

PAPER

Effects of Augmented Reality-Based Digital Mobile Game-Based Learning on the Engagement of Students

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ABSTRACT

Augmented reality, or AR, has become increasingly popular over the past ten years, particularly in education. Only a small number of publications, meanwhile, have thoroughly examined the research trends in the application of AR to mathematics education. Globally, two trends that are being implemented in education are AR and digital game-based mobile learning. It is still important to monitor the consequences of implementing both trends simultaneously in inclusive learning, though. We have created an inclusive AR video game to teach mathematical logic skills. To highlight the patterns in this study's emphasis, eight themes were identified from the analysis of these literary works: learning challenges, testing strategies, benefits of AR for mathematics, different kinds of AR apps, tools for developing AR apps, research contribution categories, and math subtopics. Additionally, by providing researchers and educators with a synthesized review of learning mathematics through AR, this study may open up new research directions. Our study demonstrated that children with varying needs perform similarly when playing. The findings and the teaching staff's input indicate that DGBL and AR should permit the inclusion of kids with disabilities in the instruction procedure.

KEYWORDS

mobile learning, mathematics education, playing, digital game-based learning (GBL), augmented reality (AR)

1 INTRODUCTION

The game is as old as mankind when it comes to enjoyable activities. Play is how we practice some mental, physical, and social skills from the moment we are born. Video or electronic games operate similarly. Apart from the various genres that video games come in and the multiple mediums in which they can be shown, all games share several characteristics (such as high levels of involvement, entertainment, regulations that the player must follow, a scoring system, or a competitive element). However, we may use the game's capacity to help us mentally

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and physically work out. That’s exactly what occurs when you play in serious competitions [1]. In addition to being entertaining, serious games also aim to use player interaction to advance causes including legislation, health, schooling, and communication.

Serious game science has indeed produced a significant amount more research since 2007. A comprehensive review of the research on serious games from 1990 to 2012 showed that 64% of the papers published in this field were written between 2007 and 2012. Vargas provides another pertinent statistic, indicating that 60.71% of serious games found through a systematic search fall into the educational category. These findings could be clarified through issues like students quitting school for lack of incentive; instructional video games could fill in the motivation gap and end up being a great resource for educators and parents. Accordingly, numerous studies highlight the benefits of using video games in the classroom because they, among other things, shorten reaction times, enhance hand-eye coordination, boost self-esteem, enhance spatial perception, promote collaborative learning, motivate learning through difficulties, encourage exploratory behavior and an eagerness to learn, allow users to practice on simulators without risk of failure, enhance social skills and basic math, express abstract thought, and improve cognitive skills.

