The use of game-based learning in teaching STEM subjects

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Abstract- This paper examines the use of Game-based learning in teaching STEM(science, technology, engineering, and mathematics) subjects. The main purpose of this research work is to identify the possible impacts of game-based learning on improving student engagement, motivation, and achievement in STEM subjects. The research results contribute to the well-understanding of the effectiveness of Game-based studies in STEM subjects and provide the potential benefits and challenges of this approach.

Index Terms-video games, education, courses, STEM, motivation of students

I. Introduction

Game-based learning is gaining popularity as a pedagogical strategy for STEM education. It has been found to increase learners' motivation, critical thinking skills, and problem-solving abilities. This approach involves using interactive digital games, simulations, and other technologies to immerse students in the learning process. This review article aims to provide a comprehensive overview of game-based learning in STEM education, including theoretical underpinnings, empirical evidence on effectiveness, best practices for development and implementation, and potential future areas for research and development.

The paper first discusses the cognitive, motivational, and social aspects of game-based learning. Then, it reviews empirical evidence on the effectiveness of this approach, highlighting a 2012 review that found positive effects on learning languages, history, and physical education, but little support for learning science and math. Best practices for developing and implementing game-based learning activities in STEM education are also emphasized, such as matching games with learning objectives, offering feedback and assessment, and encouraging collaboration among students.[1]

The final section of the paper considers potential future areas for research and development, including the need for more thorough investigations and the potential to combine game-based learning with other cutting-edge technologies like artificial intelligence and virtual reality. Overall, this survey paper aims to provide a current and thorough understanding of game-based learning in STEM education and to highlight potential areas for further exploration and development.

II. Background

To understand the necessity of using video games in education, it is important to analyze past experiences and assess the already identified advantages and disadvantages of video games.

A. Benefits of video games in Education

One of the primary benefits of implementing video games in education is the opportunity to engage students and stimulate the learning process, which can lead to faster and more effective learning. Students typically find an entertaining option much more appealing and successful in maintaining their interest in the material, compared to a more traditional educational environment. According to an anonymous writer, integrating entertaining features in the educational process can help students be more invested in their learning. For instance, the video game "Minecraft: Education Edition" was used to teach history, which resulted in increased student motivation and faster learning.[6]

By incorporating video games in education, educators can provide an interactive and enjoyable learning experience that encourages student engagement and participation. Video games can also provide a way to present complex information in a simplified and accessible way, making it easier for students to understand and retain information. The use of video games in education can thus be a powerful tool in promoting student learning and success.

B. Drawbacks of video games in Education

In contrast to the previously mentioned views, Matthew presented a different perspective in his paper. He argued that using video games solely to engage students in educational contexts would have an adverse effect on their motivation. According to him, video games can be effective only in teaching materials that have already been covered and not in teaching new information altogether.[7]

Thus, both authors' papers provide information about the positive and possible negative sides of using video games in education, but they are based on general experiences of teaching social or natural courses such as history and biology. The main purpose of this study is to determine the best implementation of video games to teach STEM subjects.

III. Main Body

Video games have the potential to be utilized in various aspects of education, including teaching lessons, research purposes, and laboratory/practice exercises. The following provides a clear explanation for each implementation.

A. Teaching Lessons

The potential impact of video games in various fields of study and educational activities is a topic that merits discussion. For instance, the use of video games to teach university courses and for research purposes should be explored. Professor Nagataki from Japan conducted an experimental course titled "Introduction of Video Games in Computer Science" at the University of Okayama and shared insightful information on students' involvement in the course design.

Based on the data gathered from a 2013 survey, which was filled out by 88 non-Computer Science major students who took the course and evaluated it, 67 students expressed interest in the video games. These students indicated that despite Computer Science being a challenging subject to learn, they were motivated to complete the course because of their interest in the use of video games as a teaching tool, which had not been previously utilized in the university. Nagataki's findings suggested that video games could be used to teach non-major courses to students of other majors.[4]

Another study focused on the teaching of Computer Science courses and was carried out by a team led by Mario. The team developed a two-level game to teach Security. The first level aimed to teach the basics of coding for security and prototype creation, while the second level involved a real-life scenario where the student was attacked and forced to defend by implementing different codes. The student was awarded points for successful protection of the system, and by saving these points for a prolonged period, they could earn rewards. According to the team, this method was effective as the students were able to practice in real-life examples and get rewards for excellent performance. Such techniques can facilitate the rapid and efficient acquisition of knowledge by students and help them implement it in real-world scenarios. [2]

B. Laboratory Practices

Video game tools can also be used in laboratory practices to ensure safety and improve efficiency for students. Video games are effective in simulating various processes through computer algorithms [9]. For instance, research conducted by Stinchcombe on students at the University of Ottawa demonstrated that driving simulators increased students' cognitive and perceptive skills and improved their attitudes towards car traffic and accidents [8]. This highlights how simulators related to different STEM courses can improve students' skills and provide a safe learning model. Teachers can create video games that simulate different physical, chemical, or biological processes, allowing students to learn about phenomena without damaging equipment, obtaining unclear information, or risking random errors. By upgrading classes with the latest technologies, schools and teachers can provide highly safe laboratory work for students while also freeing up space for other facilities. For example, a school with VR-equipped classes can share those classes with different STEM courses, creating enough space for students. Working in these classes is safe, as there are no dangerous reagents in chemistry, and it saves time to observe the plant's differences over time or to observe and understand the process of star creation and explosion without any damage or time waste.

