How to Motivate Students Using Augmented Reality in The Mathematics Classroom? An Experimental Study

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Abstract: An Augmented Reality (AR) approach to creating a maths education app is the focus of this research. To turn the 2D floor plan into 3D objects, students will use their mobile devices to scan the cards. Students can have a better understanding of the 3D shape from various angles by interacting with virtual 3D items. Students can gain a deeper understanding of the method of volume computation by utilising the decomposition or combined functions of the Assembler Edu app. This study compares the digital learning results of students who excel in maths with those of students who struggle, and it does so by analysing the students' motivation both before and after using an AR Assembler Edu app. The study analyses the learning impacts and experiences of the AR Assembler Edu App through the use of achievement assessments, questionnaires, and interviews with teachers and students. The results show that students are receptive to the institute's AR maths learning app and that it might pique their interest in studying. Compared to the pre- and post-study results, the learning effects are much more pronounced. Teacher interviews revealed that students' motivation and three-dimensional composition were significantly improved after using this digital learning resource and interactive experience model.

Keywords: Augmented reality, experimental study, geometry, students' motivation

INTRODUCTION

Mathematics is viewed as a foundation for the development of science, and technology; it is also the source of our geometric and spatial abilities, which allow us to recognize the sizes, shapes, and placements of objects in our environment. Using actions like combining, pushing and stacking, and measuring, Geometry and Spatial Competence Training can be used to construct virtual spaces, which can increase 2D and 3D spatial cognition. According to Ahmad and Junaini (2020), who also found that visual imagery and spatial skills were critical to mathematical thinking and learning, there was a degree of relationship between spatial talents and Math learning.

Important parts of learning mathematics include following traditional lesson plans, studying logical reasoning, and building formulas and definitions using very abstract symbols (Voronina et al., 2019). The practice of spoon-feeding mathematics to students usually results in a lack of interest in the subject. Research shows that when students feel good about themselves, they do better in maths (Cabero-Almenara et al., 2021; Özçakır & Özdemir, 2022). Despite its obvious importance, math is a daunting subject for many lower-secondary school students (Su et al., 2022). Strong mathematical foundations can aid students' future scientific or ideological pursuits, thus it's important to inspire their natural curiosity and love for the topic (Schutera et al., 2021).

In 2018, the Ministry of Education in Indonesia implemented a 9-year Integrated Curriculum that covered four branches of mathematics: Number and Quantity, Graphics and Space, Statistics and Probability, and Algebra. "Graphics & Space" has an ethereal quality to it, and it's not an easy course to finish (Chani & Susilowati, 2022). Other challenging courses, like "Number & Quantity", use mathematics (Lauren, 2021). Students have a more difficult time mentally converting from two-dimensional to three-dimensional images, and they also have more difficulty learning in three dimensions through direct use of instructional materials or indirect learning through floor plans. Different modules receive different amounts of time from teachers (Elsayed & Al-Najrani, 2021). To make sure that students fully understand volume, teachers should employ a variety of supplemental materials.

Making better use of Information and Communication Technology (ICT) to enhance education is one of the most distinctive features of modern civilization. Digital learning encompasses the public's and businesses' massive demands for online education (Nasrudin et al., 2021). With the proliferation of digital technologies, interactive media has become a popular subject across many sectors. Educational materials, including apps that use game-based learning, are now accessible on the move because to the growth of mobile devices. With the advent of Augmented Reality (AR) technology, it is no longer necessary to recreate the imaginative experience since the virtual world can be seamlessly integrated with the human sensory nerve and attached to the actual world in a matter of seconds (Wahyudi & Arwansyah, 2019). The usage of augmented reality has been widespread in several industries, including gaming, publishing, and navigation. Math, spatial transformation, and understanding course material are among of the many areas where augmented reality is finding increasing use in the classroom (Pujiastuti et al., 2020). Teachers can engage their students more deeply in the subject matter and help them grasp it at a deeper level by utilising the potential of digital technology to create extra teaching aids.

In order enable seventh graders to understand the benefits of incorporating digital technology into the 'Geometry' unit of study, the study has created an augmented reality maths learning app. The main objective of developing these educational resources is to motivate students to work on their own to gain a deeper understanding of *"3D shapes"*. The interactive operation method helps students better understand the composition and structure of cubes. The objectives of this research are threefold: first, to examine the relative merits of traditional and digital mathematic education; second, to gauge the motivation of the students to these changes; and third, to monitor the results of incorporating technology into the classroom.

LITERATURE REVIEW

Incorporating interactive behaviours like voices and gestures into the study in recent years has created the illusion of a more natural way of functioning. One area where information technology has the potential to advance is in the classroom, where students can use a variety of devices to engage with virtual learning resources made possible by virtual reality technology (Hamzah et al., 2021). AR, a branch of Virtual Reality (VR), integrates both digital and physical components to build a mixed-reality system that improves the quality of instruction. Using Human-Computer Interaction (HCI) in mixed reality contexts increased student engagement and retention (Dinayusadewi et al., 2020).