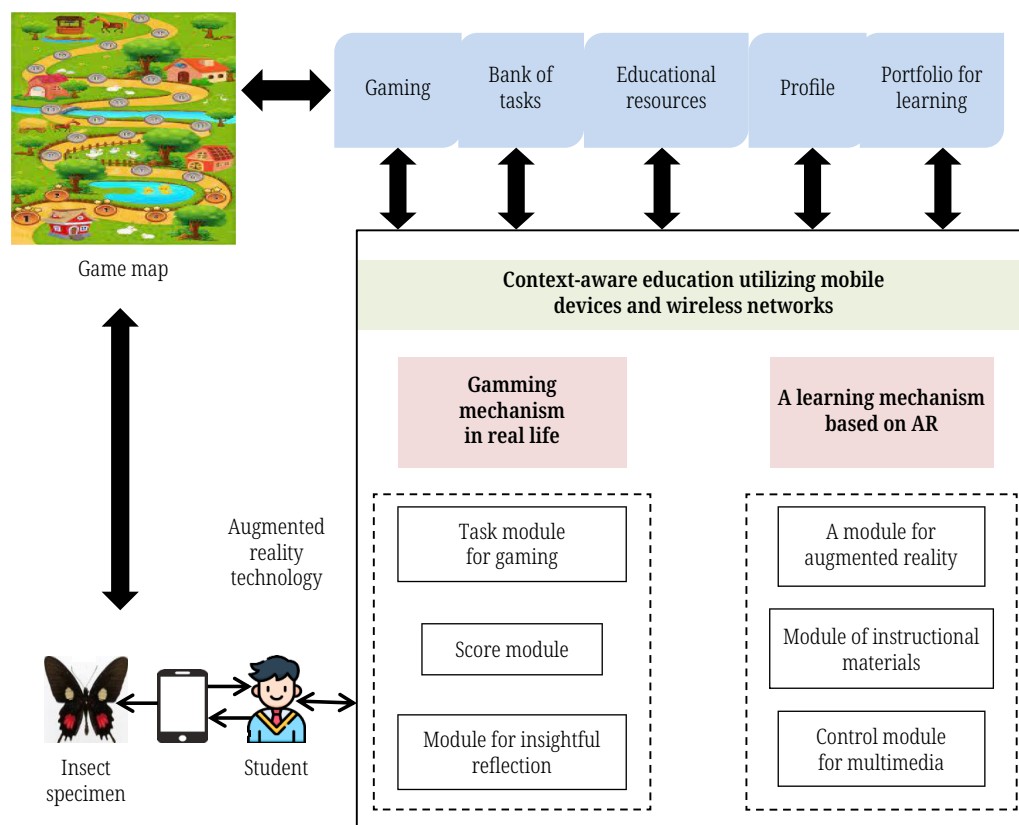


Fig. 1. Configuration of the AR learning system through games

This study conducted a context-aware mobile learning activity to improve students’ science learning about insects using multimedia learning resources and an augmented reality (AR) game-based learning (GBL) approach. Using this device, Unity 3D, and Xcode [2], an AR GBL system was created based on this technique, and each individual insect specimen was found in its natural environment in an

elementary school's learning park. Additionally, as part of the context-aware mobile instruction action, each student received a tablet that had the integrated learning system loaded on it. The arrangement of the AR GBL system is shown in Figure 1. It consists of two mechanisms—the real-world gaming system and the AR-based learning mechanism—as well as a context-aware authentic educational setting. A number of files, including gaming and learning portfolios files, were also developed to assist with the educational processes.

Augmented reality is a new technology with a lot of promise. The increased use of handheld devices has made AR more inexpensive and pervasive in recent years, even though the earliest applications debuted in the late 1960s. AR enables users to explore, alter, and interact with both digital and natural objects in real time, effectively blending virtual and real worlds together. They can also see objects in various contexts and get instant visual feedback about what they're doing in a completely secure setting.

Therefore, [3], AR improves learners' understanding of abstract and difficult subjects since it may provide rich practical and on-site instructional opportunities. Another approach to teaching that utilizes the hands-on learning concept is GBL, which uses specially designed videogames to improve the learning process. One advantage of GBL is that users build their own knowledge through games and learn how to use it in various contexts, in contrast to the traditional education model that depends on pupils absorbing new concepts. Therefore, the two educational strategies listed above are highly relevant to the education sector because they both increase learning outcomes and learners' efficacy by actively engaging them.

The remainder of the paper is organized in this manner. Section 2 presents the aim and scope of this work along with the systematic review and meta-analysis methodology. The definition and visual of AR are offered in Section 3 depiction, in addition to the AR learning system through game applications. Section 4 gives an in-depth examination regarding the utilization of AR in the metrics for performance assessment applied to analyze the caliber of the AR-based learning mechanism. The conclusion and future enhancements are presented in Section 5.

2 RELATED WORKS

Even while this kind of study is crucial, a lot of studies only included one group; this may make it more difficult to pinpoint the precise effects of AR technology. A small number of researchers used an experimental design to compare AR-assisted training to alternative teaching strategies. This study, which looked at learners of all ages [4], from young children to adults, showed that AR outperformed traditional classroom training that used printed resources, books, and illustrations. The identical vocabulary was taught to two groups of young Spanish EFL children: the experimental cohort and the comparison group. After receiving 135 minutes of training, the AR group outperformed the instruction manual group in terms of motivation, satisfaction, vocabulary acquisition, and peer interactions.

These studies generally show that the majority of paid games are significantly incompatible with educational settings. The research's conclusions also imply that the creation of games intended for use in classrooms requires a more conceptually based approach. So-called serious video games are drawing more and more attention from academics and educational professionals. These games differ from market

video games in two ways: (1) they prioritize education over amusement, and (2) they are more complicated than their commercial equivalents [5]. Based on the assessment, participants exhibited a notably enhanced understanding of the intricacy of the dispute, the capacity to view issues from an expansive standpoint, and heightened levels of independent learning.

