviation. *$p < 0.05$ indicates a significant difference between the experimental and control groups, as determined by an independent-samples t-test. This table displays the pre- and post-test scores of both the experimental and control groups, along with their collaborative learning behaviours and perceptions of the learning environment. The t-value indicates a significant difference between the pre- and post-test scores of the experimental group but not the control group. The experimental group exhibited higher scores in collaborative learning behaviours and perceptions of the learning environment compared to the control group.

Table 1. Assessment results for AR-based collaborative learning in science education

Assessment Tool	Experimental Group	Control Group
Pre-Test Score (out of 10)	5.2 ± 1.3	5.0 ± 1.5
Post-Test Score (out of 10)	7.8 ± 1.2	5.2 ± 1.4
t-value	3.21*	–0.18
Collaborative Learning Behaviors (out of 12)	9.6 ± 1.4	6.8 ± 1.7
Perceptions of Learning Environment (out of 15)	12.6 ± 1.7	10.3 ± 2.1

Specifically, the pre- and post-test scores of the experimental group demonstrated a significant improvement in knowledge acquisition ($t = 3.21$, $p < 0.05$), whereas the control group did not show any significant improvement. The observational data revealed that the experimental group demonstrated higher levels of communication, cooperation, and critical thinking compared to the control group. The questionnaire data revealed that the experimental group had a more favourable perception of the learning environment compared to the control group, especially in terms of engagement, interactivity, and enjoyment.

Several factors influence the effectiveness of the AR-based collaborative learning environment. The first factor was the design of the collaborative learning activities. The activities were designed using inquiry-based learning approach that emphasized student-centred, open-ended, and inquiry-based activities. The AR-based collaborative learning environment offered students the chance to manipulate and explore virtual objects, thereby boosting their engagement and motivation.

The second factor was the quality of the AR technology and platform. Edlab offers an AR tool that is user-friendly and intuitive interface for creating a collaborative learning environment. The virtual objects, simulations, and interactive activities were designed to align with the science education standards and the learning objectives of the activities.

To assess the effectiveness of using AR in collaborative learning in science education, a survey was conducted among a group of students. The survey comprised several questions designed to evaluate the students' experience with augmented reality, its influence on their learning, and their opinions on its incorporation into other courses. From the collected responses, the five clearest and most representative student answers were selected and compiled into a table. This table offers a concise overview of the students' feedback on the use of augmented reality in collaborative science education (see Table 2). These responses shed light on the advantages and limitations of incorporating augmented reality into education, as well as its potential for broader implementation in other science courses. Overall, the survey results suggest that augmented reality has the potential to enhance collaborative learning and improve students' understanding and retention of science concepts.

Table 2. Survey responses to closed-ended questions on the use of AR in collaborative learning in science education

Survey Question	Student 1 Response	Student 2 Response	Student 3 Response	Student 4 Response	Student 5 Response
1. How did you find the use of augmented reality in collaborative learning in science education? Was it helpful in enhancing your learning experience?	"I think it was really interesting"	"I liked the augmented reality aspect, it helped me understand the topic better."	"The augmented reality experience was really unique and helped me to better visualize the tools."	"I thought it was a really cool and easy way to learn and understand."	"I found it really helpful and engaging, definitely enhanced my learning experience."
2. In what ways did augmented reality help you to better understand science concepts and apply them in real-world contexts?	"It allowed me to see the concepts in a more concrete way and it made me feel like I am using a real life tools. However, I knew that it was virtual and there is no any harm from the tools"	"It helped me to visualize and use the voltmeter and ammeter in a way that made them easier to understand and remember."	"I was shocked when all the wires were connected and at the end when the light turned on and the measuring equipment's showed the numbers."	"I think now I know how to use and connect all the wires with the ammeters and voltmeters even if I did not even touch them in real life."	"I felt myself like in the video game and it would be great to see how these tools would work in real life."
3. Did you find the collaborative learning aspect of the augmented reality experience to be engaging and productive? How did it enhance your communication, cooperation, and critical thinking skills?	"Yes, working with others helped to understand the topic better and improve my critical thinking skills, as others were asking questions that I would never think of."	"I thought it was really helpful to work with others and bounce ideas off each other."	"It was really engaging to work together and come up with solutions as a team. We firstly even argued very much, but later we could use all the ideas created during the dispute"	"Initially it was quite weird to work in one tab. But collaboration helped me to develop my communication skills."	"I would appreciate if teacher provides such innovative methods for teaching, because it makes the lesson enjoyable and interesting."