The three main characteristics of augmented reality apps are the ability to quickly interact with virtual objects and animals in three dimensions, to combine the real and virtual worlds, and to integrate them. Khanchandani et al. (2021) stated that AR has numerous uses in the classroom, including the following: facilitating unobtrusive interactions between the virtual and physical worlds; simulating a touchable interface for object operations; and allowing for seamless transitions between the two. Abdullah et al. (2022) expressed that students' awareness of their actual surroundings can be enhanced through the use of AR, which differentiates from earlier computer interaction technologies by allowing users to fully immerse themselves in virtual worlds. As a result, AR has a lot of potential as a technology, can help students become more engaged and motivated to learn, and can supplement classroom instruction. According to Cai et al. (2019), this data is derived from the rapid evolution of products such as mobile devices, VR, and AR has led to changes in the way users interact with technological goods. Teaching using technology is another important topic that needs discussing. As the future of human-computer interaction evolves away from the traditional mouse and keyboard and towards an image-based interface and sensory control, experts and researchers from many walks of life are more concerned with user experience issues. Avila-Garzon et al. (2021), the designer of the system, service, or product is obligated to improve the user's experience by modifying the content of the interface in response to feedback received from the user at various points on the satisfaction spectrum (Korkmaz & Morali, 2022). In particular, new technology is being produced and utilised in the education sector due to the growing importance of understanding the science and technology behind the system as well as its practical applications through first-hand experience.

3D is cutting-edge software that allows users to observe and interact with three-dimensional objects in a visual context. On top of that, you can add the virtual items to a control trigger event to make the interactive effects happen instantly (Suwayid & Rezqallah, 2022). Users may find that AR provides a more compelling experience than the more traditional real-world interface. AR has a lot of promise as a teaching tool because of this and many other reasons. AR integrates digital and physical components to provide a more lifelike and engaging experience for consumers. Several fields rely heavily on AR technologies, such as education, ecology, engineering, medical, and aviation (Fendi et al., 2021; Widyasari & Mastura, 2020). With the use of AR, which combines the features of mobile devices (such as phones) with those of real-world objects (such as buildings, signs, or landscapes), users are able to immerse themselves in a scenario where they are actively involved in real-life activities.

In a wide variety of subject areas, including engineering (Munir et al., 2022) history (Studies), design (Design and Mathematics Education), mathematics (Education), and natural science (Guntur et al., 2019), AR has proven to significantly enhance learning outcomes in K-12 and higher education settings. There is hope that incorporating AR into the design classroom can help students become more self-reliant, creative, and critical thinkers. Nugraha (2023) found that when used in conjunction with traditional maths lessons in high school, AR can make pupils more engaged and successful in the subject. Putrie and Syah (2023) demonstrated that AR technology could be a useful tool for capturing the interest of junior high school history students. One significant advantage of AR technology is virtual reality's capacity to contextualise abstract concepts. Pramuditya et al. (2022) employed AR in their research to simulate the three-dimensional operation of real electrical engineering instruments, enabling students to engage in independent learning and improve their ability to connect theoretical concepts with practical applications. Permatasari and Andayani (2021) showed that students were more motivated and learned more when they used AR to simulate electrical experiments.

AR environments have numerous scientific and artistic applications. Riza et al. (2023) developed an AR system that is library-based. Researchers discovered that it not only improved students' motivation and interest in learning, but also their academic achievement. Miundy et al. (2019) investigated the impact of the AR system on the motivation to learn of Visual Arts course participants. The use of AR enhanced the motivation to learn among lower secondary school students, according to the study. Furthermore, AR has a myriad of applications in fields such as situational investigation and related learning research. The research conducted by Kazanidis and Pellas (2019) utilized an AR smartphone navigation system to assist college students in exploring cultural places. Using AR in conjunction with a mobile learning system, Khanchandani et al. (2021) helped pre-service teachers with teaching scientific and technology subjects. Researchers found that employing AR picture books and e-book reading to encourage parent-child connection and sharing activities was far more effective than using traditional methods of training (Avila-

Garzon et al., 2021). Further exploration of the subject matter and the implementation of effective strategies for reshaping the classroom were also helpful.

Earlier studies have offered taxonomies as a means of directing the development of AR applications. These taxonomies highlight potential design aspects that could improve learning results while increasing the complexity of AR applications. For instance, in their taxonomy, Kazanidis and Pellas (2019) include dimensions like reference system, which refers to how firmly the AR content is tied to the real world, and visual connection, which describes how firmly the AR visualisations are physically attached to objects or how they are connected to them through other mechanisms, like virtual lines. While AR apps that use spatially anchored virtual content to make things more understandable for users can be useful in the classroom (Munir et al., 2022), they do necessitate more involved software development for object tracking (Suwayid & Rezqallah, 2022). Multiple studies have shown that learners benefit from experiences with more visualisations (Cabero-Almenara et al., 2021; Özçakır & Özdemir, 2022). Nevertheless, as mentioned earlier, the effects of these particular design decisions on pupils are hardly investigated in experimental studies on augmented reality teaching. To build upon this previous work, we compare two augmented reality applications and look at how the design differences affect student learning and inquiry. One application has multiple anchored, dynamically changing 3D visualisations, while the other uses a smaller number of 2D representations that don't move with the real objects.

In the field of AR for education, studies have demonstrated that AR visual representations, which are also known as AR visualisations, can direct student curiosity, promote active cooperation, and enhance problem-solving strategies among classmates. As an example, Pramuditya et al. (2022) discovered that while participating in a group AR mathematics activity, participants make good use of AR visualisations as grounding representations, which facilitates questioning and explanations amongst participants. For instance, when students work together in AR-enhanced investigations of *"3D shapes"* (Korkmaz & Morali, 2022) the presence of shared representations in AR can help equalise contributions and reduce leadership dominance. The use of augmented reality visualisations improved group learning and attitudes towards problem-based learning activities, according to research by Avila-Garzon et al. (2021), when contrasted with more conventional methods of instruction that did not incorporate AR. According to research by Putrie and Syah (2023), students in a group mathematics class were more likely to actively learn through experimentation when given access to augmented reality representations, which facilitated better problem-solving and learning overall. Based on these findings, it seems that AR visualisations, especially when used in student-to-student interactions, can help students think more critically and actively learn by facilitating experimentation, quick feedback, and better communication. The authors may anticipate comparable outcomes from AR tutoring via distant connections, and we can quantify the effect of AR visualisations through qualitative analysis of student learning.

