Using mobile augmented reality games in education

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***Abstract* — Incorporating mobile augmented reality games into formal education has the potential to enhance student engagement and motivation, as well as to promote learning outcomes in a more interactive and enjoyable manner. However, this requires careful consideration of pedagogical principles to ensure that those mobile games align with educational objectives and standards. The proposed methodological approach aims to provide a framework for teachers and educators to effectively incorporate mobile augmented reality games into their teaching while also providing a means of evaluating the effectiveness of the approach in enhancing student learning outcomes and developing their skills and competences.**

Keywords— mobile augmented reality games, situated learning, outdoor learning, microlearning, spaced repetition

I. Introduction

Educational games have become increasingly popular as supplementary resources for classroom learning, with many games specifically designed to teach academic content such as math, science, or language and arts. Game-based learning increase students' motivation and engagement, promoting a student-centered learning environment. These games can help reinforce classroom learning and provide differentiated instruction for students who need additional support [1].

By incorporating mobile games into the classroom, teachers can provide students with a fun and enjoyable learning experience that can increase their motivation and enthusiasm for learning [2]. Mobile games can also provide immediate feedback to students, allowing them to improve their learning. Additionally, mobile games can be accessed from anywhere, making them a convenient tool for distance learning and independent study.

The COVID-19 pandemic has disrupted traditional classroom structures, leading to potential socialization challenges for students who have missed up to two years of in-person attendance at primary and secondary schools. These students' learning outcomes and competence levels may be similar to prior students, but their socialization may have suffered. Therefore, establishing new structures to create a friendly and harmonious class environment is crucial for optimal learning opportunities [3].

The alternate cooperative and individual learning approach has been shown to be beneficial for students. Cooperative learning encourages collaboration and promotes social skills, such as communication and conflict resolution. It also allows students to learn from one another and benefit from each other's strengths. On the other hand, individual learning promotes independent and self-directed learning, personalized instruction, and development of students' critical thinking skills. By alternating between these two approaches, teachers can provide a well-rounded learning experience [4].

While the traditional school day generally takes place indoor in a classroom, some researchers suggest that outdoor schooling can facilitate socialization among students and support the learning environment [5]-[8]. This approach may also provide opportunities for peer learning and conflict resolution.

Different mobile and location-based technologies provide opportunities to embed learning in authentic environments and thereby enhance engagement and learning outside traditional formal educational settings [9]. Moreover, this kind of experience can successfully support cooperative and individual learning.

The main objective of this paper is to present the pedagogical foundations for incorporating mobile augmented reality (AR) games into formal education, specifically in primary schools. In addition, this paper proposes a methodological approach for introducing a mobile learning environment in the education process and outlines how the effects of such an environment on education can be evaluated.

The paper is organized as follows: Section 2 discusses the theoretical foundations behind using mobile AR games in formal education. Section 3 proposes a methodology for introducing a mobile learning environment into the education process, while Section 4 elaborates on how the effects of such environment on educational process can be evaluated. Finally, Section 5 concludes the paper.

II. Theoretical Foundation

A. Outdoor learning

The research conducted on outdoor learning is primarily based on socio-cultural learning theory and focused on pupils [10]. Creating Communities of Practice involves having a common task, common tools, and mutual engagement to establish ownership of group work and facilitate social learning and identity formation [11]. In the case of incorporating mobile games into formal education, the common task can be to solve quizzes using their phones, and the pupils will have to work together to achieve it. Cooperation between pupils has been found to positively impact their learning process and social development, but may also result in differences and arguments that can teach them conflict resolution and finding solutions that work for the group [6],[8].

Outdoor learning has been shown to help students overcome social boundaries and conflicts, contribute to the development of adaptation and flexibility, and provide a different setting for getting to know each other [6]-[7]. Prioritizing the group's performance over individual achievement can strengthen social aspects, and teachers can facilitate cooperative communities among pupils to help each other socially and academically [8].

B. Augmented Reality for Situated Learning

Situated learning is a form of learning in a community of practice where students are fully participating in generating meaning. The focus during learning process is put on the relationship between the individuals and the environment [12]. Augmented reality (AR) can further enhance this experience by allowing learners to control their learning and actively interact with virtual objects placed in the real world, supporting the constructivist theory of education [13].

