BOARD # 93: WIP: Investigating the Role of Augmented Reality Science Applications as a Supportive Tool for Facilitating Collaborative Learning in Elementary Classrooms

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Fostering Collaborative Learning in Elementary Classrooms: An Investigation of Augmented Reality Science Applications as a Supportive Tool

Abstract. The goal of this article is to look at the use of Augmented Reality (AR) technology in elementary schools for making students more engaged and to facilitate teamwork among them. It particularly focuses on the progress of the FrogAR_Connect app, an AR software that we developed to teach the life cycle of frogs. The application rethinks the old textbook method by turning the traditional content into an animated one. Students can now interact with 3D AR models, which aids them in the deeper understanding of scientific concepts. FrogAR_Connect is built on the two main pillars of situated learning theory and Vygotsky's socio-cultural theory. A special highlight of our design is that the collaborative practices in FrogAR_Connect are tailored to support elementary students who are at different level of understanding to join the exploration. Given the significance attributed to collaboration in educational literature, our application was intentionally developed to enhance collaboration, with a specific focus on facilitating real-time collaboration among elementary students. Numerous augmented reality tools prioritize individual usage, thus restricting possibilities for collaborative opportunities for group learning. This gap is filled by FrogAR_Connect, the tool that helps students to work together and cooperate on the tasks concerned with the stages of the development of frog's life cycle. Furthermore, the ability to interact with 3D models proved a tangible experience that enhances understanding of complex biological processes.

Keywords: Augmented Reality, Elementary classroom, Interactive Learning, Educational Technology, Speech to Text.

1 Introduction &Background

Educators widely concur that the integration of technology into the learning process is crucial for student success [1]. The adaptability of augmented reality (AR) as a learning resource has been demonstrated to effectively support student success across all educational levels [2] and AR has been rapidly adopted and integrated into many educational settings [3], [4]. AR represents a substantial advancement towards a technology-driven educational setting, primarily due to its adaptable features that distinguish it from other learning resources [5]. The ability to interact with AR instructional technology gives students a new lens to examine information and ideas that otherwise would require more time and technology to achieve. Additionally, AR enables teachers to add a range of resources including URLs, videos, and text [6]. Moreover, the peripherals essential for AR utilization, such as smartphones, are frequently obtainable to learners because of their prevalent usage. Through the integration of augmented reality (AR) in the classroom, educators have the opportunity to support students in cultivating essential skills for the 21st century. Previous research

suggests that there is ample evidence to support the utilization of augmented reality (AR) technology in education. This technology can effectively cultivate interest in diverse subjects and provide learners with a comprehensive learning experience by integrating virtual and real-world outcomes [7].

According to [8], the incorporation of effective interaction and teamwork is crucial for successful learning. The act of collaboration is widely recognized as a potent tool for promoting interaction and teamwork within the classroom. Collaborative learning has been found to enhance higher-order thinking skills, boost motivation, and foster interpersonal relationships [9]. It was highlighted that acquiring knowledge collaboratively is a technique that can enhance the quality of national education. Previous research has indicated that learners can derive benefits from augmented reality learning environments when conducting cooperative and collaborative studies [10]. Likewise, the utilization of collaborative learning by educators in school settings significantly influences the comprehensive growth of students [11].

The achievement of AR and collaborative learning goals necessitates educators to build a learning environment that is advantageous, efficient, and accessible to all students. The incorporation of technology into the curriculum serves the purpose of helping educators improve their teaching abilities, ultimately benefiting all students. In a study conducted by [12], it was found that teachers' perception of the compatibility between new technology and students' learning goals and instructional practices influences its adoption in the classroom.

The objective of incorporating educational technology tools is to enrich the learning experience by enabling student engagement with the material. This pertains to the concept of embodied cognition from a cognitive modelling standpoint. There is a growing body of research and design exploring the creation of learning spaces that effectively foster embodied learning [13]. Ati et al. conducted a study that centers on the utilization of AR technology in the education of young children, incorporating gamification to enhance interactivity and enjoyment in the learning process. Involving both schools and homes allows parents to actively participate and monitor their children's learning progress. The research shows that using AR and gamification improves young children's learning, especially in alphabet writing [14]. Also, Thompson et al. conducted a comprehensive, multi-year study to identify and characterize educational Augmented Reality environments suitable for students of various ages and skill levels. Throughout the research, the students, parents, and teachers actively collaborated to plan, construct, and enhance six AR prototypes. Based on their student’s positive outcomes, these kinds of software can be used in classrooms. [15].

