The Use of Augmented Reality for Teaching Kazakhstani Students Physics Lessons

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Abstract—Augmented reality (AR) practices and technologies have the potential to redefine aspects of education, including laboratory work. AR tools provide an easy and cost-effective solution for helping students overcome the constraints imposed by online education. However, research into the utility of AR applications in 8th grade Physics lessons is limited and non-existent in a Kazakhstani context. Furthermore, most experiments use static or 2D images that repeat the same information without laying over additional information. The article demonstrates the use of an AR application in Physics lessons at the Lyceum School No. 85 in Nur-Sultan city, Kazakhstan. The AR application includes an interactive 3D model of circuits and circuit components that can be viewed, manipulated, and explored. The AR application helps students learn about circuits through tactile interaction with the circuit components without having to rely on expensive, time-consuming, and dangerous experiments and equipment. The results show that the use of interactive 3D models improves student learning outcomes in Physics and positively impacts student attitudes towards the adoption of AR technology in classrooms. The findings reflect strong improvements in retention and understanding of physics concepts over traditional instruction methods. The experiment is not intended as a prescription for augmentation but shows that AR tools can be an efficient alternative to the risk-prone, costly laboratory environment and that such tools can be employed to enhance learning in natural science disciplines.

Keywords—augmented reality, physics lessons, computer science, education

1 Introduction

AR is not the substitution of physical reality but builds additional layers and experiences on top of the physical world and its contents. Augmented reality uses mobile devices and cameras for expanding the scope of reality. According to [1], AR is the technology that adds "virtual objects" to real-world objects and thus enables the addition of content or information missing in the real world. Such additional information can include laboratory experiments involving dangerous chemicals or human cadavers that might otherwise require high cost, effort, and expertise for execution. Augmenting reality has the potential to enhance learning itself [2]. AR technologies enhance learning by inculcating immersion and inclusion into the reference materials. Thus, AR affords greater flexibility in terms of course design, on-screen visual representation and enables students to interact with the course material in new ways relying on haptic feedback alongside audio-visual stimuli. Kazakhstani schools sometimes face constraints related to unavailability of laboratory equipment or limited capacity of the laboratory that cannot accommodate all of the students. AR applications can rapidly fulfil the need for structured and constructed student activities at a fraction of the original cost. Therefore, the research focuses on evaluating the effectiveness of using augmented reality for Physics lessons in an 8th grade classroom. Although significant research has been undertaken at the secondary, higher secondary and university levels. However, no study has evaluated the effectiveness of augmented reality in a middle school classroom in a Kazakhstani context.

Furthermore, student absence from classroom can often lead them to miss out on important laboratory work that cannot be performed again. Moreover, the greater flexibility in lesson plans and execution afforded by augmented reality increases mobility by reducing the need for physical presence and linking students through a networked learning approach for situated learning beyond the classroom [3]. More importantly, the goal to expand the outreach of education programs often faces multiple constraints including time and resources. The affordability of smartphones incorporating multiple sensors, cameras, and a touch screen with internet access favour the adoption of AR for education. The affordability of smartphones and AR applications makes laboratory work accessible at a fraction of the original cost, and such experiments can even be performed remotely [4]. Thus, students spread across a large distance can learn laboratory application without having to be physically present in a laboratory or being bound by a specific schedule.

The subsequent experiment and its results demonstrate the utility of the interactive 3D models in crystalizing learning by using flexible course material, on-screen visual representation, and haptic feedback. The research suggests that the effectiveness of augmented reality in supporting skills acquisition and academic achievement can also be replicated in a virtual classroom environment. The research fills the gap in the existing literature by elucidating the utility of augmented reality applications in a middle school classroom in a Kazakhstani context. Furthermore, the study utilizes augmented reality application at the augmentation, modification, and redefinition level as defined by the Puentedura framework [5] that relates technology adoption in education at different stages.

1.1 Augmented reality and education

AR offers novel opportunities for students to learn beyond the classroom context. According to [3], mobile augmented reality is mainly used as part of a "teacher-directed paradigm" for creative knowledge delivery within "new contexts". The goal of these AR activities is to "augment traditional methods of content delivery or learning experiences" [3]. Learning in these new contexts includes instructional video games, 3D modelling, training modules, experiential learning, and augmented books. Puentedura [5] developed a framework that relates technology adoption in education at different stages. The Puentedura [5] framework succinctly characterizes four levels: Substitution, Augmentation, Modification, and Redefinition and are collectively known as the (SAMR) framework. According to [3], the SAMR framework interacts with student creativity at three levels: incrimination, replication, and redirection.

Therefore, the authors of this study have also utilized an augmented version of a standard physics textbook used in Kazakhstan schools to evaluate the impact of augmentation on student learning outcomes. In the purview of the SAMR framework, the application (EDLAB) is not a substitution for the standard textbook. However, it satisfies the characteristics of augmentation, modification, and redefinition. The application (EDLAB) augments the standard textbook by adding new elements that facilitate student interaction with the course content. Furthermore, the application also modifies traditional educational practices as it replaces laboratory demonstration of circuits with a mobile application-based version. Consequently, the application seeks to redefine educational practices and evaluations more than was traditionally achievable in the absence of AR technology.