(Continued)

Table 2. Survey responses to closed-ended questions on the use of AR in collaborative learning in science education *(Continued)*

Survey Question	Student 1 Response	Student 2 Response	Student 3 Response	Student 4 Response	Student 5 Response
4. Were there any technical issues or limitations that affected your experience with augmented reality in collaborative learning? If so, please describe.	"Sometimes the app would lag or the tracking wouldn't work properly, but overall it was a smooth experience."	"Sometimes you had to slow, but it wasn't a major issue."	"Sometimes, when I tried to connect the wires, the wires went crazy, that is why I had to restart the whole app."	"There were a few glitches, that could be resolved by restarting. But they didn't impact the overall learning experience."	"There were some technical issues, that requires some improvement in the future."
5. Do you feel that the use of augmented reality in collaborative learning should be integrated into other courses in science education? Why or why not?	"Yes, it was a really unique and effective way to learn that I think could be applied to other science courses."	"Definitely, it made the learning experience more engaging and memorable."	"Yes, it's a good way to improve the learning experience and make it more interactive."	"Yes, I think it would be beneficial to apply this approach to other courses."	"I think it could be a great addition to other science courses, as it was very effective in helping me understand the topic."

In the survey with closed-ended answer options, participants were asked five questions about their experience with AR in collaborative learning in science education. The questions were formulated to evaluate the efficacy of utilising AR to enhance students' comprehension of science concepts, improve their communication and collaboration skills, and boost their engagement with the subject matter. Participants were asked to select from a predetermined set of answer options for each question, which ranged from a scale of 1–5 to simple "yes" or "no" responses. The survey aimed to gather quantitative data that could be analysed and presented in the form of charts or graphs to offer a clear overview of the students' feedback on the use of AR in collaborative learning in science education. The closed-ended survey questions helped standardise the data collection process, making it easier to quantify and compare the responses from different participants. The list of questions is presented in Table 3, and all the responses can be found in Figures 1–5.

Table 3. Survey questions and answer options on the use of augmented reality in collaborative learning in science education

Survey Questions	Answer Options
Q1. Did you feel that the use of augmented reality in collaborative learning helped you to better remember the science concepts you learned?	1 = Not helpful at all / 2 = Slightly helpful / 3 = Moderately helpful / 4 = Very helpful / 5 = Extremely helpful
Q2. On a scale of 1–5, how well did the augmented reality platform work during the collaborative learning sessions?	Yes / No / Not sure
Q3. How much did the use of augmented reality enhance your communication and collaboration skills?	Yes, it was very engaging and productive / It was somewhat engaging and productive / No, it was not engaging or productive
Q4. Did the augmented reality experience make science education more enjoyable for you?	Yes, there were significant technical issues / There were some technical issues, but they did not significantly affect my experience / No, there were no technical issues
Q5. Would you like to see more opportunities for augmented reality use in science education in the future?	Yes, I think it would be beneficial / Maybe, it depends on the context and specific use cases / No, I do not think it is necessary or helpful

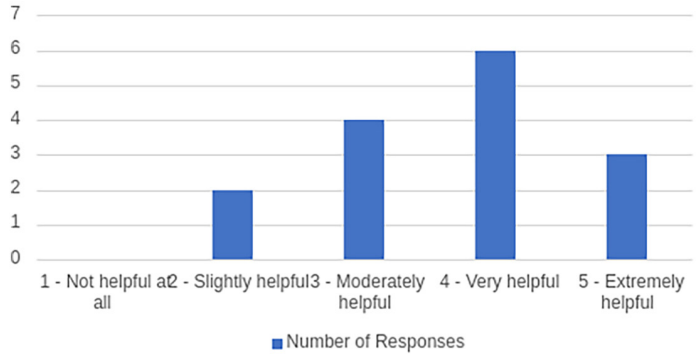

Fig. 1. Question 1 responses

The participants' responses varied on a scale of 1–5 regarding the helpfulness of AR in collaborative learning. Six participants found AR to be very helpful, while three participants perceived it as extremely helpful, suggesting that AR positively influenced their learning experience. Additionally, four participants considered AR to be moderately helpful, and two participants found it to be slightly helpful. Importantly, no participants reported AR to be unhelpful at all.