It's critical to define engagement before examining the research on digital GBL and its effects on student participation. When pupils actively participate in their education, involvement occurs. Though engagement encompasses much more than a student engaging in class (increasing their hand and responding to inquiries) and acting appropriately, teachers may mistakenly believe that their well-behaved pupils demonstrate high levels of involvement [6]. There is more to student involvement than just them appearing focused or busy while working on tasks or assignments. When a student perceives an activity as personally significant and deserving of effort, it is considered true engagement among students.

The application of GBL is supported by several psychological and educational theories. According to the idea of constructivism, learning occurs most effectively when students actively create their knowledge via interactions and experiences. Students can experiment [7], investigate, and make choices that affect the game's outcomes through games. This aids in the purposeful construction of their knowledge as well. Direct exposure and reflection are critical components of the learning process, according to the experiential learning theory. Playing games gives students the chance to experience many situations and think back on their choices, which helps them comprehend the material they are learning more deeply. When someone is absorbed in an activity, they can reach a level of profound involvement and delight, which is described by the flow hypothesis.

The development of location-based mobile applications is made possible by the significant advancements in mobile device features, such as battery life and the incorporation of sensors such as incorporated GPS, compass points, and accelerometers. These developments also enable more interactions with the real world. The majority of suggestions about GBL, however, focus on marker-based AR. This could be because marker tracking is a more reliable and efficient method of tracking than other tracking approaches [8]. Because it has a MAR location-based use that provides an immersive experience in the real world—where the player moves while capturing planets that orbit stars and other celestial bodies—Planetary System GO is a significant contribution in this regard.

As their capstone project, undergraduate higher education students at a Portuguese polytechnic college are working with higher education instructors to develop Planetary System GO [9], a smartphone virtual reality platform. Smartphones with cameras, gyroscopes, GPS, and accelerometers can be used to play the game. The smartphone app is a sort of planet hunt where users identify planets and their orbits in the shortest amount of time by starting at a specific coordinate (the star) and using an AR programmer to assist them. Players get scores at each level of the game. Tapping the earth on the smartphone screen after it has been located may provide details about its characteristics.

Large volumes of mental and non-cognitive data are produced by learners in immersive environments, and this data is recorded in log files to provide an approximation of the students' knowledge and abilities. Immersion technologies offer accurate representations of real-world work contexts by simulating realistic scenarios. This helps students understand how classroom knowledge is applied in real-world situations. With the use of these technologies, teachers can now evaluate their students' application of numerous cognitive capabilities to challenging tasks [10].

Crucially, this type of evaluation is performance-based, meaning it is determined by students' actions rather than their words or the answers they select on multiple-choice exams. In these situations, it is advisable to take into account more conventional techniques of evaluation, such as multiple-choice questions and essay inquiries.

3 METHODS AND MATERIALS

3.1 A method of flipped learning that is based on augmented reality

The present work established an AR-based flipped learning system and flipped classroom teaching activities, as Figure 2 illustrates. The AR technology was created using Unity, a 3D game-development program released by Unity Technologies. An e-learning platform, a classroom that is flipped, an activity administration system, an AR-based flipped learning system, and an online database administration mechanism make up the study's structure, which is depicted in Figure 2. The AR-based flipped learning system also includes multiple databases, including ones for teaching materials, textbooks, and student portfolios.

The additional resources, training sheets, and leading instructions are kept in the learning resources database. Educational records and private information are stored in the learning profile system and the student portfolio database, respectively. Additionally, the instructional films that teachers produce can be stored in the teaching materials repository.