1.2 Effects of augmented reality on student education

The use of augmented reality provides numerous pedagogical opportunities. There are several possibilities associated with the adoption of AR, such as content visualization and enhanced user mobility [6]. Furthermore, AR technologies facilitate the generation, comparison, contrast, and integration of multiple perspectives. Furthermore, AR can provide additional information about an object, enable access to physically inaccessible views of an object and augment the human senses to visualize microscopic or infrared objects [6]. Therefore, AR technology offers multiple opportunities for improving pedagogical practices and improving the learning experience.

The associated benefits of AR technology are not restricted to any single discipline or age group. [7] have found a positive effect of AR applications on first-grade students' English learning performance and motivation. [7] defines motivation in the context of sustained desire and efforts to achieve the specified goals and uses the Instructional Materials Motivation Survey (IMMS) to measure student motivation. The analysis of variance between the control and experiment groups shows that student motivation is more significant in the group that learned using AR application [7]. Similarly, [8], using pre and post usage data from the Instructional Materials Motivation Survey (IMMS), found that augmented reality mobile application use is associated with an increased motivation to learn among undergraduate medical students.

Furthermore, [8] suggests that AR applications can reduce the need for specialized equipment for teaching medical procedures. Additionally, [9] evaluated the impact of teaching human heart anatomy using an AR application and in a sample of 30 subjects and found that the use of AR improved learning and was acceptable to the users at the highest level. Furthermore, [10] using survey and systematic review data asserts that AR applications can improve learning effectiveness, motivation and processes in STEAM education. Therefore, AR facilitates student education by allowing teachers to overlay additional information, incorporate visuals, and provide access to contextual equipment and experiments for the on-hand experience.

Vicente dos Anjos et al. [11] have undertaken a systematic literature review of 37 texts to assess the effects of virtual reality (VR) and augmented reality (AR) in the teaching methods of engineering courses. The assessment by [11] shows that in 70 percent of the cases, students learned more when taught using AR or VR, and in 90 percent of the cases, students displayed higher levels of satisfaction with the new pedagogical approaches compared to the traditional method of instruction. Furthermore, [12] show that educational AR games promote student learning from the affective, cognitive and retention perspectives. Therefore, an analysis of the literature highlights the positive impact of the adoption of augmented reality in teaching and learning processes.

The novelty of the present experiment lies in the context that although augmented reality applications already exist, they are usually static 3D objects that are usually either just visualize an object or, in extreme cases, rotate the said object. The current 3D model relies on dynamic interactive processes such that circuit components can be viewed in greater detail, manipulated on-screen, and connected with other components to form working circuits. Furthermore, the circuit does not work if the components are not connected correctly or if the rating of one or more components (resistance, voltage, current) does not meet the circuit specifications, i.e., battery capacity. Additionally, the research explores the utility of augmented reality applications in an eighth grade or elementary school cohort. The age group is largely unexplored in the Kazakhstani context.

Research has consistently shown that young children learn by utilizing their innate curiosity and exploring the real world. According to [13], children comprehend the world and form interpretations about it through exploration and interaction. Therefore, children involved in the study of natural sciences often face problems because of the limited opportunities to explore the objects under study and interact with the course content in a real-world environment [14]. Therefore, augmented reality fills the gap by combining learning and experimentation in a way that enables young students to better visualize educational concepts and phenomena. Casteleiro-Pitrez [15] has undertaken a similar study to evaluate AR technology's impact on sixth-grade students' learning outcomes. [15] developed an AR prototype of the natural sciences textbook. The results show that the AR prototype positively impacts students' understanding and learning [15].

Modern education reform efforts rely on innovation for the fulfilment of contemporary social needs. However, teaching natural sciences to students faces certain difficulties when attempting to utilize novel approaches. However, augmented reality appears to address the challenges associated with traditional natural science curriculums. [16] examine the natural science teacher’s handling of Digital Learning Objects (DLOs) and the degree of utilization of Digital Simulation Tools (DST) Experiments. DLOs are digital learning activities that enable teachers to incorporate audio and visual content in the educational process for achieving the educational objectives. According to [16], DLOs facilitate the formulation of conceptual connections in students and leads to educational benefits. In contrast, simulation tools allow practitioners and teachers to replicate natural phenomena realistically and safely. Simulations assist students with understanding, recording, and analysing numerous phenomena connected to the Natural Sciences, as well as thinking critically about experiments, repeating them, and solving any issues that may arise. The present study uses an augmented reality application that includes a simulation of an electric circuit and its components. The students can connect multiple components to build working circuits. According to [16], simulation helps learners build on their existing knowledge, enables them to manipulate variables to observe effects, aids in controlling the experiment conditions to ensure reliability of results, empowers students to obtain feedback, and allows them to observe natural phenomena under control conditions. However, research from Greece shows that despite 36.8% teachers agreeing that DLOs and 42.1% agreeing that DSTs facilitate learning, the school's technological equipment remained a fundamental obstacle for the adoption of digital learning techniques.