METHOD

Development of Mathematics Teaching Materials

According to a study, lower secondary school students had difficulty grasping the *"Graphics and Space"* subfield of mathematics (Korkmaz & Morali 2022). The *"3D shapes"* units of lower secondary school mathematics provide the basis of the study's material. With a combined ten years of classroom experience, two senior teachers co-created the mathematical curriculum. This AR math app was built using the Assembler Edu. The Assembler Edu app allows users to create games that run on a variety of platforms, including iOS, Android, Windows, Mac OS X, and Linux. When it comes to creating AR/VR applications, Assembler Edu 3D is the way to go. It has an excellent module for digital sceneries, 3D objects, and a logic technique for programming.

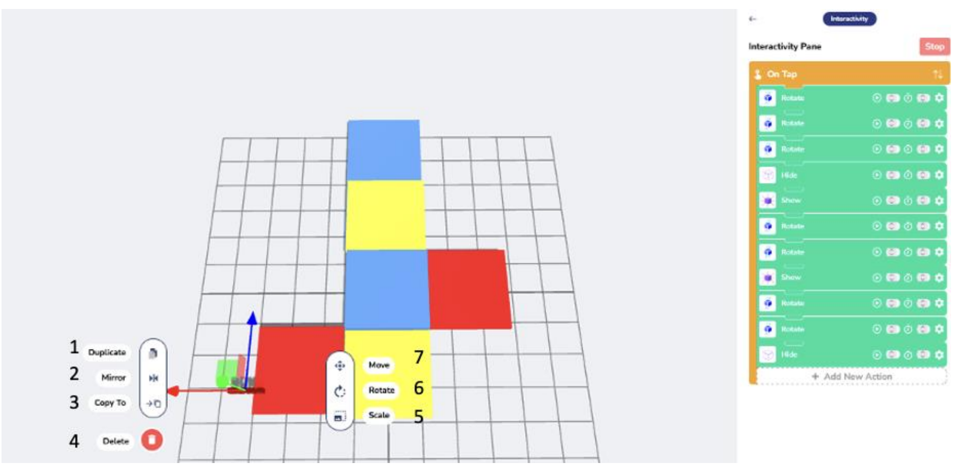

Figure 1: Assembler edu apps interaction

A mathematics software with augmented reality that is both directed and participatory has been developed by the research group. The app can be accessed and installed by students using their mobile devices. The software's built-in interactive operating instructions and user-friendly design make math easier to remember and increase motivation to learn. Figure 1 and Table 1 describe the App's interactive functions.

No.	Descriptions Menu
1	Alternative duplicate
2	Mirror
3	Copy
4	Delete
5	Scale figure
6	Rotate figure
7	Move figure

Table 1: Assembler edu menu descriptions

This study's overarching goal is to recommend digital learning tools that seventh graders can utilize to better understand the mathematical concept of the *"3D shapes"* unit. Students are guided in their understanding of 3D composition, and geometry through the use of information technology and an interactive learning paradigm. The story goes on to describe an AR math learning tool and how it can improve students' grades, motivation, and attitude towards science and technology.

Participants

A total of ninety graders from two different classrooms took part in the study; forty-six of them were assigned in the experimental and forty-four control groups students (see Table 2). Both maths classes were taught by the same teacher. The effectiveness of the method was tested in a four-week teaching trial utilizing the Maths *"3D shapes"* course material.

Profile	Experimental Group	Control Group	Total
Male	28	24	52
Female	18	20	38
Total	46	44	90

Table 2: The participants profile

Research Questions

Based on the study's methodology, we developed the following research questions to help shed light on it: 1. What is the difference between the experimental and control groups regarding students' learning achievement? 2. How does the experimental group compare in terms of students' motivation? 3. What is the difference in terms of the experimental group's and the control group's technological acceptance value?

Experimental Process

To ensure that the two groups of students using the Assembler Edu app for mathematics classrooms had the same prior knowledge, they were asked to complete a pre-test and a pre-study survey before the course began.

The students on the experimental team attended a tutorial before the activity started to make sure they were familiar with the augmented reality programme. Thereafter, a wide range of educational activities were carried out by two sets of students. The subjects in the experiment learned the information through an AR Assembler Edu app, while the subjects in the control group learned it through the use of computers and video data. Figure 2 shows the experimental flowchart after both groups completed the post-test and post-study surveys and interview. In order to measure the effect, we administered a questionnaire to students before and after the experiment to gauge their level of motivation.

Along with the study questionnaire, there is a survey of students' attitudes towards technology. Subsequently, to determine how well the AR technologies worked, both the experimental and control groups were given an achievement test after the experiment. Students who volunteered to be part of the experimental group also had to endure interviews. We asked the students for their thoughts on the execution plan.