Students need to be active participants in their learning, fully engaged in exploring the various aspects of 21st-century education. Moreover, there is a necessity to enhance the demanded qualifications, which encompass actively engaging with society and adequately preparing students for academic success. The value of collaborative research lies in its capacity to enhance students' social management skills. According to El Kouzi and McArthur, students develop a positive attitude towards learning activities enhanced with augmented reality, exhibiting enthusiasm and liveliness [16]. Augmented reality's primary benefit lies in its capacity to merge digital

elements with the physical world, providing users with an immersive experience that seamlessly integrates virtual sensations into their environment, as opposed to solely displaying information [17]. The study conducted by Iqbal et al. [18] underscored the importance of augmented reality (AR) in facilitating learning in ubiquitous, collaborative, and localized environments. It has been found that the use of AR aids in the reduction of cognitive burden and offers valuable hands-on experiences. The authors highlighted potential avenues for future research, including personalized learning, kinesthetic learning with touchless hand interaction, collaborative learning in remote setups, and the incorporation of machine learning into AR applications[18]. The collective studies emphasize the potential advantages of AR in STEM education, while also recognizing the hurdles and suggesting promising directions for further investigation and advancement of AR's educational capabilities.

In this article, we present FrogAR_Connect, an application that incorporates both situated learning theory and Vygotsky's sociocultural theory to foster captivating and immersive learning experiences. Our research begins with a literature review. We then identify the research gap and the motivation behind our study. Next, we discuss the FrogAR_Connect application. Finally, we conclude by reflecting on the advantages of situated learning theory and Vygotsky's theories.

2 Research Gap and Motivation

In our examination of the literature discussing STEM-based AR applications, we identified a scarcity of collaborative augmented reality applications targeting classroom science textbooks that specifically address the Animals Life Cycle. The first step in our process involved the creation of an application aimed at primary school students, specifically addressing the Frog Life Cycle. In pursuit of this objective, we have created FrogAR_Connect, an interactive AR application designed to enhance students' ability to memorize the lesson. Our application, FrogAR_Connect, fosters a self-directed learning approach by transforming textbook material into an immersive, 3D model that can be explored by uncovering relevant sections of their school textbooks.

The FrogAR_Connect application utilizes augmented reality technology to transform the traditional depiction of frog life cycle stages from a two-dimensional textbook into an immersive three-dimensional model, allowing students to interact with it directly. Through the use of the application, which is operable on both smartphones and tablets, students can enhance their visual comprehension of each stage by adjusting the camera's position in the 3D virtual content. Not only does the application present 3D virtual content, but it also provides students with interactive buttons that allow them to check if they have placed the markers in the correct stage place. FrogAR_Connect adopts a distinctive methodology that fosters student collaboration in the construction of the Frog Life Cycle. Every student engages in active participation by strategically placing markers that symbolize various stages of the life cycle within the augmented reality environment. Through this collaborative interaction, students work together to construct the proper sequence of the Frog Life Cycle, cultivating teamwork and fostering mutual understanding.

We decided to name this application FrogAR_Connect because the term "FrogAR" represents the core functionality of the application, which revolves around the visualization and interactive exploration of the frog life cycle through augmented reality. The combination of "Frog" and "AR" in the name explicitly suggests that the subject matter is the life cycle of frogs and that augmented reality technology is involved. This clear and concise combination instantly conveys the application's focus to users. The inclusion of "Connect" in the name underscores the application's focus on fostering collaborative learning experiences. The idea is to create a shared virtual space where students can connect and collaboratively build their understanding of the frog life cycle. This fosters an environment where peers interact, share knowledge, and collaborate to solve problems, in line with situated learning theory and constructivist learning theory. Through teamwork, students can engage in discussions and validate their choices, resulting in a more profound comprehension of the life cycle and strengthening their learning.