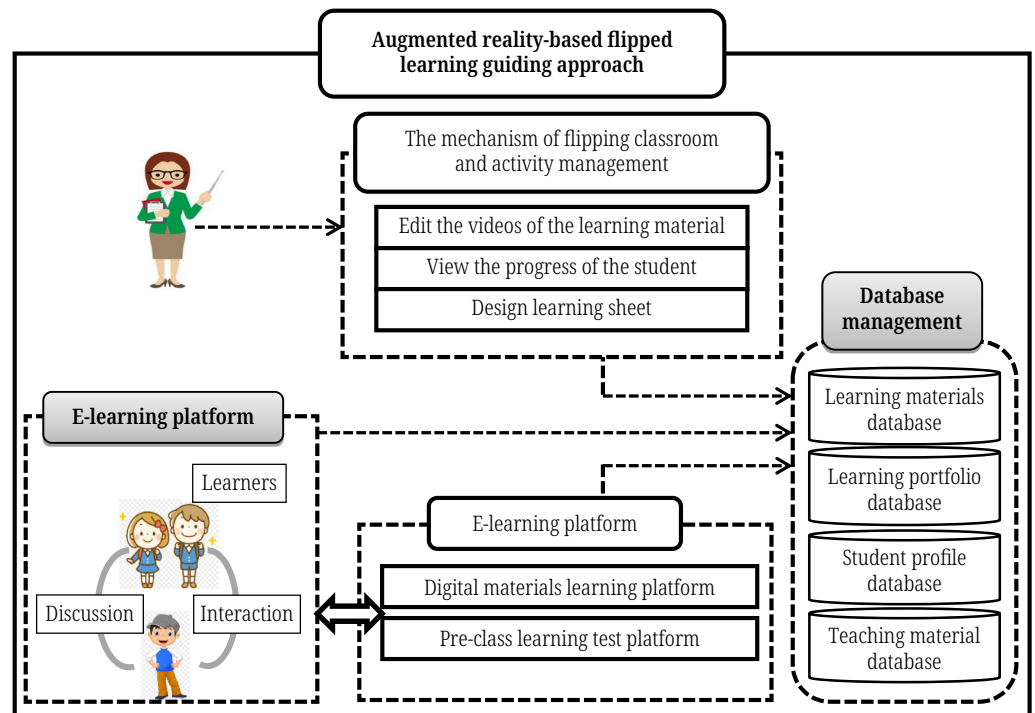


Fig. 2. The augmented reality flipped learning system's organizational framework

The additional resources [11], training sheets, and guiding instructions are kept in the instructional materials database. Educational records and private information are stored in the educational portfolio database and the student portfolio database,

respectively. Additionally, the instructional films that teachers produce can be stored in the teaching materials database.

3.2 Augmented reality

There are three primary components of AR: simultaneous interactive information, 3D displays, and virtual things mixed with actual ones. Stated differently, AR can offer users interaction between virtual and real-world objects, thereby enhancing user involvement. It is thought that merging real-world and virtual spaces to facilitate real-time interaction can provide users a feeling of participation and involvement in the situations. There are two types of AR: marker-based and marker less. In the first case, users must use their cell phones to scan the designated AR code in order to access virtual data; in the latter case, users' positions are used by the mobile devices' GPS function to give comparable virtual data.

Augmented reality may now be delivered through visual recognition thanks to advances in both technology and identification abilities. Location-based AR and image-based AR are the two categories into which AR is currently subdivided. Under the former scenario, users' location can be determined using the GPS feature on their mobile devices, and virtual information can be presented to them based on that location. Students would not be constrained by location when doing mobile learning with this feature, allowing them to observe the surrounding things more closely [2]. The latter, however, consists of both picture and real image recognition.

Using AR in a mathematics exhibition tour allowed visitors to watch the exhibits' animations while maintaining their understanding of mathematics and the concepts presented. The results of the tour revealed that visitors were pleased with the method of touring and that it helped them comprehend the exhibits better. Applied AR software in an innovative design course and examined students' learning motivation, learning outcomes, and creativity in relation to the course design component. The findings demonstrated that this approach could raise students' learning drive, imagination, and learning outcomes; suggested using AR to teach electromagnetic in mathematics, obviously; and looked into the flow, user interface, and system utility of the students.

According to the aforementioned visual recognition AR experiments, pupils who learned using AR outperformed those who learned using traditional teaching techniques in terms of their learning outcomes. In order to convey abstract material or virtual data that textbooks or instructional materials can present, such as collision effects in physics or shifts in magnetic force, the visual recognition type of AR can recognize 2D graphics in textbooks or read AR code. As an alternative to utilizing their imaginations or formulating theories, it enables pupils to engage with virtual items or data.

In terms of location-based AR, a touring activity was conducted using AR in conjunction with interview techniques to locate historical material. With the goal of improving their learning outcomes and sense of localization, 86 undergraduates were split up into three groups and given the opportunity to participate in tour education. Researchers have also used AR on field trips for biological science classes. In order to teach students about aquatic life, AR with inquiry-based mobile learning was combined, and a location-based AR investigation mobile learning system was created. The findings of the study indicated that students who used this system raised novel inquiries and learned new material continually. Additionally, the system allowed students to read the material on their handheld devices, which made it easier for them to obtain additional knowledge and possess it with their peers.