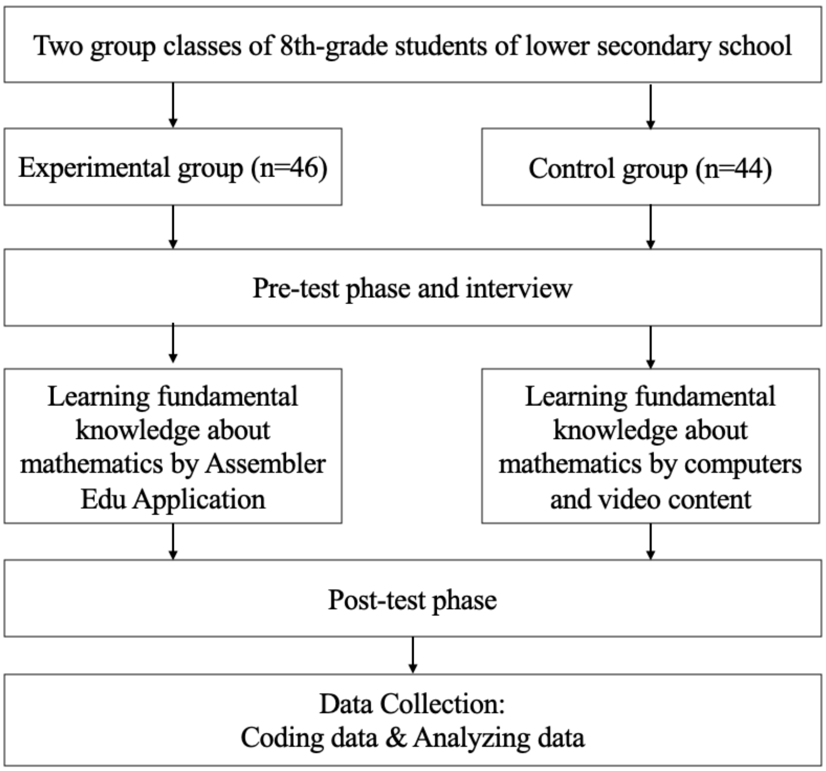

Figure 2: The experimental phase

Meanwhile, figure 3 shows a math 3D shape unit that incorporates multiple interactive operations into its learning activities.

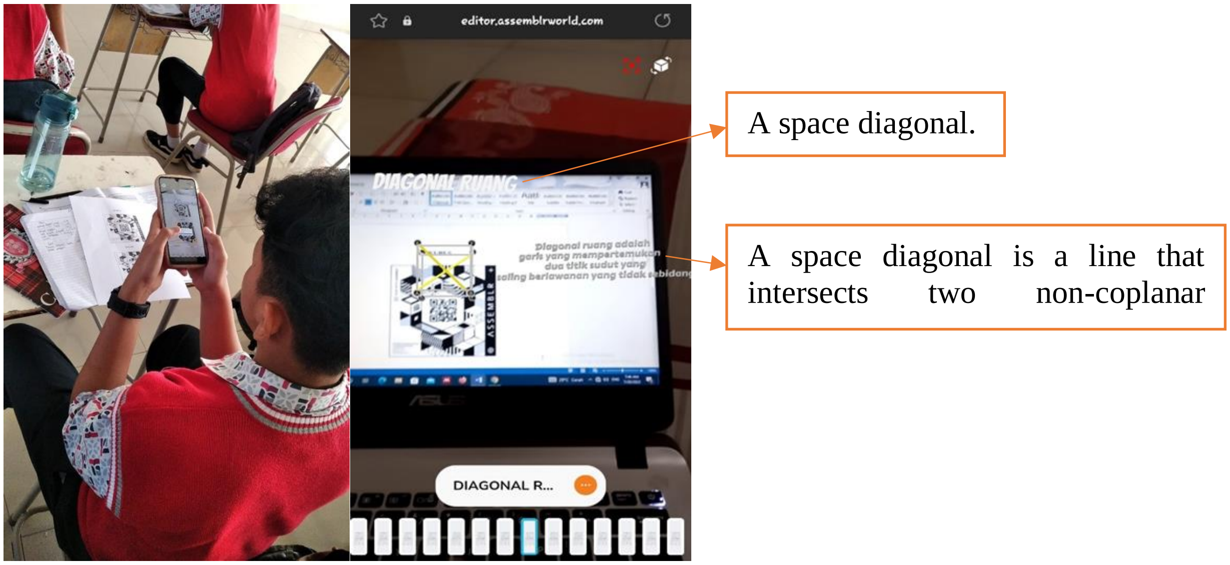

Figure 3: Assembler edu apps of students' activity in experimental class

Research Tools

The research instruments utilized in this project include a learning accomplishment exam and a questionnaire. A questionnaire was used to gauge the student's openness to technology and their motivation for learning. The content of the accomplishment test was developed by two teachers with a combined ten years of classroom experience. Preliminary testing focuses on students' 3D common sense. The test content consisted of ten questions for a total of one hundred points. Students' prior knowledge of 3D shapes could be gauged through pre-testing. The post-test had a total of 100 points and consisted of 10 questions. Using a knowledge quiz and their grasp of the graphic concepts of 3D shapes, and 3D composition, the issue assessed whether students could effectively distinguish between the three after engaging in digital learning.

Following the trial, participants filled out science and technology acceptance assessment forms. After some revisions to meet the requirements of the study, the technology acceptance rating measures developed by Cai et al. (2019) were used. Two parts of the survey, "Cognitive Usefulness" and "Cognitive Easy-to-use," comprised thirteen items administered using Likert's 5-point scale. To what extent did users' acquisition of learning aids improve their learning? That was the "cognitive usefulness" focus. Cognitive Easy-to-use was employed to ascertain if learners could utilize the learning aids without difficulty. The computations required to prove the test's validity and reliability were all carried out. Using Cronbach's Alpha, we found that the test has a reliability of 0.910. Scale dependability is vital when Cronbach's alpha is between 0.6 and 0.80.