Further research by [17] shows that tablets and touchscreens have redefined the interactive digital experiences of students and children. Therefore, they increasingly learn through trial and error and by using their natural sense of touch. The present study builds on these assertions and attempts to explore the impact of the use of 3D interactive models in physics lessons on elementary students' learning outcomes.

1.3 Purpose of the present study

In the present study, the authors examined the impact of AR technology and its application at a Kazakhstani school. The authors explored four questions: First, does the student performance on a standardized test improve when the students are taught using AR technology? Second, do AR technology lessons produce better results than traditional teaching methods? Third, what are student attitudes towards adopting AR technology for classroom instruction and learning? Fourth, do increased awareness among students about AR technology translate into better student perception of AR technology? The research relied on a small sample of students (N=97) as part of the pilot project. The authors controlled for individual differences between students by dividing students into groups based on their academic performance at the school and using group average for comparison. Nearly 20% of the students at the school had used an AR application before, and only 15% had used it for education purposes. Therefore, this allowed the authors to examine the effect of a variable (AR application) that was new for the majority of the students. More importantly, the quiz results allowed the authors to measure the differences in the impact of AR application-based compared to traditional lessons.

2 Methodology

The research methodology for studying the development of the augmented reality tool to teach students physics included the following:

2.1 Sample

A quasi-experimental design with two experimental and two control groups was applied, and the data was collected from groups in an eighth-grade classroom. Students from the 8th grade at the Lyceum School No. 85 in Nur-Sultan city, Kazakhstan were used as the test subjects for a pilot demonstration of the EDLAB application. There were 97 students in the class. The academic performance data of the students was obtained from the class teacher. The performance data is independent of the student's characteristics such as gender and age, and no systemic incentives were provided or offered for using the mobile application (EDLAB).

The school administrators use the students' academic performance data as a benchmark for dividing them into four distinct groups. The first group, 8A, includes 24 students and has an academic average of 68%. The second group, 8B, includes 25 students with an academic average of 83%. The third group, 8V, includes 23 students with an academic average of 71%. The fourth Group 8G, includes 25 students with an academic average of 79%. Group B and Group G comprise academically better students, and these groups are known as the Lyceum classes. Table 1 provides an overview of the student groups. The academic averages are based on the year-round evaluations of the students conducted by the school. Therefore, they are more representative than a single test score and free from researcher bias.

Table 1. Characteristics of the student groups

Group Name	Group Type	No. of Participants	Group Average based on school evaluation (%)	Group Name
Group A	Experimental Group	24	68	Group A
Group B	Experimental Group	25	83	Group B
Group V	Control Group	23	71	Group V
Group G	Control Group	25	79	Group G

The majority of the students had not used a tablet before and were not taught about circuits before. In each group, a teaching tool (textbook or tablet) was assigned, and the teachers were advised to strictly follow the teaching method assigned to each group. The research involved minors and therefore permission was obtained both from the University's ethical committee and the children's parents. The class teachers were also briefed on the objectives and methods of the study. The project ran for a one-month period and involved four sessions. Each session lasted more than three hours. The first session included a pre-test survey. The second session included physics lessons. The third session included a post-lesson test, and the fourth session included a post-test survey.

2.2 The development of the augmented reality application for teaching physics

The instrument for AR lessons included an AR application running on an android tablet. The "EdLab" application was created for Android Studio using Unity, C#, and

AR foundation. The models in the application were created using 3D Max. The application can be accessed on the tablet using the "EdLab" icon displayed on the screen. The main window displays four options, including start, available topics, manual and about authors. After pressing "Start," the camera turns on and should be navigated to the specific pages of a physics book. The application is compatible with a physics textbook taught in Kazakhstani schools written by "Krongart". The topic taught to the students was "Introduction to Electricity". The application displays 3D models of equipment printed in the book, and the students can interact with the contents of the textbook by pointing their device's camera at the printed picture. The application also contained demonstration exercises that allowed students to connect equipment and complete circuits on their tablets. In the “available topics” section, the topics developed by the authors are listed alongside the reference pages of the book. The rules and instructions are defined in the “manual” section. The “about authors” section contains information about the developers and a link to a telegram group that can be used by the students to ask questions and participate in discussions.

