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The Use of Roblox in Elementary School Science Education during Pandemics

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Abstract

During COVID-19 Pandemic lockdown, global education systems rapidly transitioned to internet-based classes to maintain the continuity of learning. This shift, however, highlighted significant challenges within elementary science education. A great disparity exists between the expected "hands-on experiments", "critical thinking" in science education and the reality of online elementary science education. The unique capabilities of natural sciences to leverage serious games, utilizing quantitative and predictive models for creating engaging microworlds and simulations, present a viable solution. These games enhance interactivity and engagement, fostering a deeper understanding of scientific concepts through the "learning by doing" approach. Given the great popularity among gen z students, VR-Supported immerse Learning environment, the flexibility for user creation, and the social interactive and collaborative learning experiences, Implementing Roblox for elementary science education emerges as a promising strategy to enrich science learning, despite the existing hurdles such as a shortage of educational games on Roblox, the lack of teacher training in leveraging such digital tools effectively and challenges from cyberbully and cybersecurity.

Keywords

Roblox, Serious Games, Educational Games, Science Education, Elementary Education

1. Introduction

Starting from March 11, 2020, the Covid-19 Pandemic (COVID-19) put the world on lockdown. A pandemic is "an epidemic occurring worldwide, or over a

very wide area, crossing international boundaries, and usually affecting a large number of people". According to UNESCO, by the end of April 2020, 186 countries have implemented nationwide closures, affecting about 73.3% of the total enrolled learners (Selvaraj et al., 2021). To continue the education process, educational institutions needed to undergo a paradigm shift, adopting internet-based delivery of lectures through synchronous (live) and/or asynchronous (recorded) sessions (De, 2020). Online classes can offer numerous benefits for education, including flexibility, accessibility, and the ability to incorporate digital resources. However, there are also certain limitations when it comes to elementary science education in an online setting. Elementary school science covers a wide range of topics to help students build a foundational understanding of the natural world, such as life science, earth science, physical science etc. A research conducted by Professor Martin-Hansen from California State University emphasizes the importance of science identity, which is shaped by experiences within educational settings and social interactions. The research suggests that early, positive science education experiences are crucial for fostering a strong science identity, which in turn influences students' future academic paths and their ability to engage with complex scientific issues (Martin-Hansen, 2018). Per National Science Teachers Association (NSTA), the emphasis of science education is often on hands-on experiments, critical-thinking, and deeper understanding of scientific concepts. However, there is a great disparity between the expected "hands-on experiments", "critical thinking" and the reality of elementary science education (King et al., 2001). During the pandemic, the current online class setting (applications such as Zoomand Team meetings), further increases this disparity by limiting the hands-on experiments, observational opportunities, and social interaction. Thus, it's important to improve the science education of elementary school students especially during times of social isolation such as a Pandemic. The aim of this paper is to explore the feasibility of incorporating Roblox games into elementary science education that can bridge the gap between the anticipated hands-on experiments, critical thinking skills and the current reality of elementary science education during pandemics.

2. "Learning by Doing" Theory in Elementary Science Education

2.1. "Learning by Doing" Theory

The "Taking Science to School" report (Duschl et al., 2007) points out that K-8 students can acquire a more profound understanding of science by engaging in activities similar to those undertaken by professionals in scientific fields. This report presents four critical strands integral to achieving science proficiency among K-8 learners: (1) the grasp of scientific explanations, (2) the ability to generate scientific evidence, (3) the capacity for reflection on scientific knowledge, and (4) productive participation in scientific processes. These strands are presented as interrelated and of equal importance for fostering comprehensive

science education for all students.

Famous American philosopher and educational crusader John Dewey developed the "learning by doing" theory (Sikandar, 2015). He believed that individuals grow and learn as they interact with the world. Through encounters with their surroundings, individuals discover new ideas, concepts, and practices that allow them to form their own understandings, which they gradually reinforce through their learning and social experiences (Garrison, 1999).