The study's qualitative section made use of a self-designed semi-structured interview guide. After the study, the survey's main goal was to get the experimental group students' thoughts on how AR was used. The questionnaire was double-checked for validity and reliability by interviewing two additional experts alongside the researchers. The experts' advice was carefully followed, and the required changes were made without a hitch.

Data Analysis

The quantitative data collected for the study's main objective was examined using the statistical analysis program SPSS 28.0. Before running any statistical tests on the data, it was crucial to determine whether the data adhered to a normal distribution and how similar the variance was. The researchers employed the Levene test to investigate the homogeneity of conflicts in the dataset and the Kolmogorov-Smirnov test to evaluate the normalcy assumption. The homogeneity of group variances and the data set's normal distribution ($p > .05$) impacted the parametric tests selected for the study.

Analysis was conducted using the independent sample t-test on data obtained from both the experimental and control groups both before and after the test was administered. After the experiment, a descriptive analysis was done on the qualitative data collected from student interviews. The students' comments were examined using a method called content analysis. Consequently, content analysis identifies the core concepts and relationships that provide the most satisfactory explanation for the collected data (Robinson, 2017). For each subject, the content analysis used actual quotes from students to establish the credibility of the findings. The authorities have not been altered in any way; they were extracted straight from the student interviews. To keep track of which kids were the most vocal, we used the abbreviations S1, S2, S3, etc. For more reliable results, the researchers and two experts from the outside coded the qualitative data independently. Having impartial experts present significantly bolstered the analysis's credibility. The data analysis's dependability was assessed using the article's reliability formula (Ishtiaq, 2019). The computation yielded a 94% confidence level. The study's findings supported this particular conclusion. The qualitative data was evaluated, and the interview was scheduled using NVIVO 12.

RESULTS

Learning Achievement Analysis – RQ1

To evaluate the math-based abilities of the two teams prior to the experiment and determine whether the students' prior knowledge was similar before the learning activity, we utilised an independent samples t test on the pre-test findings. The control group averaged 67.41 points on the pre-test Maths, while the experimental group averaged 67.21 points, according to the statistical analysis. The experimental group and the control group did not differ substantially, according to the data (t = 0.439, p> 0.1). The findings showed that the students in the experimental and control groups had the same level of pre-experiment mathematical proficiency.

We examined the post-test results of the experimental and control groups using analysis of covariance (ANCOVA) to see whether there was a statistically significant difference in their learning outcomes. To see if our theories regarding the covariance analysis held true, we looked at two sets of data.

The pre- and post-test scores are related variables, as can be shown from the fact that the regression coefficients were the same (F=0.526, p =.470>.05). We know that changes in the treatment level of the independent variable will not have an impact on the regression coefficient since covariance analysis is predicated on the idea that the regression coefficient is homogeneous in the covariate set.

Table 3 shows that there was a significant difference between two test scores after the Math test (F = 4.348, p =.039 <.05) after controlling for the influence of covariance (pre-test score) on the dependent test items (post-test score). The experimental squad's average score was 75.86, with a 14.83 standard deviation. With a standard deviation of 20.32, the control group's average score was 69.75. Stated differently, traditional information coupled with math learning was outperformed by interactive AR app math learning to the statistical significance level.

Criteria Group	**N**	**M**	**SD**	**Adjusted Mean**	**S.E**	**F**
Experimental group	46	78.31	15.32	79.45	2.53	4.525*
Control group	44	69.42	18.46	69.73	2.01	

*p < .05

Table 3: The ANCOVA value of the pst-test study

Math Students' Motivation Analysis – RQ2

Researchers looked at two teams' pre- and post-test results on the Math learning motivation evaluation scale to see how different teaching philosophies affected students' motivation to study. This gave them the chance to talk about whether interactive augmented reality learning could improve the experimental team's motivation to learn maths.

An independent sample t-test was performed on the total score obtained from the Pickett-Like 5-point assessment of learning motivation scale prior to the instructional activity. The control group did remarkably well, with an average score of 4.27 points and a standard deviation of 1.06. The average score for the entire experimental group was 4.28, with a standard deviation of 1.17. The t-test results showed that there was no significant difference between the two teams' pre-lesson motivation. "p" =.957>.05. and "t" = 0.054>.05. After the trial, a motivational questionnaire was given to each of the two groups, and one-factor covariates (ANCOVA) were used to assess the data.

Firstly, we tested the homogeneity of regression coefficients to confirm the covariates' (pretest scores) relationship with the dependent variables. The results showed that the coefficients were homogeneous (F = 2.921, p =.09 >.05). the outcomes of the following evaluation It was not different because the treatment levels of the independent variables were different, assuming that the covariate's regression coefficients are homogeneous.

The outcomes of the ensuing covariate analysis are displayed in Table 4. After adjusting for the impact of the independent variable (pre-motivation questionnaire) on the dependent variable (post-motivation questionnaire), there were significant differences between the post-Math motivation levels of the two teams. There is statistical evidence to corroborate this (F = 8.80, p =.004 <.01). That is to say, the statistical significance of learning through interactive augmented reality apps was significantly higher than that of learning through more traditional techniques that blended maths with conventional knowledge.