3 The Application

The research application was developed using Unity Editor 2019.3.14f1 and the Vuforia Software Development Kit (SDK) for Android. Unity is a powerful game development engine that can create applications for PC, Android, and iOS. Vuforia is an Augmented Reality SDK that uses computer vision to recognize markers and connect virtual content to real-world objects. In this project, we chose to integrate the Vuforia SDK with Unity to create the application. The application has a notable feature - multiplayer functionality using the Photon Pun2 tool. This feature allows users to join the same server and share data, creating an interactive collaborative experience. To make this possible, the application includes the Photon Pun2 Manager and PhotonView components. These components manage and coordinate game sessions between players. Additionally, a user interface was created to enable seamless interaction among participants as seen in Figure 1.

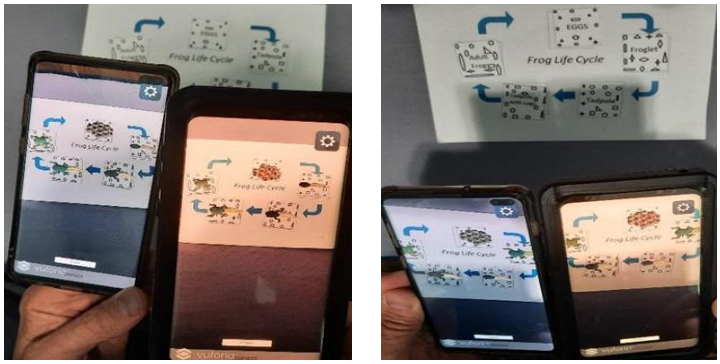

Figure 1. FrogAR_Connect application interface.

Multiplayer functionality improves engagement and fun for users. It promotes collaborative learning and teamwork. With this interactive AR application, students can explore and understand the frog life cycle in an engaging and immersive way. It fosters

a self-driven approach to learning and a deeper understanding of the subject. The application uses cutting-edge technology like Unity and Vuforia. It shows the potential of Augmented Reality in educational settings, providing a unique and effective way to enhance the learning experience for students. The main goal of the application was to create an interactive Augmented Reality experience for primary school students. It focused on the frog life cycle. The application works by recognizing markers placed by users. These markers display a 3D model of the five stages of the frog life cycle. Users must organize the markers correctly to ensure an accurate representation of the life cycle

Two students would need to access the application at the same time. Then one of them has to create a room and the other can join the same room so that they can collaborate at the same time/location(as the created room). Else the teacher can create one and ask both students to join the same created room. Upon arranging the markers, students can verify the correctness of their placement by pressing the "check" button. Feedback is provided on the screen to inform the student whether the markers are in the correct order or not. If the arrangement is incorrect, students have the opportunity to rearrange them until they are correctly ordered.

4 Theoretical Reflection

4.1 Situated Learning Theory Principles in FrogAR_Connect

Situated learning, a theory pioneered by educational psychologist Jean Lave and anthropologist Etienne Wenger in the 1990s, emphasizes the importance of learning within authentic contexts. It highlights the significance of learning through authentic and meaningful activities, where knowledge is gained not in isolation but in real-world situations and social interactions. Adhering to the key principles of situated learning theory, the FrogAR_Connect application aligns with the guidelines set by Herrington & Oliver (1995).

Authentic Context Enhances Understanding: This pertains to establishing a learning environment that closely mirrors real-world scenarios. In FrogAR_Connect, it refers to showcasing the life cycle of a frog in a realistic 3D environment, accurately mimicking its natural progression. Through the integration of real-world experiences, this approach promotes a more profound understanding of the subject matter among students.

Engagement through Authentic Activities: The process involves the development of learning tasks that accurately simulate real-world activities that are applicable to the subject. FrogAR_Connect enables students to engage with and manipulate 3D models depicting the various stages of the frog life cycle. By engaging in these hands-on activities, students actively explore the topic and gain a practical understanding of its different stages.

Access to Expert Performances: This concept involves providing learners with exposure to examples of exemplary work or demonstrations conducted by field experts. In FrogAR_Connect, it translates to providing students with accurate representations of

the frog life cycle stages, allowing them to closely observe and interact with expert-level models. This exposure provides valuable insights into every stage of the cycle.