The aforementioned instances of AR’s application in educational research demonstrate how well it can raise students’ learning outcomes and motivation, which in turn can enhance their peer collaboration and interaction. Additionally, a number of researchers have shown that using AR in educational settings has a strong chance of raising students’ motivation. Therefore, using image-based AR to aid students in doing electromagnetic experiments, this study aims at assessing students’ learning motivation, analytical mental workload, and confidence.

3.3 AR framework for learning

Exciting and more practical usage patterns and application scenarios will emerge as we integrate new technologies, such as AR, into the learning ecosystem, as shown in Figure 3 [12]. New software development frameworks will be needed to implement these apps. The authors are developing a software development framework at their lab to address this need. The blending of four key entities—the user of AR, the style of engagement, different forms of learning, and context awareness inside the AR ecosystem—is the heart of this picture.

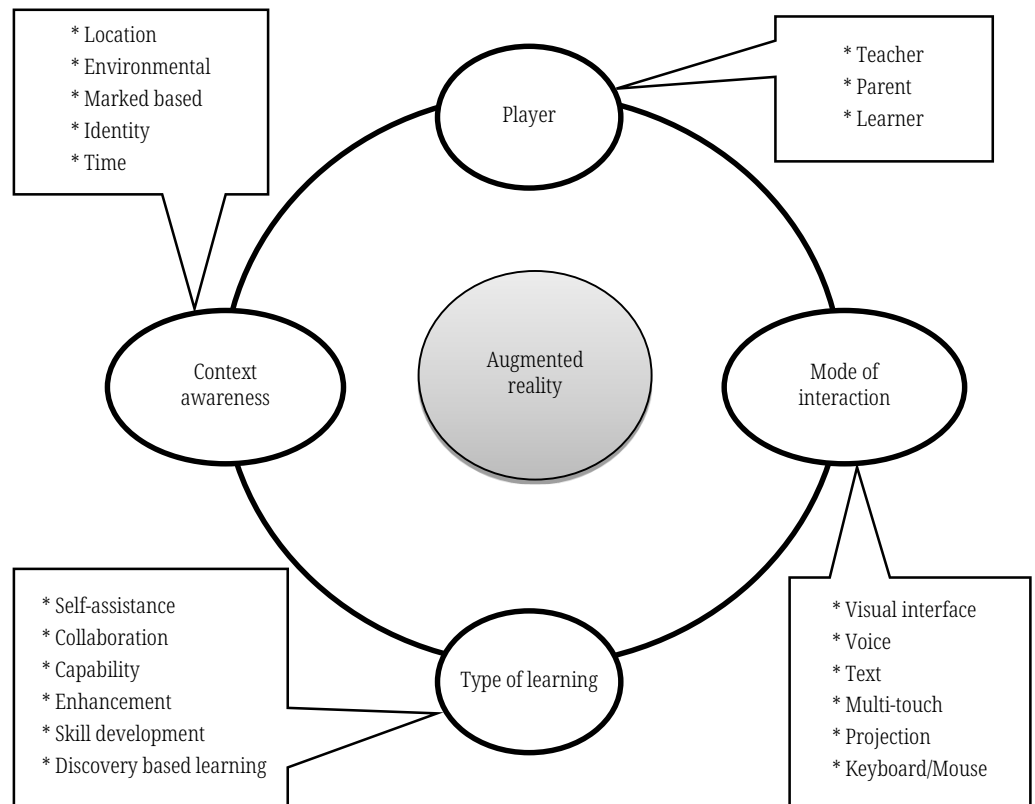


Fig. 3. AR learning environments

Blocks of an ecosystem. The descriptions of each diagram block are arranged as follows:

- Users of the structure, such as educators, learners, developers, and producers of three-dimensional material, are referred to as participants.

- The several ways a person interacts with their surroundings and AR inputs are referred to as their mode of engagement. Keyboard/mouse and other mobile-centric interface modes, such as touch, graphical, pronunciation, and written content, are used.
- Types of learning: This section describes the different approaches to learning. One type of technological help-based instruction is self-learning.
- Contextually aware: Apps that gather user context by utilizing various inputs from various sensors are referred to be context-aware apps. The application selects which content to display based on this setting.