2.2. "Learning by Doing" via Serious Game in Science Education

Natural sciences could have a special relation to serious games by their systematic use of quantitative and predictive models that can generate microworlds and simulations (Riopel et al., 2019). Through these simulated environments, learners can experiment, observe outcomes, and understand the underlying principles governing natural phenomena, all within the safe confines of a game. This approach not only makes learning more interactive and engaging but also deepens the understanding of scientific concepts by effectively utilizing "learning by doing theory". A recent study with 496 participants demonstrated significant relations between overall play time in video games and major cognitive functions including mental flexibility, planning, visual working memory, visuospatial processing, fluid intelligence, and verbal working memory (Martinez et al., 2023). The gamification can positively impact learning results by increasing engagement in online programs and enhance related outcomes. This review also provided preliminary evidence that leader boards are a particularly effective form of gamification. This is consistent with research indicating that social comparison promotes motivation through competition amongst peers (Looyestyn et al., 2017).

2.3. Limitations of Serious Game in Current Science Education

Despite its potential, the gameful approach is underrepresented as media in science education. Most gameful solutions for science education are developed as closed, standalone solutions (e.g., computer, browser, or mobile games) (Kara, 2021). One disadvantage with standalone games is the need to be introduced to the community of players instead of building upon games and game platforms with an existing player base. The AR and VR games with immersive technologies integrated games in science education are still underrepresented (Kara, 2021). A systematic review of 61 empirical studies by a research team from Hunan University of Science & Technology indicates that the integration of Virtual Reality (VR) and Augmented Reality (AR) in K-12 science education is still in a beginning stage with certain challenges and underrepresentation in deeper educational contexts, such as lacking deep integration with science content, limitation on developing higher-order cognitive skills etc. Additionally, there was a tendency to utilize lower-end technologies, indicating a need for more accessible yet sophisticated VR/AR solutions (Zhang & Wang, 2021).

3. The Use of Roblox in Elementary Science Education

3.1. The Main Benefits of Roblox Used in Elementary Science Education

Roblox, a sustainable and shared 3D virtual space in the virtual universe (Wang et al., 2022), attracts millions of young users, which gain a great potential as gameful solution for science education. According to 2021 statistics, Roblox had 150 million monthly active users and 40 million daily users. The majority of users of the Metaverse are children and primary and secondary school students, and it is extremely popular among children who are 5 - 16 years old. Users under 13 years old account for 54.86% of the total number of Roblox users (Han et al., 2023). In the United States, more than 55% of Generation Z (Gen Z: born in 1997-2012) children registered with Roblox, and they spend 2.6 hours on average using Roblox every day (Lee, 2021). It's evident see that many student users have a positive attitude toward Roblox. For example, Citlali & Estrella surveyed 300 students, most of whom noted that they were willing to accept the content and thought it was very innovative (Citlali & Estrella, 2022). Roblox's widespread popularity has made it a prominent gaming platform among elementary school-aged children, and the shared knowledge within its vast community makes it easier for newcomers to navigate in Roblox, offering unique opportunities for educators to leverage its potential in creating gameful learning experiences.

Second, Roblox is a VR Environment-Supported Learning, which allows users to immerse themselves into virtual scenes to observe the subjects in science education, providing a great "learning by doing" experience by interacting with the virtual world. For example, to explore the use of the metaverse platform Roblox for science education, researchers developed an Inflammation 3D Roblox game, which communicates insights about the autoimmune diseases and cures. In this game, the inflammation is visualized as fire that spreads throughout the patient's body. Players, inside the patient body, must keep the inflammation and the piles of dead cells under control and try to keep the patient alive by using different weapons that represent other immune cells and medication. In the survey conducted after playing the game, many participants highlighted that the immersive experience of teleporting themselves into the body of the patient helped them better understand the complex topic (Greiner et al., 2023). This makes learning more engaging for students, allowing them to explore concepts in a virtual environment that might be impractical or impossible in the real world, such as a virtual field trip to a solar system, space exploration, an immersive visit inside human body to learn functions and interactions of major body systems, a travel of a recycling life to understand the environmental conservation, etc.