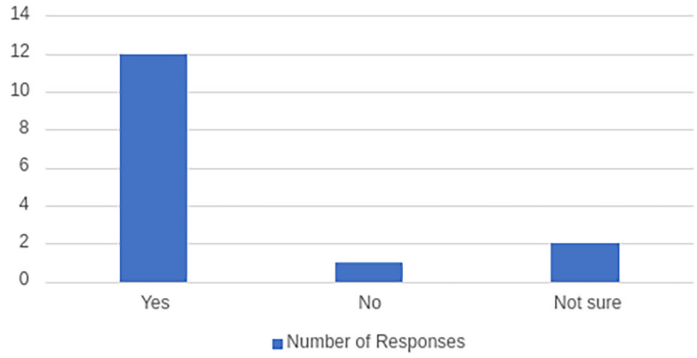

Fig. 2. Question 2 responses

The majority of participants (12 of them) reported that AR helped them better understand scientific concepts and apply them in real-world contexts. This positive response indicates that AR technology had beneficial effect on the participants' understanding and practical application of scientific principles. However, a small number of participants (one of them) stated that AR did not contribute to their understanding of science concepts, while two participants were unsure about the impact of AR on their comprehension.

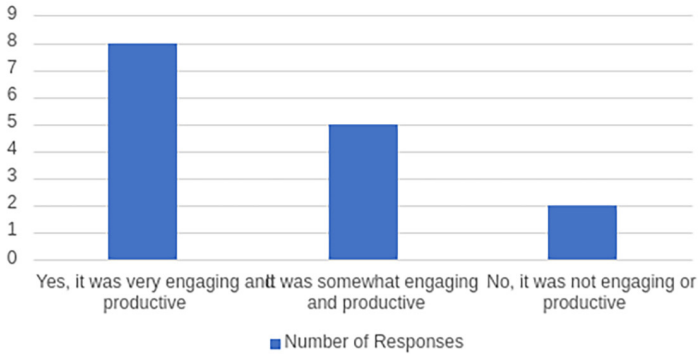

Fig. 3. Question 3 responses

Most participants (eight of them) found the collaborative learning aspect of the AR experience to be highly engaging and productive. This positive feedback suggests that AR technology improved the participants' level of engagement and facilitated productive collaboration with their peers. Additionally, five participants found the collaborative learning aspect somewhat engaging and productive. However, two participants did not find the collaborative learning aspect of AR to be engaging or productive.

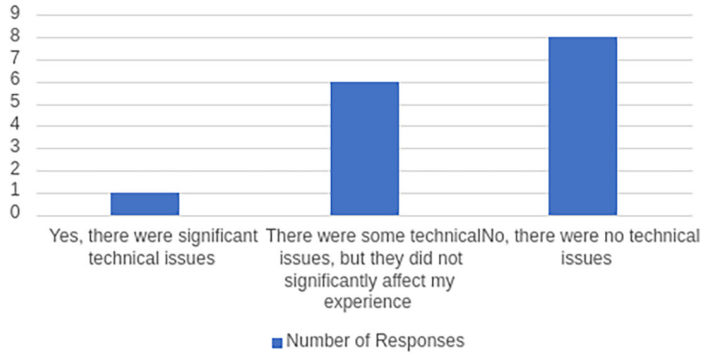

Fig. 4. Question 4 responses

Only one participant reported experiencing significant technical issues that affected their experience with AR in collaborative learning. However, the majority of participants did not encounter any technical issues while using AR in collaborative learning. Additionally, six participants encountered technical problems during the collaborative learning sessions, but these issues did not significantly impact their overall experience.