Using AR in education is revolutionizing the way we teach and learn, making unique learning experiences that are both entertaining and rewarding [14]. AR in education has implications for learning practices, as virtual learning spaces can be created where students can explore and collaborate with others, leading to inquiry-based learning [13]. In addition, situated learning, when presented using AR in a contextually relevant environment, can increase the relevance of new information for students, enabling them to see how new knowledge can impact their environment [15].

C. Microlearning

Microlearning is a learning approach that involves breaking down complex topics into small, bite-sized pieces of easily digestible information [16]. These bite-sized pieces of information can be presented in various forms, including quizzes [17], infographics [18], or interactive tasks. Microlearning is an instructional unit that provides a short engagement in the activity [19] and this content is usually created on demand to provoke some outcome from the participants.

Microlearning is used to support the new generation of learners, that are reaching to a lot of information, but are challenging to remain focused for a long time. It aims to help learners absorb information quickly and efficiently and retain it for longer periods. In addition, because microlearning modules are short and focused, learners can engage with them more frequently, making it easier to remember the information.

D. Spaced repetition

Spaced repetition is a learning technique [20] that involves reviewing information at increasing intervals over time. Spaced repetition aims to help learners retain information for longer periods of time by spacing out the time between reviews to help the information stick in their long-term memory. Learners review material at increasing intervals optimized to their specific learning needs in spaced repetition. The intervals maximize learning efficiency and minimize the time needed to review the material.

Spaced repetition is particularly effective for learning complex topics, as it allows learners to review material optimally for long-term retention. By spacing out the reviews, learners are forced to recall the information from their memory, which helps to reinforce the neural pathways associated with the information, leading to better retention over time.

E. Combination of approaches

Mobile AR games allow embedding learning in an outdoor environment, while guiding and facilitating participatory and metacognitive learning processes [21]. Thus, the use of mobile games may be an excellent way to combine situated and active learning, providing endless opportunities for designing engaging learning experiences.

Microlearning and spaced repetition can be incorporated into mobile AR games as effective learning methodologies. They can help learners to acquire new information and retain it for longer periods.

Microlearning can be used to provide more dynamic interaction with mobile games, which can increase students' effectiveness during learning. Short activities in form of interactive games can provide students' active participation and engagement during learning.

Spaced repetition can be used to help learners retain information for longer periods. For example, a game could use a levelling system where players must repeatedly play and master certain levels before advancing to new levels. By spacing out the reviews of these levels over time, players are forced to recall the information from their memory, reinforcing the neural pathways associated with it and leading to better long-term retention. Additionally, games could use adaptive learning algorithms to customize the gameplay experience for each player. These algorithms could track the player's progress and adjust the game difficulty accordingly, presenting new challenges optimized for the player's specific learning needs.

Because very often mobile AR game is connected to specific locations and settings, teachers cannot rely on professional game designers, but are expected to design this kind of engaging learning experiences by themselves. Additionally, teachers can design the most appropriate materials because they know their learners, educational context of the game and are aware of the opportunities offered by chosen locations to design meaningful situated activities [22]. However, all these create challenges for the teachers since they lack the expertise and time to design and construct them.

III. PROPOSED METHODOLOGY FOR THE INTRODUCTION OF A MOBILE AR GAME LEARNING ENVIRONMENT

Use of digital games can create new ways of learning in the classrooms. For example, they provide interactive experiences that can increase students' engagement, interest and motivation for learning. In addition, games offer students opportunities to develop problem-solving, decision making and strategic planning skills [23].

The use of mobile games in education can combine situated and active learning with fun. Teachers can use mobile games to gamify their learning activities, making them more engaging and interactive for students. For example, a quiz game can be used to review content from a previous lesson, or a treasure hunt game can help students explore a new topic.

A treasure hunt game is a type of game where players are challenged to search for hidden objects or clues within a virtual or real environment present on a digital map in order to solve a mystery or puzzle and ultimately find a treasure.

These games typically involve exploration, problem-solving, and attention to detail. In a treasure hunt game, players may be given a list of items to find or a series of puzzles to solve to progress through the game. As they explore the game world, they may encounter obstacles and challenges that they must overcome to reach their goal.

Incorporating educational elements in treasure hunt game enables creating a game-based learning environment that is interesting and educational at the same time.

In our approach, the game designer strategically places digital posts on a designated map area and assigns quizzes to each post, which can be labelled with different labels chosen by the game designer (Figure 1). Questions in the quizzes correspond to the educational outcomes that are planned to be achieved.