Fig. 1. Students using augmented reality application to scan the physics textbook

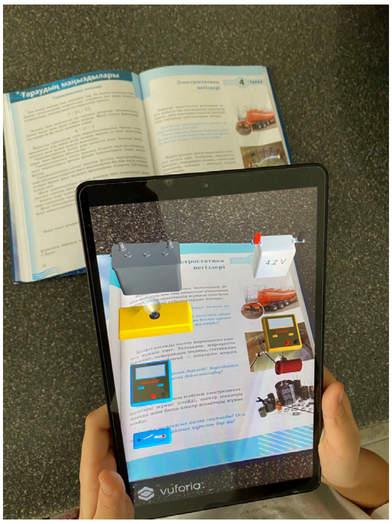

Fig. 2. Display of 3D interactive models of circuit components listed in the physics textbook

2.3 Evaluation of the effectiveness of the augmented reality application for teaching physics

The evaluation instrument included a 10-question survey and an 8-question quiz developed by the researchers. The first four questions in the survey are designed to measure the proportion of students with mobile phones, their knowledge of augmented reality, and the proportion of students who have used augmented reality applications before, including for educational purposes. The following five questions are designed to measure the student's views on the impact of AR technology in improving quality of education, increasing interest in course material and motivation to learn, offering an alternative to laboratory work, and prospects of adoption of AR technology. The survey questions have face validity [18], and the last question is intended to measure the student’s understanding of the questions.

Students were asked to respond to each question with Yes, No or No Answer. Response percentage was calculated for each question and answer. All 97 students in the four groups were asked to respond to the survey before the commencement of the lessons. Subsequently, only 49 students in groups B and G who were taught using AR application were surveyed in the post-assessment phase. The difference in sample size is because the second survey was intended to measure the impact of the use of the AR application on the student's attitude and perception of AR. Therefore, it did not make sense to include the participants that were not taught using AR lessons as no significant difference was expected in their responses as the fundamental condition, i.e., exposure to AR, did not change. Therefore, the second survey had the selection criteria in which participants taught using only AR were included (N=49). The responses to the second survey reflect internal consistency of the evaluation instrument as the percentage of students who responded in the affirmative to the question of using AR applications, including for educational purposes (questions 3 and 4), increased to 100% from 19.6% for AR applications and 15.5% for educational applications in the first survey. Therefore, answers to these two questions also help explain the greater understanding of the survey questions in the second survey at 85.7% compared to 62.9% in the first survey (question 10).

2.4 The design of the experiment for evaluating the effectiveness of the Augmented Reality Application

The present research relies on an action research methodology to evaluate the impact of mobile AR lessons on student performance on a standardized physics test. The experimental groups 8B and 8G had higher initial grades than 8A and 8V. Therefore, one group (8A) with the lowest initial average of 68% and the highest-performing group (8B) with 83% average are taught using the AR application. Meanwhile, students in group 8V with a 71% average score and group 8G comprising high-performing students with 79% average are taught using the traditional method. Before the commencement of the experiment, all 97 students in the four groups were administered the first survey. Subsequently, the students in all four groups are tested on a physics quiz after the lessons. Finally, only the students in AR application groups (8A and 8B) who are taught using the AR application (N=49) are administered the second survey. The selection criteria for the post-test or second survey was that the student had to be taught using the AR application. The dependent variables were student responses on the survey and student performance on the quiz.

Data analysis is available for all ten questions on the survey. However, group average has been calculated for quiz scores instead of individual scores to facilitate cross-group comparison. The higher percentage of students with experience of AR in survey two and their better performance on the quiz reflects the strong correlation between access to AR technology and quiz scores.