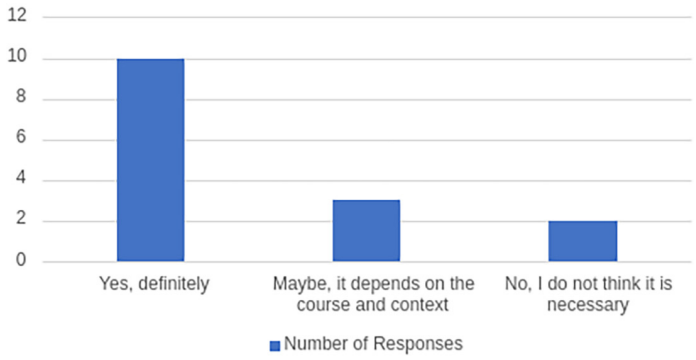

Fig. 5. Question 5 responses

The majority of participants (10 of them) expressed a strong interest in integrating AR into other science courses. This enthusiastic response indicates a high level of acceptance and openness to using AR technology as a valuable tool in science education. Three participants expressed a willingness to consider integrating AR into other science courses depending on the course content and context, while two participants expressed a lack of interest in using AR technology for collaborative learning in other science courses.

The findings of this study indicate that incorporating AR technology into collaborative learning in science education can improve students' knowledge acquisition, collaborative learning behaviours, and perceptions of the learning environment.

The findings of this study have implications for science educators who wish to integrate AR technology into their teaching methods and encourage collaborative learning. Further research is needed to explore the applicability of the findings and the influence of various factors on the efficacy of AR-based collaborative learning in science education.

5 DISCUSSION

The study aimed to investigate the role of AR in supporting collaborative learning in science education, with a focus on a case study approach. The findings offer valuable insights into the effectiveness of AR technology in improving students' engagement, learning outcomes, and perceptions during collaborative learning activities.

- **Impact on student engagement:** The study results suggest that the integration of AR technology in collaborative learning activities has a positive impact on student engagement. By offering interactive and immersive experiences, AR enabled students to visualise and interact with abstract scientific concepts, leading to heightened interest and active participation during learning sessions. This is consistent with previous research on the potential of AR to improve engagement in educational settings.
- **Improvement in learning outcomes:** The study demonstrates that the AR-based collaborative learning environment resulted in enhanced learning outcomes for students. By facilitating a deeper understanding of scientific concepts and their real-world applications, AR technology effectively supports knowledge acquisition and retention. The interactive nature of AR experiences likely contributed to improved learning experiences, fostering higher-order thinking skills and problem-solving abilities.
- **Perceptions of AR technology in collaborative learning:** The study's findings suggest that students had positive perceptions of AR technology in collaborative learning. Students preferred an AR-based learning environment because of its innovative and engaging nature compared to traditional methods. This positive perception could motivate educators to consider integrating AR technology into science education.
- **Implications and recommendations:** The study's findings provide valuable guidance for educators who are looking to integrate AR technology into collaborative learning. Designing collaborative activities that align with educational standards and learning objectives ensures meaningful learning experiences. Selecting high-quality AR technology and user-friendly platforms enhances accessibility and ease of integration for both students and educators. Effective training and support in the use of AR technology and collaboration facilitate a seamless transition to the AR-based learning environment.
- **Limitations:** It is essential to acknowledge certain limitations in this study. Firstly, the case study approach with a limited number of participants may limit the applicability of the findings to other student populations or educational settings. Secondly, the duration of the study may have affected the depth of understanding of the long-term effects on learning outcomes. Thirdly, external factors such as students' previous exposure to AR technology and their individual learning preferences might have influenced the outcomes.
- **Future research:** While the findings show promising results, further research is recommended to investigate the applicability of these findings to larger and

more diverse student populations. Furthermore, exploring the influence of factors such as content design, various AR platforms, and educator facilitation could provide more profound insights into optimizing the advantages of AR technology in collaborative science education.

6 CONCLUSION

This study aimed to investigate the role of AR in supporting collaborative learning in science education using a case study approach. The study involved 30 students in grades 9 and 10, who were divided into an experimental group and a control group. The experimental group received instruction using an AR-based collaborative learning environment, while the control group received instruction using a traditional collaborative learning environment. The study found that the AR-based collaborative learning environment was more effective in improving students' knowledge acquisition, collaborative learning behaviours, and perceptions of the learning environment compared to the traditional collaborative learning environment.