Third, Roblox allows users to create and shape the environment. Roblox provides a programmable environment, where users can build games and interactive worlds in Roblox according to their own needs (Han et al., 2023). Moreover, Roblox Studio is a simple and intuitive program in which no previous pro-

gramming skills are required (Meier et al., 2020). During the 2018/2019 academic year, Dr. Cecile Meier from University of La Laguna carried out a pilot experience with 53 secondary school students. The students were given the task of designing a virtual environment in Roblox in which they had to include 3D models of the sculptural heritage of the city of Santa Cruz de Tenerife. The students created video games that allow navigation in interactive three-dimensional worlds. After the experiences, the students emphasized that they were more aware of the sculptural heritage of Santa Cruz through interactive worlds with Roblox (Meier et al., 2020). Taking Science to School report (Duschl et al., 2007) recommended the science education community to integrate science problem-solving activities into the elementary education curriculum. This recommendation challenges the notion that young learners are incapable of navigating complex cognitive tasks, suggesting such an assumption lacks foundation. By designing mini games, students engage in creative thinking and problem-solving. Educators can also create custom games tailored to their curriculum, making a great supplement to current online science classes.

Fourth, Roblox supports social Interactive Learning and collaborative Learning. One disadvantage with the existing online learning environment, such as Zoom, or Microsoft Team meetings, is the lack of feeling present with others or feeling "disconnected and isolated" (Wang et al., 2020). Since Roblox supports text and voice communication, it is convenient for learners to collaborate. The gaming and task settings in Roblox emphasize challenges and cooperations, so learners can compete and/or cooperate to successfully complete a task (Han et al., 2021). By enhancing interaction among students and teachers, Roblox can effectively reduce "disconnected and isolated" feelings in current online science classes.

Despite the novelty of Roblox as an educational resource, educators have been exploring the development of educational games within the platform. For example, Boston Museum of Science developed the immersive 3D Roblox game "Mission: Mars" (**Figure 1**). The game enables individuals to step into a Mars survival suit, navigate terrain in a hi-tech Mars Rover, help their team in specific level-based missions to discover past evidence of water, collect samples of water ice,

Figure 1. Roblox game in science education (Cited from "Mission Mars").

and rescue fellow explorers from certain doom experience. The game focuses on engaging students of all ages in the engineering design process, providing a high-quality, entertaining digital experience for both formal and informal learning. The game is also aligned with Next Generation Science Standards, providing a connection with science curriculum settings (Museum of Science, Boston).

3.2. Primary Challenges of Roblox Learnings Setting

Despite all the benefits, there are challenges in implementing Roblox games in science education to the national scale. First is the lack of effective teaching design and guidance in Roblox (Han et al., 2021). Although Roblox allows users to create their own games, developing complex games able to teach scientific content effectively while maintaining a balance between curriculum focus and the appeal and fun of the game is a complex and cost-intensive undertaking. For designers, games for children are challenging. Game designers need to understand the developmental milestones that cover the cognitive, physical, and emotional development of children (Fisher, 2014). A research team from North Carolina State University has designed a game-based learning environment for upper elementary science education: CRYSTAL ISLAND: UNCHARTED DISCOVERY. The project has brought together researchers from computer science, curriculum and instruction, science education, and educational psychology to build and systematically study the cognitive impact of 3D story worlds. To balance curricular focus and the appeal and fun of the game, three theories provide the foundation for the development of the game: narrative-centered learning, problem-solving theory, and engagement theory. Over the four years of development, they discovered that one of the most promising approaches to creating such complex systems is adopting an iterative approach in which designs are created, implemented, and refined in an ongoing cycle of rapid development and extensive testing. The team's findings support the notion that game-based learning environments not only increase student engagement, but also positively impact content knowledge on science topics and problem-solving skills (Lester et al., 2014). However, this iterative process, while beneficial, can be both time-consuming and financially demanding.

Second, oftentimes the teachers' unfamiliarity with technological experiences reduced their willingness to use VR applications (Ertmer et al., 2012). Teachers are responsible for the facilitation of instructional games, the perspectives of teachers are critical to the effectiveness of the learning experience. For example, to assess teachers' perceptions regarding game-based teaching and its potential to promote active learning, a survey was given to geology teachers (n = 112) from public and private middle and secondary schools in Portugal. Though most teachers recognize digital games' potential to motivate, enhance, and reinforce the learning of geological content, they do not always use games to promote learning in geology. Teachers emphasize the importance of teacher training in this area and the inclusion of game applications in school textbooks to approach

different geology-related themes (Teixeira & Vasconcelos, 2024). Through experienced community and professional learning and working, teachers are shown to have positive implications of their relationships with classroom applications (Stevenson et al., 2019).