4 IMPLEMENTATION AND EXPERIMENTAL RESULTS

4.1 Learning success

The communication system (split into AR and non-AR methods) and the playing system (split into game and non-game methods) were used as separate variables in the two-way ANCOVA to examine the learning outcomes of the four groups, with the pre- and post-test scores acting as the reliant and correlate variables, accordingly.

First, the homogeneity check was run to assess whether the two-way ANCOVA was executed appropriately. With $F = 0.78$ ($p > .06$), it was found that the regression's homogeneity assumption was not broken. Additionally [13], Table 1 shows the descriptive information and interpretation of the two-way ANCOVA on the learning outcomes of the pupils, accordingly. The main effects of the independent variables were deemed acceptable, as there was no significant influence on the relationship among the communication method and the gaming mechanism, as indicated by $F = 0.30$ ($p > .06$). As indicated, a substantial effect on the students' learning successes was confirmed for the playing technique ($F = 7.40$, $p < .05$, $\eta^2 = 0.073$), whereas no significant difference was discovered for the media method ($F = 0.70$, $p > .06$).

Table 1. The students' educational accomplishments' descriptive information

| Media Mechanism | Gaming Mechanism | Mean | Adjusted Mean | SD | n |
|-----------------|------------------|-------|---------------|-------|-----|
| AR | Game | 97.44 | 97.68 | 22.85 | 36 |
| | Non-game | 91.29 | 91.85 | 24.80 | 35 |
| | Total | 94.43 | 94.76 | 24.08 | 59 |
| Non-AR | Game | 93.51 | 96.99 | 28.35 | 28 |
| | Non-game | 88.38 | 87.99 | 31.45 | 36 |
| | Total | 90.99 | 92.51 | 19.92 | 62 |
| Total | Game | 95.44 | 97.34 | 25.89 | 62 |
| | Non-game | 89.80 | 89.93 | 28.39 | 59 |
| | Total | 92.58 | 93.63 | 27.33 | 111 |

This suggested that the various playing methods (i.e., play or non-game) had a significant impact on the students' post-test results in Figure 4. Additionally, the pupils who used the game-based instructional method had adjusted averages and variances of 96.23 and 15.89 for their post-test scores, respectively, compared to 88.82 and 18.39 for the pupils who used the non-game approach. In regard to how

they learned, it was determined that the students benefited more from the game method than from the non-game strategy for context-aware mobile instruction with reflection prompts.