The findings of this study have significant implications for science educators seeking to integrate AR technology into their teaching methods and foster collaborative learning in science education. First, educators should develop collaborative learning activities that align with the national science education standards and the learning objectives of the activities. Second, educators should utilise high-quality AR technology and platforms that offer a user-friendly and intuitive interface for creating a collaborative learning environment based on AR. Third, educators should offer sufficient training and support to students on how to utilise AR technology and collaborate effectively.

Overall, the findings of this study suggest that AR technology can be a promising tool to facilitate collaborative learning in science education. AR technology can offer students the opportunity to visualise and interact with abstract concepts, while collaborative learning can facilitate knowledge exchange and promote critical thinking. Further research is needed to explore the applicability of the findings and the influence of various factors on the efficacy of AR-based collaborative learning in science education.

7 REFERENCES

[1] K. Mukhtarkyzy, G. Abildinova, M. Serik, K. Kariyeva, and O. Sayakov, "Systematic review of augmented reality methodologies for high school courses," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 4, pp. 79–92, 2023. https://doi.org/10.3991/ijep.v13i4.38165

[2] D. H. Kang, H. R. Choi, and S. H. Nam, "Learning cultural spaces: A collaborative creation of a virtual art museum using Roblox," *International Journal of Emerging Technologies in Learning*, vol. 17, no. 22, pp. 232–245, 2022. https://doi.org/10.3991/ijet.v17i22.33023

[3] F. Chen, "Collaborative grouping and interactive relationship construction of college students based on group preference," *International Journal of Emerging Technologies in Learning*, vol. 18, no. 3, pp. 160–175, 2023. https://doi.org/10.3991/ijet.v18i03.38051

[4] E. Klopfer, J. Perry, K. Squire, and M. F. Jan, "Collaborative learning through augmented reality role playing," in *CSCL 2005: The Next 10 Years – Proceedings of the International Conference on Computer Supported Collaborative Learning 2005,* 2005, pp. 311–315. https://doi.org/10.3115/1149293.1149333

[5] M. F. Silva, B. Malheiro, P. Guedes, A. Duarte, and P. Ferreira, "Collaborative learning with sustainability-driven projects: A summary of the EPS@ISEP programme," *International Journal of Engineering Pedagogy*, vol. 8, no. 4, pp. 106–130, 2018. https://doi.org/10.3991/ijep.v8i4.8260

[6] M. Kesim and Y. Ozarslan, "Augmented reality in education: Current technologies and the potential for education," *Procedia – Social and Behavioral Sciences*, vol. 47, pp. 297–302, 2012. https://doi.org/10.1016/j.sbspro.2012.06.654

[7] M. Dunleavy, C. Dede, and R. Mitchell, "Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning," *Journal of Science Education and Technology*, vol. 18, no. 1, pp. 7–22, 2009. https://doi.org/10.1007/s10956-008-9119-1

[8] H. Kaufmann and B. Meyer, "Simulating educational physical experiments in augmented reality," *ACM SIGGRAPH ASIA 2008 Educators Programme, SIGGRAPH Asia'08*, 2008. https://doi.org/10.1145/1507713.1507717

[9] S. Sannikov, F. Zhdanov, P. Chebotarev, and P. Rabinovich, "Interactive educational content based on augmented reality and 3D visualization," *Procedia Computer Sciences,* vol. 66, pp. 720–729, 2015. https://doi.org/10.1016/j.procs.2015.11.082

[10] A. D. Samala *et al.*, "Global publication trends in augmented reality and virtual reality for learning: The last twenty-one years," *International Journal of Engineering Pedagogy*, vol. 13, no. 2, pp. 109–128, 2023. https://doi.org/10.3991/ijep.v13i2.35965

[11] Y. Daineko, M. Ipalakova, D. Tsoy, Z. Bolatov, Z. Baurzhan, and Y. Yelgondy, "Augmented and virtual reality for physics: Experience of Kazakhstan secondary educational institutions," *Computer Applications in Engineering Education*, vol. 28, no. 5, pp. 1220–1231, 2020. https://doi.org/10.1002/cae.22297

[12] Temirgaliyev Radik, "A book on the history of Kazakhs with augmented reality was presented in Astana," 2017. https://adebiportal.kz/en/news/view/a-book-on-the-history-of-kazakhs-with-augmented-reality-was-presented-in-astana__3204. [Accessed: Apr. 01, 2023].