Third, the integration of Roblox into education faces the challenge of cyberbullying. As students spend more time engaged in online learning and activities, they become increasingly vulnerable to encountering instances of cyberbullying. Common forms of cyberbullying experienced by students include curses, insults, and humiliation (Chen, 2018). In a study conducted by Xavier University, 436 participants from first to fifth grade were surveyed about their encounters with cyberbullying and bystander behavior. A notable 62.6% reported witnessing cyberbullying incidents, often occurring during videogame play or while using video-sharing platforms, including Roblox. Moreover, a significant portion of participants reported engaging in active bystander behavior when observing cyberbullying. These findings underscore the early onset of cyberbullying, with rates escalating across elementary school grade levels (Lewis, 2021).

Lastly, Cybersecurity is also a challenge to implement Roblox in elementary science education. Roblox is extremely popular among children who are 5 - 16 years old (Han et al., 2023), while there is a lack of K-5 cybersecurity education, which makes the young users vulnerable to the growing number of cyberattacks (Tyner & Rajabion, 2022). For example, Roblox has an in-game virtual currency (Robux), where businesses can sell virtual goods to users. A lack of cybersecurity may lead to serious financial loss. To reduce the Cybersecurity risk, cybersecurity should be integrated into K-12 STEM education (Dutta & Mathur, 2012). Various curricular designs (Chase et al., 2020) and teaching strategies (Chen et al., 2021) have been proposed to effectively incorporate cybersecurity into K-12 education. This integration ensures that students are prepared to understand, identify, and mitigate cybersecurity threats in Roblox.

These challenges create a gap to scale up the implementation of Roblox in science education nationally. Addressing these challenges in research and learning related to Roblox will require interdisciplinary collaboration among researchers, educators, game developers, policymakers, and other stakeholders.

4. Conclusion

The COVID-19 pandemic has not been the only pandemic throughout history as noted by David Morens, the Senior Advisor to the Director at the National Institute of Allergy and Infectious Diseases, pandemics have challenged human existence throughout human history, and they are now becoming more common as the world population increases (Morens et al., 2020). Thus, it can be implied that through the coming years, pandemics will stay in occurrence and interrupt school education.

In contemporary elementary science education, there exists a noticeable discrepancy between the anticipated hands-on experiments and critical thinking

integral to science learning, and the actual experiences provided to students. The online class setting further expands this gap. The natural sciences have a unique potential to employ serious games that use quantitative and predictive models to create captivating microworlds and simulations. These games promote interactivity and engagement, thereby deepening understanding of scientific principles through "learning by doing" theory. With its massive appeal among the Z-generation, VR-supported immersive learning environments, user-generated content flexibility, and opportunities for social interaction and collaborative learning, Roblox stands out as a promising avenue for enhancing elementary science education.

However, learning in Roblox is a relatively new research area, relevant academic research is limited. The main objective of this paper is to explore the potential of incorporating the Roblox games into elementary science education. Based on the findings, several proposals can be offered to researchers and educators in this field. First, Comprehensive examination of Roblox educational game guidance and instructional designs in science education should be conducted more in research studies, aiming to integrate the games into established curriculum frameworks, thereby enhancing the relevance and effectiveness of the use of Roblox games. Second, more qualitative studies should be conducted to understand the experiences related to the use of Roblox games in science education, such as attitude, interaction between students and teachers and social connections. Social connections, including the social bonds formed and the collaborative learning experiences facilitated by Roblox games, are especially important during pandemics. Third, teachers should be integrated more into the research studies related with the use of Roblox games in science education. By collaborating closely with teachers throughout the research process, from conceptualization to implementation and evaluation, researchers can leverage their expertise and firsthand experiences to inform the design, refinement, and adaptation of Roblox games to meet the diverse needs and contexts of classroom settings. Fourth, Roblox games integrating new immersive technologies, such as VR and AR technologies should also be investigated in science education. By integrating VR and AR technologies into Roblox games, educators can provide students a "learning by doing" experience with immersive environments where they can actively participate in scientific experiments, manipulate virtual objects, and engage in problem-solving activities. Fifth, as gaming environments evolve, it becomes imperative for educators and parents to pay attention to the escalating issues of cybersecurity and cyberbullying.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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