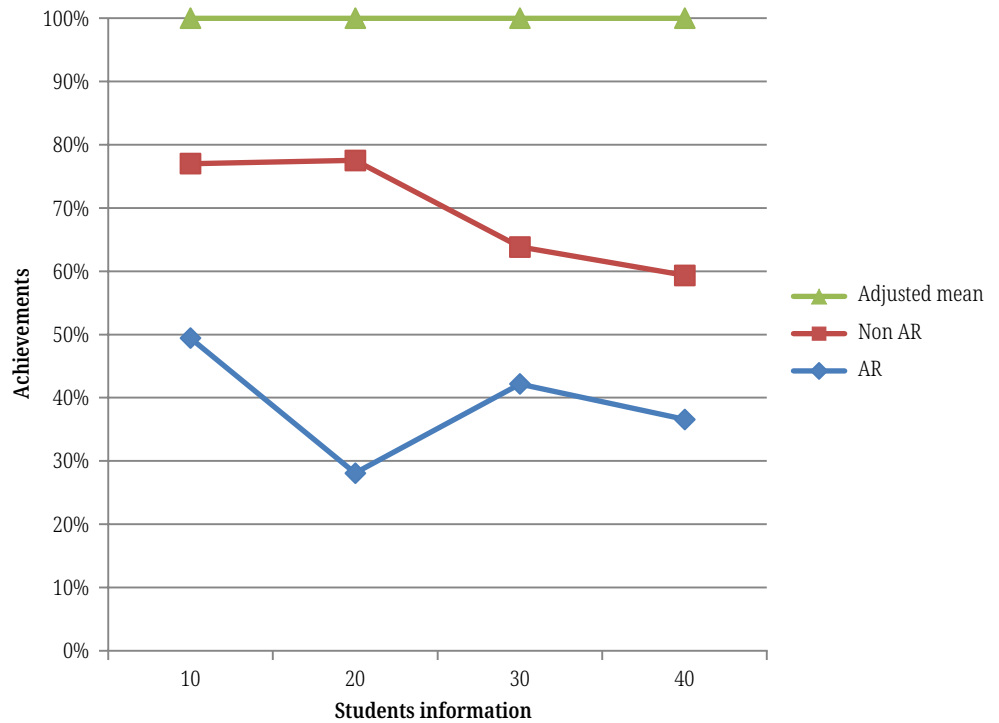


Fig. 4. The various playing methods

4.2 Acquiring drive education

The press system and the playing system were used as separate variables in a two-way ANCOVA to examine the effects of the four different learning approaches on students' learning motivation [14]. The post- and pre-test ratings of learning motivation were used as the dependent and correlate factors, accordingly.

Table 2. The descriptive information about the reasons behind pupils' learning

| Media Mechanism | Gaming Mechanism | Mean | Adjusted Mean | SD | n |
|-----------------|------------------|-------|---------------|------|-----|
| AR | Game | 5.28 | 5.25 | 1.56 | 36 |
| | Non-game | 4.98 | 5.12 | 1.71 | 35 |
| | Total | 5.51 | 5.27 | 1.65 | 60 |
| Non-AR | Game | 5.19 | 5.13 | 1.77 | 37 |
| | Non-game | 4.69 | 4.69 | 1.97 | 36 |
| | Total | 4.95 | 4.91 | 1.90 | 62 |
| Total | Game | 5.23 | 5.19 | 1.67 | 62 |
| | Non-game | 4.85 | 4.89 | 1.86 | 60 |
| | Total | 4.105 | 4.105 | 1.79 | 112 |

Following the successful verification of the regression's homogeneous hypothesis with $F = 1.19$ ($p > .05$), a two-way ANCOVA was conducted. Table 2 demonstrates that there was no significant interaction between the communication system and the playing system ($F = 1.85$, $p > .05$). However, there were significant effects on the students' learning motivation for the two mechanisms: the media mechanism. The ANCOVA results for the press mechanisms and the playing mechanisms both showed a moderate effect size (η^2). Furthermore, for students using the AR approach, the modified averages of the post-test evaluations of learning motivation were 4.07 (SD = 0.75) (see Figure 5), while for students using the non-AR approach, they were 4.80 (SD = 0.80). Conversely, for students using the DGBL strategy, the adjusted mean principles of the post-test evaluations of acquiring drive were 5.08 (SD = 0.77), and for pupils using the non-game approach, they were 4.79 (SD = 0.96). This showed that context-aware mobile instruction with reflection prompts can benefit from both AR and digital gaming techniques in terms of improving students' learning motivation.