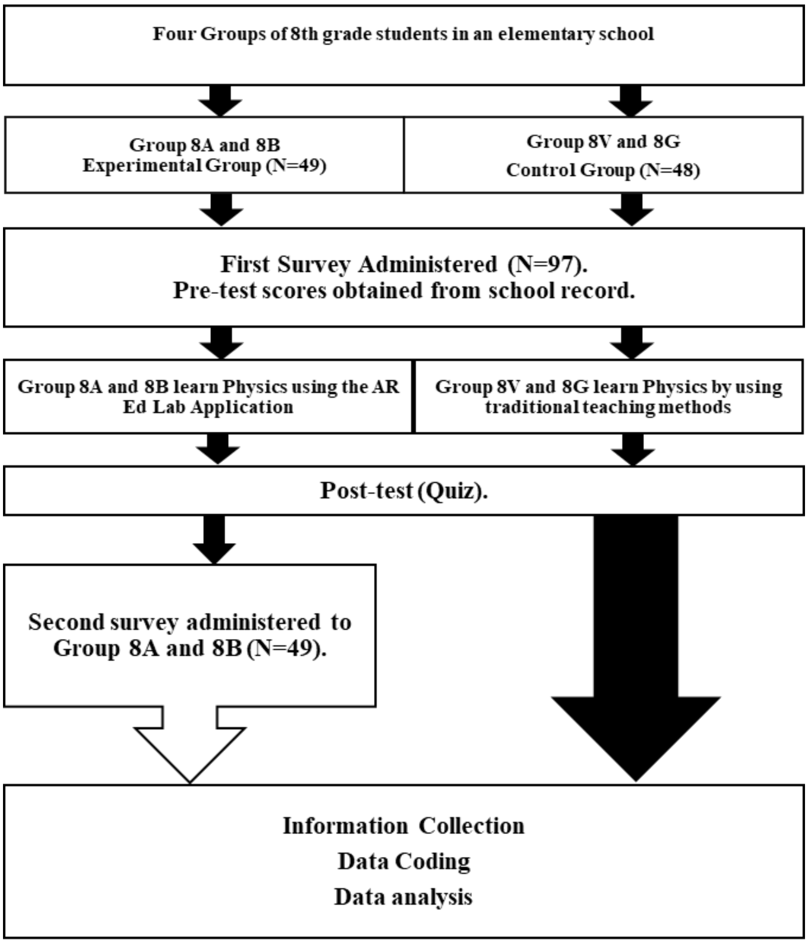

Fig. 3. Experimental procedure

3 Results

3.1 Survey response

Survey Response rates and percentages are presented in Table 2. The findings indicate that student exposure to and knowledge of augmented reality significantly increased after the EdLab activity. In the first survey, when all students (N=97) participated in the survey, the familiarity with augmented reality applications remained at 19.6% for general (Question 3) and 15.5 % for educational applications (Question 4). The second survey was administered to a select cohort of students from Group A and B (N=49) who were taught using AR applications; therefore, their familiarity with AR applications in general and for educational purposes reached the maximum value of

100% (Question 2 and 3). Furthermore, the average of students with experience of AR in survey 1 (Question 2 and 3) remained 27.35% and increased to 100% in survey 2. Moreover, although the proportion of respondents in both surveys who use smartphones for educational purposes (Question 1) remained significantly high at approximately 84%, the percentage of students who understood the meaning of augmented reality (Question 2) increased from approximately 47% in the survey one to 92% in survey two. These findings indicate a significant impact of the AR activity on promoting the student's understanding of augmented reality in survey two (Question 2).

The familiarity and understanding of AR measured by questions 2-4 coincided with a favourable view of augmented reality measured by questions 5 to 9. The average number of students who responded favourably towards AR increased from 29.1% in survey one to 82.4% in survey two, as their understanding and experience of AR increased from 27.5% to 97.3%. The most significant change in perceptions emerged in response to question 7, in which 100% of the students in the second survey compared to 27.3% in the first survey agreed with the suggestion that augmented reality could be used for laboratory work. Furthermore, on aspects of the impact of AR in improving quality of education (question 5), increasing interest in learning materials (question 6), and increasing motivation to learn (question 9), 28.9%, 38.1% and 26.8% of the respondents in the first survey responded positively. More importantly, in the second survey, 85.7%, 83.7%, and 75.5% of the students responded positively to the same three questions. However, a smaller change in perception emerged in response to question 8, with 27.8% of respondents in the first survey and 67.3% in the second survey agreeing that there were prospects for the use of AR in education. Comparatively, the students were also less convinced of the utility of AR applications in increasing the motivation to learn (question 9). Therefore, responses to questions 8 and 9 could be possibly mediated by other statistically significant variables and interactions.

Table 2. Sum and Percentage of Student Responses on the first and second survey

Q No.	Survey 1 (N=97)			Survey 2 (N=49)			Survey 1 (N=97)			Survey 2 (N=49)		
	Yes	*No*	*(N/A)*	*Yes*	*No*	*(N/A)*	*% Yes*	*% No*	*% N/A*	*% Yes*	*% No*	*% N/A*
1	81	16	0	41	8	0	83.50%	16.50%	0.00%	83.7%	8.2%	0.0%
2	46	51	0	45	4	0	47.40%	52.60%	0.00%	91.8%	4.1%	0.0%
3	19	78	0	49	0	0	19.60%	80.40%	0.00%	100.0%	0.0%	0.0%
4	15	82	0	49	0	0	15.50%	84.50%	0.00%	100.0%	0.0%	0.0%
5	28	8	61	42	2	5	28.90%	8.20%	62.90%	85.7%	2.1%	5.2%
6	37	6	54	41	1	7	38.10%	6.20%	55.70%	83.7%	1.0%	7.2%
7	23	5	69	49	0	0	23.70%	5.20%	71.10%	100.0%	0.0%	0.0%
8	27	3	67	33	5	11	27.80%	3.10%	69.10%	67.3%	5.2%	11.3%
9	26	11	60	37	4	8	26.80%	11.30%	61.90%	75.5%	4.1%	8.2%
10	61	36	0	42	7	0	62.90%	37.10%	0.00%	85.7%	7.2%	0.0%