Criteria Group	**N**	**M**	**SD**	**Adjusted Mean**	**S.E**	**F**
Experimental group	46	4.83	0.93	4.85	0.105	8.74**
Control group	44	4.15	1.26	4.17	0.103	

** p < .01

Table 4: The ANCOVA value of students' motivation in post-test study

Subsequently, figure 4 shows that the majority of students had results on the Students' Motivation test that fell into the top two categories. As an example, 84.3% of the participants (76 out of 90) thought AR applications were very attractive. In addition, the top-2-box score shows that 74.3% of participants agreed that the given authoring choices were useful for building AR applications. Furthermore, it is worth mentioning that a considerable majority of the participants, specifically 82.6% (74 out of 90), thought that augmented reality technologies can be useful while teaching mathematics. In a similar vein, a sizeable majority of respondents (78.3 percent, or 70 out of 90) agreed that augmented reality tools are usually appropriate for developing educational interventions. Finally, 73.3% of people think it's easy to combine AR with a traditional textbook.

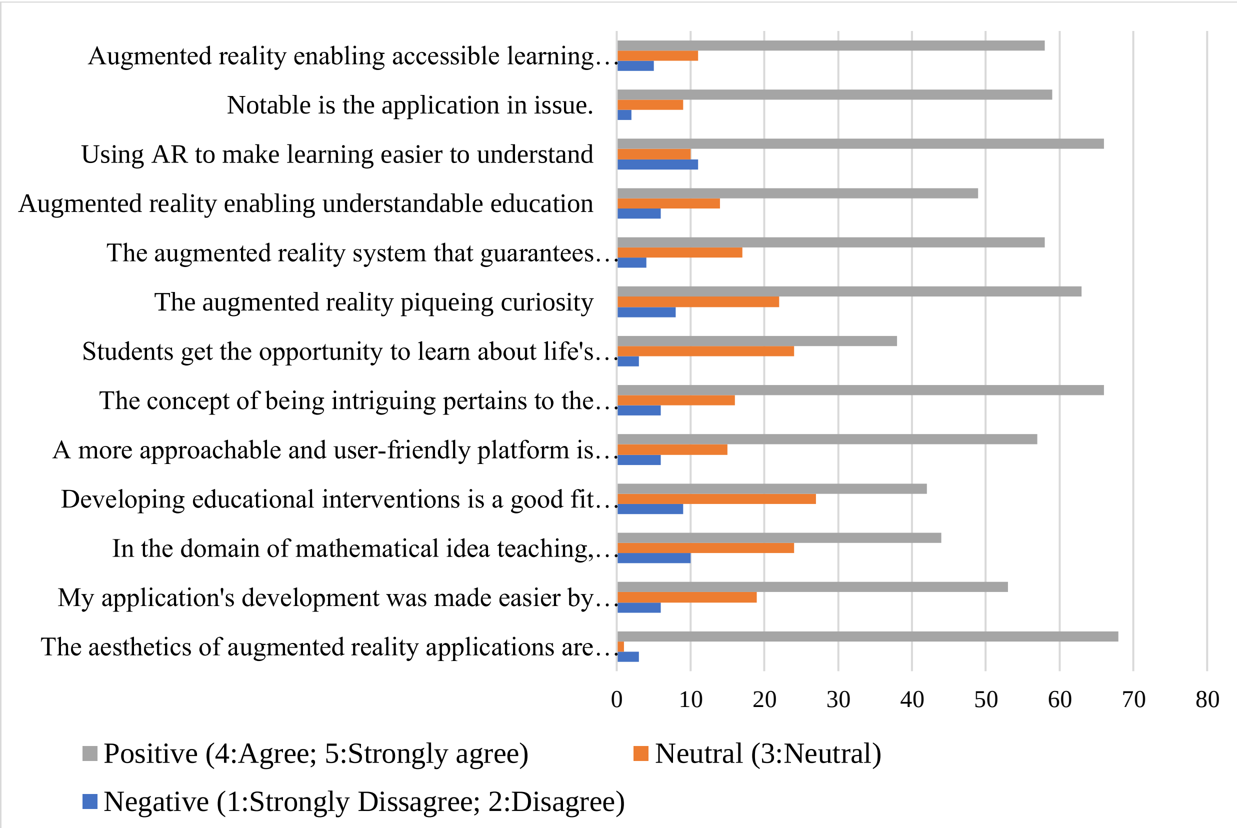

Figure 4: Vertical graph on students' experience on motivation

Numerous participants have reported having excellent experiences using AR. We chose "Both AR tools are easily learnable without any prior knowledge of computer programming or domain-specific expertise" because it best describes the scenario. A different students commented, "It is noteworthy that, three weeks prior, I possessed no foresight regarding the opportunity that would arise for me to engage in the development of AR app." With the use of supplemental materials, I was able to become proficient in fractional mathematics, and for that I am grateful.

Extra information regarding the use of AR technology in mathematics instruction was gleaned from short discussions with focus group session participants. The majority of participants expressed a strong preference for AR and expressed their intention to incorporate it into several fields. The use of an AR writing tool has been suggested by students as a potential solution to the problems that exist in cooperation. Using AR in the classroom is something that the majority of kids are interested in doing. During a discussion on augmented reality authoring tools, three students voiced a need for more feature-rich tools for AR reality applications, such a hybrid of Unity 3D and Vuforia. The majority of students in this class thought the AR exercise was the best part of the class. However, participants reported that making instructional videos was the most time-consuming and challenging task. They also came to the conclusion that mathematical themes were properly covered by an existing classroom content development method. More than that, a handful of students said they had problems with the technical aspects of their software programmes. With the help of their classmates, students were able to fix the problems in the majority of cases. On rare occasions, pupils may choose to approach the instructor for individual attention.