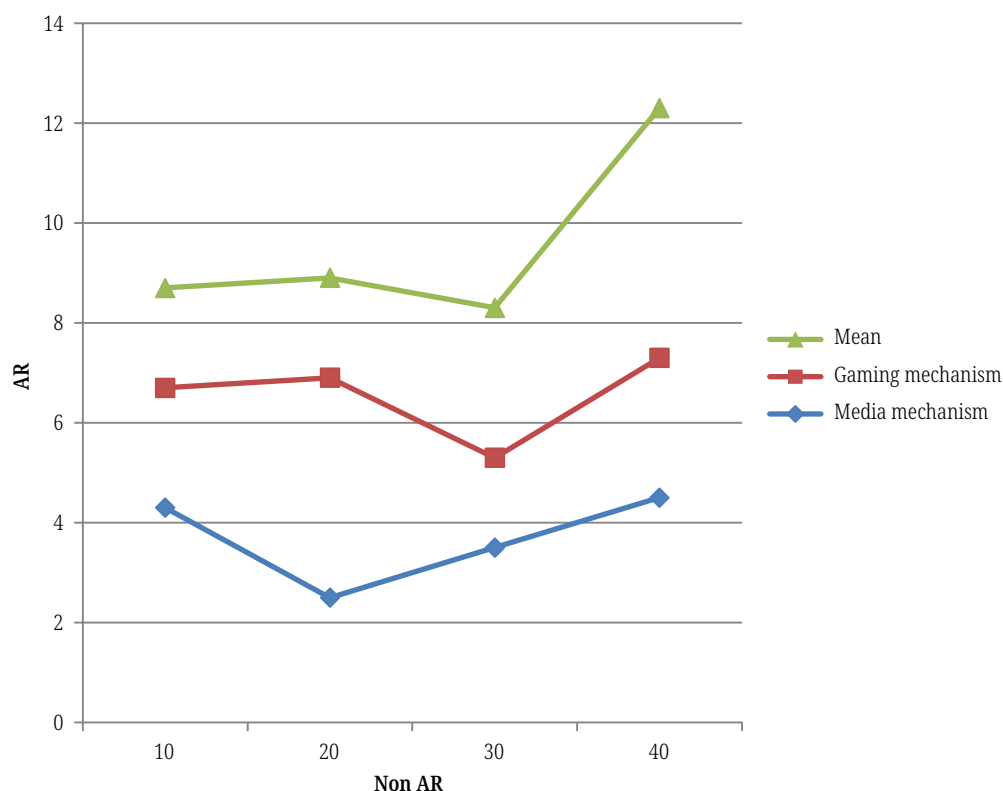


Fig. 5. Post- and pre-test ratings of learning motivation

4.3 Condition of flow

A two-way ANOVA was used to examine the effects of the various learning approaches—the television mechanisms and the video game system, for example—on the participants' subjective states during the lessons. According to Table 3, it was acceptable to analyze the primary effects of dependent variables directly because no significant effect was found on the relationship between the communication method and the playing method ($F = 0.02$, $p > .06$).

Table 3. The pupils' descriptive data from the following states

| Media Mechanism | Gaming Mechanism | Mean | S.D | n |
|-----------------|------------------|-------|------|-----|
| AR | Game | 5.52 | 1.77 | 36 |
| | Non-game | 4.101 | 1.74 | 35 |
| | Total | 5.27 | 1.79 | 60 |
| Non-AR | Game | 5.63 | 1.57 | 37 |
| | Non-game | 4.108 | 1.95 | 36 |
| | Total | 5.36 | 1.86 | 62 |
| Total | Game | 5.57 | 1.72 | 62 |
| | Non-game | 4.104 | 1.85 | 59 |
| | Total | 5.31 | 1.83 | 110 |

The study's findings showed that there was no significant effect of the communication system ($F = 0.40$, $p > .05$) on the students' FOW states, indicating that the AR technology did not enhance their FOW states during the learning activities. However, a significant effect was confirmed with the video game system ($F = 25.21$, $p < .002$, $\eta^2 = 0.236$) [15], indicating that the pupils' FOW states were significantly higher for those who learned using the game-based instructional look at (mean = 5.46; SD = 0.71) than for the non-gaming approach (mean = 3.93; SD = 0.84). In other words, the use of games in context-aware mobile learning can help students improve their emotional states by providing them with reflection cues.

5 CONCLUSIONS

The involvement and desire of undergraduate students enrolled in an intermediate seminar course were evaluated through the use of game-based examinations, specifically based on the Vortex sorting game. The results show how well digital games may stimulate students and maintain their interest in the subject matter when they are taught engineering technology. Students gave the game-based activities positive ratings, according to an analysis of anonymous feedback surveys. The gamified Vortex exercises had a more favorable effect on student motivation and engagement, even if the difference was not statistically significant. The implementation of a scoreboard as a gaming component, however, was found to have both beneficial and negative impacts, encouraging some students while discouraging others.

The positive feedback that students have given to GBL initiatives implies that including games in general engineering undergraduate lectures can be a fun and interesting experience. Gender disparities in how students view game-based activities were also noted. Female students, for example, showed somewhat higher levels of enthusiasm and engagement than their male counterparts, but they did not express a preference for comparing themselves to other students. To summarize, the design of game-based activities and their teaching methods requires careful thought and backing from academic institutions. Particular attention should be given to developing games that suit the learning needs and preferences of male students specifically, offer suitable opposition levels, concise directions, pertinent content, and important comments.

The present study investigated how students' context-aware mobile learning with reflection prompts in multimedia learning was affected by AR and digital games. Teachers and researchers who intend to provide students with effective support in a context-aware mobile learning environment may find this developed method useful. The findings might also serve as a useful guide for future multimedia learning studies. It is advised that larger groups be recruited for future studies to collect more data, as the treatment and control groups' sample sizes were insufficient. The swift advancement of media technology necessitates exploring methods to leverage cutting-edge media for students' education, enabling them to thrive in multimodal learning settings. An additional matter that warrants additional research is examining the impact of cognitive burden theory on multimodal concepts in advanced technologies.

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