3.2 Quiz scores

The responses to an eight-question quiz on electricity were used to evaluate class averages. The analysis shown in Figure 4 produced several statistically significant effects. First, the students in the low-performing group, 8A (average 68%), showed the most remarkable improvement of 15% after being taught using the AR application. Second, the students in the high performing group, 8B (average 83%), showed a remarkable improvement of 8% after being taught using the AR application. Third, the low-performing students in group 8V (average 71%) showed a modest improvement of 2% after being taught using traditional teaching methods. Fourth, the high-performing students in group 8G (average 79%) showed a decline in the performance of 3% after being taught using traditional teaching methods. Thus, all students except group 8G showed improvement. However, the improvement was most significant for students who were taught using the AR application. The effect of traditional teaching methods in the control group was small in one instance and negative in the other. However, quite possibly the negative effect was mediated by repetition of technique and information [19] as well as the lack of novelty, possibly resulting in a lack of student interest and attention [20] as the current study did not incorporate new learning material or techniques for the control group. Furthermore, the initial class averages were obtained from school data. Further research could improve these evaluations by incorporating an additional assessment before the beginning of the experiment, as done by [21].

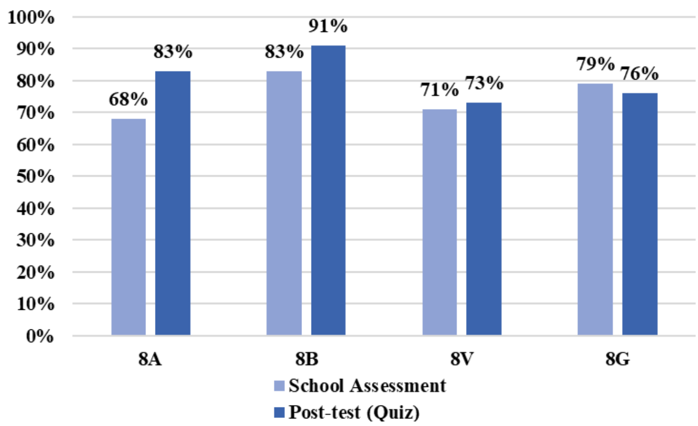

Fig. 4. Group academic performance

3.3 Stability of results

The line chart in Figure 5 illustrates the relation between average understanding and experience of AR (Question 2-4) scores and quiz scores. The data set is insufficient to calculate the co-relation between proficiency in AR and quiz scores. However, the visual inspection of the chart shows that the increase in average experience and understanding of AR in survey 2 for groups A and B leads to improvements in average quiz scores and positive views of AR. The responses to survey one and the initial average academic group score reported by the school provided baseline values for comparison.

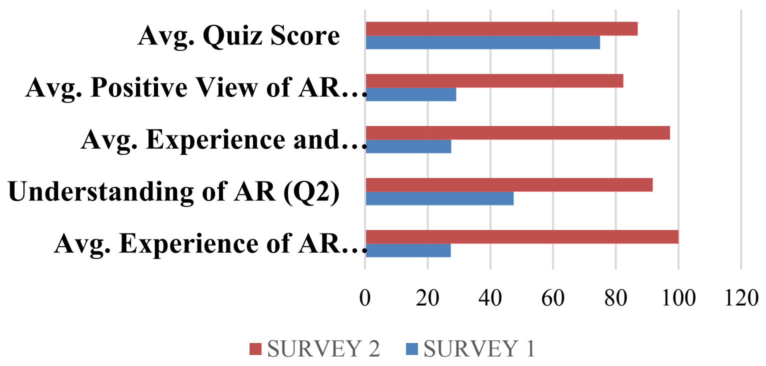

Fig. 5. Proficiency in AR and effects on perception of AR and quiz score

4 Discussion

AR technology was associated with better scores on the quiz. Improvements in experience and understanding of AR were associated with improved quiz scores in groups A and B. It is important to note that group A experienced a 15% improvement, and Group B showed an 8% improvement in their quiz scores compared to the initial class average. The performance of students in groups V and G who were taught using traditional teaching methods either showed modest improvement or declined (see Figure 4). The improvements amongst students taught using the AR application can be attributed to increased student engagement with the course material, greater interest and the interactive scenario generated by the EdLab application that allowed students to manipulate circuits and their components in real-time, similar to practical work performed in a laboratory [2].

Furthermore, the augmented reality allowed the researchers to layer additional information [1] on top of the two-dimensional, non-interactive physics textbook that increased student interest in the content and allowed for three-dimensional engagement with augmented reality models of the course content. In a similar experiment, [15] found that using an augmented textbook was affiliated with improved learning outcomes and understanding among sixth-grade students. Thus, student performance on standardized tests improves when the students are taught using AR technology.

Although the average quiz scores were significantly higher than the initial class average in three out of the four groups, the magnitude of differences was small (differences ranged from 2 to -3) in groups that were taught using traditional methods. The differences are in sharp contrast to the improvement of 15% and 8% reported amongst students taught using the AR textbook. The results are in line with reports by [21], who found a statistically significant increase in the average final scores of students when AR experience is paired with the lectures. Therefore, the experiment shows that AR technology lessons produce better results than traditional teaching methods.