[13] S. Orazova and I. Stebletsova, "С. АМАНЖОЛОВ АТЫНДАҒЫ ШЫҒЫС ҚАЗАҚСТАН МЕМЛЕКЕТТІК УНИВЕРСИТЕТІ «БІЛІМ БЕРУДІҢ ЖАҢАРТЫЛҒАН МАЗМҰНЫ ШЕҢБЕРІНДЕГІ ИННОВАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАР» (ІС ТӘЖІРИБЕДЕН)," *Сборник материалов методического практикума «Актуальные вопросы обновления содержания образования: от теории - к практике»*, 2020.

[14] I. Omirzak, A. Ralin, B. Kasatkin, L. Vorona-Slivinskaya, and N. Dubinina, "Students' perception about the use of mobile learning in solving engineering problems collaboratively," *International Journal of Engineering Pedagogy*, vol. 11, no. 6, pp. 102–116, 2021. https://doi.org/10.3991/ijep.v11i6.24647

[15] J. Barbadillo, N. Barrena, V. Goñi, and J. R. Sánchez, "Collaborative e-learning framework for creating augmented reality mobile educational activities," *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 8867, pp. 52–59, 2014. https://doi.org/10.1007/978-3-319-13102-3_11

[16] H. K. Wu, S. W. Y. Lee, H. Y. Chang, and J. C. Liang, "Current status, opportunities and challenges of augmented reality in education," *Computers & Education*, vol. 62, pp. 41–49, 2013. https://doi.org/10.1016/j.compedu.2012.10.024

[17] M. C. R. Harrington, M. Tatzgern, T. Langer, and J. W. Wenzel, "Augmented reality brings the real world into natural history dioramas with data visualizations and bioacoustics at the carnegie museum of natural history," *Curator*, vol. 62, no. 2, pp. 177–193, 2019. https://doi.org/10.1111/cura.12308

[18] K. Mukhtarkyzy, G. Abildinova, and O. Sayakov, "The use of augmented reality for teaching Kazakhstani students physics lessons," *International Journal of Emerging Technologies in Learning*, vol. 17, no. 12, pp. 215–235, 2022. https://doi.org/10.3991/ijet.v17i12.29501

8 AUTHORS

Bayan Kuanbayeva is a Candidate of Pedagogical Sciences, Associate Professor, Faculty of Physics, Mathematics and Information Technology, Department of Physics and Technical Disciplines, Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan (E-mail: b.kuanbaeva@asu.edu.kz; ORCID: https://orcid.org/0000-0003-0134-1379).

Nurgul Shazhdekeyeva is a Candidate of Physical and Mathematical Sciences, Associate Professor, Faculty of Physics, Mathematics and Information Technology, Department of Mathematics and Methods of Teaching Mathematic, Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan (E-mail: n.shazhdekeeva@asu.edu.kz; ORCID: https://orcid.org/0000-0002-6282-8124).

Galiya Zhusupkaliyeva is a Candidate of Pedagogical Sciences, Associate Professor, Faculty of Physics, Mathematics and Information Technology, Department of Physics and Technical Disciplines, Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan (E-mail: g.zhusupkalieva@asu.edu.kz; ORCID: https://orcid.org/0000-0003-4848-1344).

Kaussar Mukhtarkyzy is a PhD student at the Department of Computer Science, Faculty of Information Technologies, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan (E-mail: kausar_m94@mail.ru; ORCID: https://orcid.org/0000-0001-7889-4495).

Gulmira Abildinova is a Candidate of Pedagogical Sciences, Associate Professor, Department of Computer Science, Faculty of Information Technology, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan (E-mail: abildinova_gm@enu.kz; ORCID: https://orcid.org/0000-0001-9054-6549).