Diverse Perspectives through Collaboration: This implies the promotion of collaborative efforts among students, fostering the exchange of their distinct perspectives and experiences. In the context of FrogAR_Connect, collaboration enables multiple students to participate, each taking on different roles. This diverse participation fosters a rich exchange of ideas and promotes a deeper understanding of the material.

Collaborative Knowledge Construction: This pertains to the practice in which learners collaboratively construct knowledge and enhance their understanding through collective activities. FrogAR_Connect, involves students working together to position markers representing different life cycle stages. Through this collaborative effort, students co-create knowledge, discuss concepts, and learn from each other, leading to a more comprehensive comprehension of the topic.

In a nutshell, FrogAR_Connect strives to enrich students' comprehension and retention of the frog life cycle by adhering to the principles of situated learning theory, resulting in a more significant and immersive learning experience.

4.2 Vygotsky's theory Principles in FrogAR_Connect

The incorporation of Vygotsky's theory in a technology-driven and collaborative environment, such as an augmented reality (AR) collaborative application, offers valuable benefits in enhancing learning and problem-solving experiences. Here, we outline a number of approaches to effectively apply Vygotsky's theory in this specific context:

Create Collaborative Learning Opportunities: Design educational activities that promote group problem-solving and cooperative exploration of learning content. FrogAR_Connect facilitates collaborative learning by enabling students to place markers representing various life cycle stages together. This fosters collaborative problem-solving and joint exploration of virtual environments.

Facilitate Peer Collaboration: The implementation of tools and features allows students to interact, share ideas, and collaborate on tasks. This promotes mutual learning and engagement. The AR application helps facilitate peer collaboration by enabling students to chat and discuss their actions when placing markers. This sharing of information and knowledge enhances their understanding of the frog life cycle and supports peer-driven learning.

Incorporate Scaffolding Mechanisms: Incorporate supportive cues, hints, or guidance into learning materials to help students navigate challenges and develop their understanding incrementally. FrogAR_Connect incorporates scaffolding mechanisms, such as interactive buttons, which assist students in accurately placing markers. These mechanisms serve to offer hints or guidance as necessary, thereby aiding learners in challenging tasks and fostering their learning progression.

Encourage Verbalization and Discussion: FrogAR_Connect promotes active dialogue among learners. It encourages them to express their thoughts, articulate concepts, and engage in meaningful discussions. This helps them deepen their understanding of the subject matter. Following Vygotsky's emphasis on language in cognitive development, FrogAR_Connect encourages users to discuss their thought processes and articulate ideas. It also encourages them to explain concepts to one another. This verbal interaction facilitates deeper comprehension and knowledge construction among participants.

The combination of situated learning theory and Vygotsky's theory provides a framework to investigate the interplay between authentic learning environments, social interactions, and the utilization of cultural tools in collaborative augmented reality learning. This integration can enhance your research by providing a stronger theoretical framework. It will also contribute to a deeper understanding of the learning processes in your FrogAR_Connect application.

5 Conclusion

This Article presents FrogAR_Connect, an innovative augmented reality (AR) application grounded in situated learning theory and Vygotsky's sociocultural theory, to enhance the educational experiences of elementary students. The motivation behind this exploration is to establish learning environments that foster collaboration, engagement, and immersion, thereby bridging the divide between theory and practice. FrogAR_Connect serves as a tangible embodiment of this vision and represents remarkable progress in science education. FrogAR_Connect not only enables students to engage with the frog life cycle in an immersive augmented reality (AR) environment but also fosters collaborative comprehension as they collectively construct the stages of the life cycle. This conceptual exploration illustrates the potential of AR to revolutionize the learning landscape through a collaborative approach involving technology, theory, and education. Through the integration of this intersection, we aim to empower students as active contributors in their educational journey, cultivating an environment where learning is characterized by collaboration, interactivity, and profound engagement.

References

[1] T. K. F. Chiu, “School learning support for teacher technology integration from a self-determination theory perspective,” *Educ. Technol. Res. Dev.*, vol. 70, no. 3, p. 931, Jun. 2022.