Despite improvements in quiz scores, student views remained comparatively less favourable on the prospect of the use of AR in education and the impact of AR in increasing student motivation to learn. The comparatively smaller change in opinion appeared in answer to question 8, with 27.8 percent of respondents in the first survey and 67.3 percent in the second survey agreeing that the idea of the use of AR in education has merit. Comparatively, in the present study, the students were less convinced of the utility of AR applications in increasing the motivation to learn (question 9). These differences might be attributed to a status-quo bias [22] amongst students, the characteristics of the students who used the AR application and the differences in the quality of student interaction with the AR module. [20] argues that the regular usage of an existing system, perceived costs of switching, and psychological commitment lead to inertia that mediates the adoption of new systems and components. Inertia influences perceptions and discounts the advantages or ease of use of the new system. It is important to note here that these alternative explanations become more likely as [8], [10] find considerable evidence of the impact of AR in increasing student motivation to learn and [11], [12] show greater satisfaction with the new pedagogical approaches.

Collectively, the responses to questions 8 and 9 dealing with the prospects of the use of AR in teaching and the impact on motivation reflect greater student reluctance and scepticism. However, further research is needed to gauge the reason for this scepticism and understand if this is rooted in the favourable views of teachers and status quo bias. Furthermore, the question related to motivation demands greater scrutiny to examine if the greater potential for distractions on a smartphone affects motivation levels [23] and whether the supervised use of AR applications could help minimize these risks. [21] found out that prior to usage, the students assessed the smartphone's utility to aid in education as beneficial; but, towards the end of the research, they considered their phones harmful to their educational aims. Therefore, student views of smartphones as a distraction and impediment to learning shape their perception of the utility of adopting augmented reality in classrooms.

Remarkably, knowledge and comprehension of augmented reality as measured by questions 2-4 corresponded with a favourable view of augmented reality as indicated by questions 5–9. As their awareness and experience of AR grew from 27.5 percent to 97.3 percent, the average percentage of students who responded favourably to AR increased from 29.1 percent in survey one to 82.4 percent in survey two. The findings show that familiarity and exposure to AR have a substantial influence on generating positive impressions and opinions amongst students. The most significant shift in perceptions occurred in answer to question 7, whereby 100 percent of students in the second survey agreed with the notion that augmented reality may be utilized for laboratory work, compared to 27.3 percent in the first survey. Furthermore, 28.9 percent and 38.1 percent of respondents in the first survey reacted positively to questions about the influence of AR on enhancing educational quality (question 5) and raising interest in learning materials (question 6). More crucially, 85.7 percent and 83.7 percent of students reacted positively to the same two questions in the second study. As a result, the findings indicate that familiarity with AR technology assists in the development of favourable attitudes about the use of augmented reality as a teaching technique.

Researchers may raise concerns about the validity of the claims since 37% of the respondents in the first and 7% in the second survey responded that they had not understood all of the questions (question 10). However, the variability in this percentage and the smaller proportion of students who hold this view in the second survey lends greater validity to the claims being made. The greater familiarity with AR in the second survey coincided with the greater understanding of survey questions. Thus, reviewers should remain receptive to this assertion when interpreting the survey responses. Furthermore, decision-makers often argue that conclusions derived from small samples cannot accurately represent the views of the larger population [24]. Therefore, reviewers often treat such differences as meaningful [25]. However, since the experiment required a typical middle school classroom, we believed that a standard 8th grade class in Kazakhstan would provide the best sample for a pilot study. Therefore, the absence of selection criteria for choosing students and relying on the school's criteria for student grading and grouping makes our results more reflective of the general trends in public schools. Furthermore, 60% to 80% of the survey respondents understood the research questions. Thus, differences in responses with larger samples are unlikely to be very significant.

5 Implications for practice

5.1 Incorporating AR technology

Innovative techniques increase student interest and responsiveness towards the course material [10]. Furthermore, adopting new pedagogical approaches coincides with greater student satisfaction [11], and the student's perception of novelty shapes the learning outcomes [19]. Furthermore, the impact is mediated by interaction with the student's affective, cognitive, and retention capabilities [12]. Therefore, educational institutions would be wise to take steps that incorporate aspects of augmented reality in their classrooms and laboratories. Puentedura Framework [5] provides four avenues for adopting augmented reality: substitution, augmentation, modification, and redefinition (SAMR). Augmentation is the least likely to face considerable inertia [22] as it poses no challenges to the existing system and learning techniques. Therefore, augmenting existing education modules and textbooks with additional content, 3D models, and microscopic views is likely to experience the least resistance. These approaches will bolster the existing human capabilities for learning, and there are no traditional alternatives for these additions that are as cheap and readily available as AR.