C. Research Purposes

Video games can serve as a valuable tool for research purposes, including investigations into topics such as human error, addiction, and user experience [3]. However, there is no common ground for the methods used by different researchers in implementing video games for their studies. A group of scientists identified the main purposes and facets of using video games in research in 2022 [9]. Their research revealed that video games can be employed as a psycho-physiological stimulus, intervention mechanism, incentive for task completion, and modeling platform to facilitate understanding. With these benefits, researchers can more easily explore and investigate various phenomena, as simple computer games

can highlight different aspects of both problems and solutions.

IV. Discussions

As mentioned previously, there are various methods of implementing video games in STEM education, including using them to teach lessons, conduct laboratory work, and for research purposes. The examples provided indicate that video games can offer numerous benefits to educational institutions. However, it is important to note that there are also drawbacks associated with the use of video games in education.

As Heins pointed out, there can be issues with equipped classes and video games. For instance, there may be conflicts between different teachers over the use of equipped classes for a particular day, which can limit the amount of new material that students can be taught [5]. Before widely implementing the use of video games in education, all of these limitations should be thoroughly discussed.

By analyzing all aspects of video games in STEM education, it becomes clear that they can be a powerful, efficient, and easy-to-use tool. However, it is important to fully understand both the benefits and limitations of video games in order to make informed decisions about their implementation in educational settings.

V. Ethical Considerations

Despite the numerous benefits and drawbacks of implementing video games in STEM education, it is crucial to address certain ethical aspects. Firstly, the use of video games in STEM education raises concerns about screen time and addiction. Educators must ensure that students are not spending excessive amounts of time playing video games and that they are using them in moderation. Additionally, video games can be costly, and not all students have access to the requisite technology or resources to use them effectively. Therefore, educators need to ensure that they are not inadvertently creating a digital divide by relying solely on video games as a primary teaching tool. [10]

VI. Conclusion

Video games are a powerful tool with enormous potential for teaching STEM subjects. Examples discussed in the background are essential for demonstrating the importance of video games. They can be used for teaching lessons, laboratory work, and research papers. However, despite their valuable benefits, video games can also raise ethical issues regarding the attitudes and motivation of teachers and students.

The paper's limitation was the lack of updated information and recent examples, as well as the inability to implement different methodologies.

Future research should attempt to use video games for educational purposes, such as teaching lessons, laboratory work, and research, and then compare the collected data to analyze their efficiency for each purpose. Additionally, a more detailed explanation of creating games for these specific purposes should be developed.

References

[1] A. Novotney, "Do educational computer and video games lead to real learning gains? Psychologists say more research is needed," American Psychological Association, 2015.

[2] M. Guimaraes, H. Said, and R. Austin, "Using video games to teach security," in Proceedings of the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education (ITiCSE '11), Association for Computing Machinery, New York, NY, USA, 2011, pp. 346.

[3] E. H. Calvillo Gámez, P. Cairns, J. Gow, J. Back, and E. Capstick, "Video games as research instruments," in CHI '10 Extended Abstracts on Human Factors in Computing Systems (CHI EA '10), Association for Computing Machinery, New York, NY, USA, 2010, pp. 4493-4496.

[4] H. Nagataki, "Learning computer science by watching video games," in Proceedings of the 9th Workshop in Primary and Secondary Computing Education (WiPSCE '14), Association for Computing Machinery, New York, NY, USA, 2014, pp. 134-135.

[5] S. Egenfeldt-Nielsen, "Overview of research on the educational use of video games," Digital Kompetanse, vol. 1, 2006.

[6] Pressbooks, "Video games in the world of education (research essay). Chapter 6: 21st-century media and issues," 2021.

[7] M. C. Heins, "Video Games In Education," The College at Brockport: State University of New York Digital Commons @Brockport, 2017.

[8] V. Marín-Díaz, M. Morales-Díaz and E. Reche-Urbano, "Educational Possibilities of Video Games in the Primary Education Stage According to Teachers in Training. A Case Study," Journal of New Approaches in Educational Research, vol. 8, no. 1, pp. 42-49, 2019.

[9] M. A. Gómez-Maureira, M. van Duijn, C. Rieffe and A. Plaat, "Academic Games - Mapping the Use of Video Games in Research Contexts," in Proceedings of the 17th International Conference on the Foundations of Digital Games (FDG '22), Association for Computing Machinery, New York, NY, USA, 2022

[10] G. Tavinor, "Towards an ethics of video gaming," in Proceedings of the 2007 conference on Future Play (Future Play '07), Association for Computing Machinery, New York, NY, USA, 2007, pp. 1-8.