[2] Y. Wen, “Augmented reality enhanced cognitive engagement: designing classroom-based collaborative learning activities for young language learners,” *Educ. Technol. Res. Dev.*, vol. 69, no. 2, pp. 843–860, Apr. 2021.

[3] J. Bacca, S. Baldiris, R. Fabregat, and S. Graf, “Augmented Reality Trends in Education: A Systematic Review of Research and Applications,” *Educ. Technol. Soc.*, vol. 17, no. 4, pp. 1176–3647, 2014.

[4] L. Johnson, S. Adams Becker, V. Estrada, and A. Freeman, “The NMC Horizon

Report: 2015 Higher Education Edition.," New Media Consortium. 6101 West Courtyard Drive Building One Suite 100, Austin, TX 78730. Tel: 512-445-4200; Fax: 512-445-4205; Web site: http://www.nmc.org, 2015.

[5] P. D. Petrov and T. V. Atanasova, "The Effect of augmented reality on students' learning performance in stem education," *Inf.*, vol. 11, no. 4, Apr. 2020.

[6] O. B. Petrovych, A. P. Vinnichuk, V. P. Krupka, I. A. Zelenenka, and A. V Voznyak, "The usage of augmented reality technologies in professional training of future teachers of Ukrainian language and literature," 2021.

[7] F. Abbasi, A. Waseem, and E. Ashraf, "Augmented reality based teaching in classrooms," *Proc. 2017 Int. Conf. Commun. Comput. Digit. Syst. C-CODE 2017*, pp. 259–264, May 2017.

[8] D. Atwood-Blaine and D. Huffman, "Mobile Gaming and Student Interactions in a Science Center: the Future of Gaming in Science Education," *Int. J. Sci. Math. Educ.*, vol. 15, pp. 45–65, May 2017.

[9] H. Le, J. Janssen, and T. Wubbels, "Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration," *Cambridge J. Educ.*, vol. 48, no. 1, pp. 103–122, Jan. 2018.

[10] A. Ruiz-Ariza, R. A. Casuso, S. Suarez-Manzano, and E. J. Martínez-López, "Effect of augmented reality game Pokémon GO on cognitive performance and emotional intelligence in adolescent young," *Comput. Educ.*, vol. 116, pp. 49–63, Jan. 2018.

[11] M. Burns, E. Pierson, and S. Reddy, "Working Together: How Teachers Teach and Students Learn in Collaborative Learning Environments.," *Int. J. Instr.*, vol. 7, no. 1, pp. 17–32, Jan. 2014.

[12] J. Roschelle, W. Penuel, and N. Shechtman, "Co-design of Innovations with Teachers: Definition and Dynamics," *Int. Conf. Learn. Sci.*, 2006.

[13] D. Abrahamson and R. Lindgren, *Embodiment and embodied design*. Cambridge University Press, 2014.

[14] M. Ati, H. Abdullahi, K. Kabir, and M. Ahmed, "Implementation of augmented reality in the teaching of young children," *Commun. Comput. Inf. Sci.*, vol. 938, pp. 287–297, 2018.

[15] B. Thompson *et al.*, "Participatory Design of STEM Education AR Experiences for Heterogeneous Student Groups: Exploring Dimensions of Tangibility, Simulation, and Interaction," *Adjun. Proc. 2016 IEEE Int. Symp. Mix. Augment. Reality, ISMAR-Adjunct 2016*, pp. 53–58, Jan. 2017.

[16] M. El Kouzi and V. McArthur, "FLCARA: Frog Life Cycle Augmented Reality Game-Based Learning Application," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 12785 LNCS, pp. 17–30, 2021.

[17] F. Galati, B. Bigliardi, A. Deiana, S. Filippelli, and A. Petroni, “PROS AND CONS OF AUGMENTED REALITY IN EDUCATION,” *EDULEARN19 Proc.*, vol. 1, pp. 9165–9168, Jul. 2019.

[18] M. Z. Iqbal, E. Mangina, and A. G. Campbell, “Current Challenges and Future Research Directions in Augmented Reality for Education,” *Multimodal Technol. Interact. 2022, Vol. 6, Page 75*, vol. 6, no. 9, p. 75, Sep. 2022.