Education boards and departments must offer incentives to schools for adopting AR techniques, creating high-quality content, providing training, and fostering an institutional culture that favours the adoption and use of AR tools to improve education and learning. [26] has shown the impact of teacher training in promoting teacher understanding, adoption and utilization of AR tools in their teaching methods. Therefore, offering appropriate incentives that facilitate participation in such programs and creating opportunities for teacher development will help minimize the inertia and facilitate the move towards eventual substitution, modification and redefinition of educational activities using the AR toolkit.

5.2 Designing lessons

In addition to ensuring the availability of desired AR applications, lesson designers must consider areas where adoption and use of AR will make the most significant difference. As discussed earlier, the initial goal of augmented reality is not to redefine or substitute critical aspects of the education system but to provide additional value wherever feasible. Therefore, adoption strategies must not rely on quantitative data and experimental studies alone. Reviewers must not treat the impact in one context as a proxy for similar results in other scenarios. In a meta-analysis, [27] has found out that AR has a medium effect on the learning gains of students ($d=0.68$, $p<0.001$). However, [26] shows that new technologies can sometimes be ineffective, uneconomical, and too complex for achieving the desired learning outcomes.

Nevertheless, CTML provides the essential framework for incorporating instructional media like augmented reality in education practices [28], [29]. CTML is founded on three key assumptions [30]. The first principle states that individuals process information using audio and visual channels. The second principle posits that "human working memory capacity is limited", and therefore educational tools must reduce extraneous cognitive load [31]–[33]. The third principle asserts that learning is effective when the active cognitive processing is stimulated by an interplay between already stored information and new stimuli [34], [35]. Therefore, meaningful learning in a multimedia environment depends on acquiring skills and knowledge for problem-solving [36].

[37] uses the CTML framework to suggest efficient lesson designs. First, extraneous load processing must be reduced by disabling background music, unnecessary pop-ups, using signals to guide attention to important information, reducing redundancy and using Spatio-temporal congruity while displaying information [37]. Second, working memory must be utilized efficiently using modality, segmenting or pre-training principles [38]. As per the modality principle, images are presented with spoken words rather than written text for more efficient learning [39]–[41]. The complex study material is divided into smaller units in segmenting to reduce load and enhance memory utilization [42]–[44]. [42]–[44] find evidence for the role of segmentation in promoting retention, transfer performance, superior learning and facilitating the application of the knowledge. The pre-training principle recommends that the students be taught basic principles before interacting with the multimedia material [38]. [45], [46] show that pre-training helps improve academic learning. The third principle asserts the importance of generative processing and recommends that user-friendly and human-like characteristics be used as social cues in prompts while also

relying on the self-explanation and drawing principle to cement understanding of the educational material [37].

Augmented reality facilitates real-time visualization of 3D models, promotes student interaction with the object under study and fosters conceptual clarity by generating quick feedback [27], [47]. Therefore, lesson plans must reduce extraneous load processing by reducing unnecessary prompts and promoting the integration of augmented content with the existing curriculum and textbooks. Furthermore, AR devices must restrict or limit unnecessary functions while ensuring that AR applications are easy to use and streamlined across multiple user platforms. One way to enhance interaction with the AR content is to restrict the minimized function and recommend that the application work only in full-window mode. More importantly, pre-training students and teachers in using AR tools must be undertaken to ensure seamless operations.

Furthermore, pre-training students in core concepts in the AR modules will promote cognitive load processing and active learning. Moreover, AR applications must rely on segmenting to divide the content into easily-manageable tasks. Furthermore, modality, signalling and social cues must be used to direct the students learning experience. AR applications must also build on existing knowledge and must be incorporated in lesson designs so that the students have sufficient prior knowledge before moving on to experimentation and interaction with AR models. Furthermore, traditional learning practices, including summarizing and laboratory enactment of the experiments, must be included wherever feasible for a holistic learning approach.

6 Conclusion

Improvements in pedagogical approaches and educational practices are ongoing, just like learning. EdLab is the first mobile application in the Kazakh language, created on the basis of augmented reality for teaching physics lessons. There are existing mobile applications created for physics but in other languages, which are not adopted under Kazakhstani books and language. The research highlights the importance of using segmented reality for improving learning outcomes, increasing interest, and performing laboratory work in Kazakhstani School using the mentioned mobile application as a tool. However, the student perception of using AR in classrooms and its impact in increasing the student's motivation reflect scepticism and status quo bias. The study is in no way exhaustive and final. The goal of our study has been to show the relevance of AR technology in education practices and create interest for further research. The SAMR and CTML frameworks provide excellent avenues for designing AR tools and measuring their effects on student performance for evidence-based policy formulation. The key findings show that augmentation of a standard physics textbook leads to better test performance even when compared to traditional teaching methods.

Furthermore, student perception of augmented reality depends on their experience and knowledge of AR. More importantly, more carefully planned and rigorously designed research is needed in classroom and laboratory settings to understand the effect of other intervening variables. The current experiment did not include all elements of CTML and studied the impact only along with the augmentation dynamic of the SAMR framework. Therefore, further research incorporating the essential elements of CTML and along other dimensions of the SAMR are required.

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