After conducting an experiment, we gathered student feedback on AR activities. In this particular context, the students were mostly asked about the motivational signs of using AR in the classroom. As shown in Table 5, we analysed and modelled the responses of the participants.

Providing visually engaging surroundings and effective learning tools.
Providing the opportunity to utilise technological benefits
Developing abilities in research and inquiry
Providing a plethora of options to gain access to important resources
Visual intelligence stimulation and application
Opening up possibilities for observation
Giving students the opportunity to learn about the nuts and bolts of life
Providing accessible, thorough, and efficient educational opportunities
Providing thorough instructional guidance
The development of creative thinking
Notable is the application in issue.
Providing visually engaging surroundings and effective learning tools
Providing the opportunity to utilise technological benefits

Table 5: The impact of assembler edu apps on students' motivation

Student responses describing the positive effects of AR applications in the classroom are included in Table 5. One of the possible uses for augmented reality is to help people learn in visually rich environments; another is to let them "become" another object or idea. Someone once claimed, "I learned better because it was visual," and they couldn't have been more right. My learning and comprehension were both enhanced by this. Part 5. "It was absolutely lifelike; I felt like I was smack dab in the middle of the action," said another pupil. The level of detail in the planet photos was breathtaking. In contrast to the first, who showed no interest, the second one said, "I was very fascinated by that" (S1). This programme has the potential to be useful in a range of educational contexts (S9). According to another student, the incorporation of augmented reality software into the class enhances the retention of information. Using the applications (S12) piqued my interest in the lesson and helped me understand the content better. "The application of AR was interesting for the topic," another student commented. Learning is also made more interesting and entertaining by the application's graphically rich environment. An easy learning curve is the end outcome" (S6).

Technology Acceptance Analysis – RQ3

To learn more about the degrees of technology adoption in the control group and the experimental group after the introduction of digital learning for maths. The researchers evaluated the results of two teams on science technology acceptance scales to determine how various learning activity strategies affected the acceptability of science technology. Twelve questions each on the topics of "Cognitive Usefulness" and "Cognitive Easy-to-use" were included in the test. The Likert 5-point scale was used to score the questions. The science technology acceptability scores were examined using an independent sample t test. The experimental group used an augmented reality app to learn, whereas the control group used more traditional digital approaches. Table 6's results demonstrate a substantial difference (p =.00 <.001) between the experimental and control teams' embrace of science and technology. This indicates that pupils were able to give normal digital learning a lower technological acceptance rating than AR App Learning.

Criteria Group	N	M	SD	F
Experimental group	46	4.47	0.72	4.29***
Control group	44	3.39	0.59	

Table 6: The t-test value for technology acceptance of this study

Meanwhile, an additional component of the research was the inclusion of students' viewpoints regarding the limitations of AR applications and their recommendations for enhancements. Table 7 shows how the students feel about it.

Category	Recommendations
Cognitive usefulness	The student takes on the position of an observer and listener.
	Very confusing user text.
	Some students might not be able to use it.
	Applying a conceptual framework that functions inside a more complex and detailed world can shed light on the phenomenon.
	It is recommended to take suggestions into account and put them into action at each level before moving forward.
	The ability to produce audible sounds is possessed by auditory stimuli.
Cognitive easy-to-use	It is necessary to create graphics that are more accurate.
	Perhaps a more interesting way to convey the text might make it more effective.
	Possible savings might materialise.
	All fields of study must make heavy use of this resource.
	It is possible to increase the level of usefulness.
	The object's three-dimensional projection needs to be shown in an appropriate spot.
	It is recommended that students cultivate an attitude of living in the here and now.
	Making sure that AR App are used to conduct tests.

Table 7: The students' viewpoints of limitations and recommendations

Table 7 highlights several problems, including excessive expense, instructors falling behind, students not actively participating, application challenges due to a large student body, insufficient availability, and time spent. The students' responses to these problems included suggestions to make the app more interesting to use, reduce expenses, and provide more realistic images and sounds. "It is not good that the connection and the technical problems we had in class take much time" (S2) is one possible student complaint. "It is a very nice app, but it is not good because we do not have money to buy it, and it is expensive" (S6) is another student's take on the downsides of AR apps. "It sometimes confused our class," another student stated, adding to the class's confusion. "What if I wanted to reach out and touch the sun?" In Section 3. Think about the consequences if we experienced it Part fourteen "For this course, augmented reality is a waste of time and energy. The student examines the digital representation. No one can really benefit from it (S11). "I think it would be good for my brother if this were used in all courses" (S7). The students who participated in the study expressed their discontent with the use of AR and provided suggestions for how to fix it (Table 7). According to a student's suggestion, "The application was interesting and exciting, but more realistic sounds and images could be used during the application" (S12), the programme may have been enhanced. A different student brought up the fact that these apps are expensive and said, "Not all students can afford to use them." as an argument against their widespread use. Making software that doesn't break the bank is essential (S8).

DISCUSSION

According to the experimental findings, AR can be a helpful tool for motivating students, making it easier to handle objects using a tactile interface metaphor, and enabling a smooth transition between the physical and virtual worlds. These advantages are in line with the need for mathematics education, particularly in mathematical modelling where students demand a relationship between mathematical concepts and real-world circumstances. This software allows students to match 3D objects with their appropriate real-world situations, in line with Cabero-Almenara et al. (2021) idea of mathematical modelling as a sub-competence, which aids students in understanding real-world difficulties.