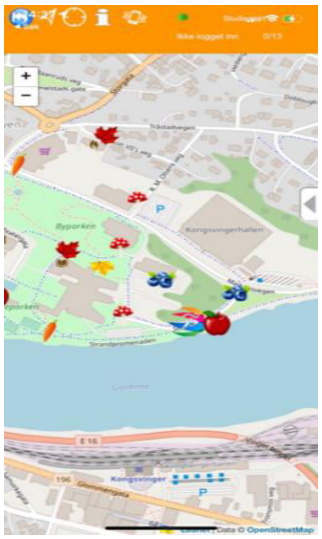

Fig 1. The placement of microlearning tasks on a digital map

Students play the game by moving through the map, following the instructions given by a teacher. Their mobile device can detect these geolocated posts when they come within a predefined distance (e.g., 20 meters) of the point, causing the device to vibrate and alert the gamer. Once a post is detected, the quiz appears based on microlearning and spaced repetition. Students answer the questions and move forward to the next location.

The quiz answers are collected in the teachers dashboard, allowing personalized feedback and progress tracking for individual pupils or groups. The quiz answers can be further analyzed to identify the most challenging topics for the students, which can lead to the adaptation of the teaching material.

IV. Proposed Evaluation of the Approach

Evaluation of game-based approach in educational context is a complex process that should involve identification of different parameters that can determine qualitative integration of games in education [24]. Those parameters mainly refer to students' attitudes, opinions and interactions during the game, as well as educational value of the game. Teachers' opinion after the implementation of game-based approach, regarding educational and entertainment elements, is also very important in measuring the effectiveness of game-based approach in learning.

The primary objective of evaluating the game should be to investigate how pupils perceive the mobile AR game regarding cooperation, competition, and social relations within groups.

Drawing upon the theory mentioned above, we propose the formation of groups by the teacher to promote social interaction amongst pupils while playing the game, thereby fostering peer learning [25]. Furthermore, team interaction may encourage competitiveness, leading to greater engagement and active learning.

Conducting the game outdoors may provide a suitable setting for fostering different social constellations to emerge, as evidenced in projects involving outdoor learning activities that report positive outcomes such as collaborative learning and mutual support amongst pupils [8]. Students' ability to handle conflicts that may arise within groups during gameplay, such as resolving differences in quiz answers, can also be improved.

To assess the game's efficacy in facilitating learning, students should be divided into two groups: one group will take a standard test on a particular subject in an indoor classroom environment (control group), while the other group will use the mobile AR game to take the test. Afterward, comparison of students' results on the tests should be done to evaluate whether the game-based approach has contributed to the achievement of learning outcomes.

Furthermore, students' subjective opinion in terms of engagement and motivation is an important factor for evaluating their interest in game-based microlearning. Focus interviews with students should be conducted to explore their perceptions of the game in relation to cooperation, competition, and social relations within groups.

Focus interviews with teachers should be made to obtain information about the effectiveness of the approach in terms of its usefulness for the development of students' competences and skills and the achievement of the educational outcomes by implementing this approach.

Analyzing the obtained results from the implementation of microlearning activities can lead to various conclusions regarding approach effectiveness based on the complex interconnections of all the parameters.

In addition, by utilizing the dashboard of the game, valuable insights can be obtained regarding learners' difficulties in comprehending certain concepts, the time required to grasp them, and the differences across age groups and schools. This information can be used to design targeted training programs for specific topics, thus enhancing the overall effectiveness of the educational system. This kind of information is difficult to gather in a traditional classroom environment.

V. Conclusion

The primary goal of this paper is to put forth the pedagogical principles that can be utilized to integrate mobile AR games into formal education, with a specific focus on primary schools. The document suggests a systematic approach to implementing a mobile learning atmosphere in the educational curriculum and explains how the impact of such an approach on education can be assessed.

By effectively integrating mobile AR games into formal education using the proposed methodological approach, the teachers can facilitate the development of 21st-century skills such as critical thinking, problem-solving, collaboration, and digital literacy. Mobile AR games often require players to use these skills to succeed, and incorporating such games into formal education can provide students with opportunities to develop and apply these skills in a learning context.

Evaluating the effectiveness of the approach can help identify improvement areas and refine the use of mobile AR games in formal education. This can contribute to the ongoing development of educational practices and the enhancement of student learning outcomes.

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