According to Salim et al. (2020), students can create mathematical models based on real-world examples with the use of AR app in students' motivation. This is a part of the stage of students' motivation in classroom instruction. The motivation of each assignment supports these two stages of instruction. Additionally, Elsayed and Al-Najrani (2021), when stuck, students can apply previously learned mathematical ideas to particular mathematical situations by using the app's hint feature.

Here, the recommendations feature refers to the idea of students' motivation scaffolding (Özçakır & Özdemir, 2022). In light of recent technology improvements, digital tools have become an effective tool for teaching students motivation (Hamzah et al., 2021; Nasrudin et al., 2021). This study 3D shape display offers clues that resemble the actual object that needs to be found in addition to the criteria.

Dinayusadewi et al. (2020) claim that this visual assistance facilitates students' ability to draw meaningful links between pertinent mathematical settings and real-world situations. According to Kazanidis and Pellas (2019), students can convert problems from the actual world into more formal mathematics. With this function, students are guided to the next level of problem solving in mathematical models. Subsequently, they conduct diverse modelling procedures as required and convert mathematical inferences into practical models, scenarios, and testing approaches. Fendi et al. (2021) noted that shapes are now easier to view and interact with AR.

Meanwhile, the findings demonstrate how AR seamlessly connects the actual and virtual worlds. By presenting geometric concepts in various ways and from many angles, AR might help students comprehend them better and lessen the possibility of misconceptions brought on by students' motivation difficulties. This is supported by the findings of Cai et al. (2019), who discovered that AR holds a lot of potential for application in the classroom, especially in subjects that require a lot of motivation aids. The positive feedback students left about using the AR mobile app also showed how excited and interested they were in learning. This finding supports the idea that more people use AR to create creative classroom learning environments (Korkmaz & Morali, 2022; Suwayid & Rezqallah, 2022). Students can employ AR, which bridges the gap between virtual and real-world scenarios, to tackle Assembler Edu tasks using mathematical modeling cycles. The study's findings can help Assembler Edu achieve its development goals, which include improving students' motivation (Fendi et al., 2021). In this educational programme, AR has brought a virtual concept into the real environment about technology (Dinayusadewi et al., 2020).

Based on the findings, the AR Assembler Edu App has a favorable impact on student's motivation for learning tasks. This training curriculum improves the ability to model mathematically. AR technology can benefit students in terms of student motivation, especially when learning to understand real-world events, build physical models, and then use those models to generate student motivation. Furthermore, field measurements verified the presence of a relationship between the students' motivation created during instrumentation and the instrumented approaches used in the AR app.

LIMITATIONS

Several limitations are associated with the present study. Because the study was designed with only two conditions, we don't know how the specific changes in complexity between them affected the students' learning and curiosity. The conditions differed in terms of the quantity of AR representations, the sorts of AR representations, and how they were anchored. To better understand how AR application designs vary along these particular dimensions, future research is required to examine more controlled variation. Both the findings and the discussion are very conjectural and point to potential avenues for further investigation due to the small sample size, which diminished the statistical ability to identify conditional differences. Furthermore, there were not many question prompts in the instructional exercise, which may have contributed to a low question volume. A bigger sample size participating in an open-ended tutoring activity for an extended length of time should allow for the detection of more statistical effects.

In addition, the data used for qualitative analyses of students' mentions of AR visuals is limited to questions that directly addressed the visuals; however, students did ask numerous questions that did not directly address the visuals, and this data could potentially provide more accurate comparisons between the groups. When applied to bigger datasets, the statistical implications and repeatability of the descriptive findings from this study should be explored in future studies. Furthermore, there was a significant gender imbalance in our sample; in each condition, women made up about two-thirds of the participants. The current study did not do a gender analysis, thus even while the gender disparity seems to be equal across situations, it is unclear if this influenced the outcomes. Whether or not the current findings are applicable to larger populations may be confirmed by future research. The perception of students' silences also has its limitations. Both outwardly visible behaviours (such as asking questions or requesting activities) and internally visible behaviors (such as students thinking critically about the subject) can constitute active learning. While the Full-AR group did show more overt indicators of active learning in our data, it doesn't imply that all students weren't involved. Students in the Basic-AR group did appear to be paying attention in class; they just weren't expressing themselves as clearly. Research in the future can make use of other tools for gauging students' internal processes, such as cognitive load measurements and more targeted pre- and post-test inquiries. In conclusion, we recognise that the activity has an effect on the sorts of inquiry that students do; students may display distinct patterns of inquiry with varied learning content and with tutoring activities that are less direction driven.

CONCLUSION

Students may need help understanding more abstract concepts taught in the classroom using traditional approaches. However, developments in AR apps can provide several levels of interaction and information presentation, improving students' motivation for learning. In recent years, there has been a steady increase in research studies and projects addressing this topic. Implementing AR apps in educational settings yields numerous advantages, such as creating a captivating learning atmosphere, raising student motivation, and enabling more profound comprehension of the subject matter. However, utilizing technology to support instruction does not guarantee that students will learn more motivated. Effective teaching practices must be implemented in addition to recently released technology so that students can benefit from it. The study results indicate that employing an AR maths app to learn the content of the "3D shape" unit can improve students' learning outcomes and motivation through interactive operations and modifications to 3D space. Students who use AR apps for learning are also more likely than the control group to accept technology, which aligns with another research.

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