FLCARA: Frog Life Cycle Augmented Reality Game-Based Learning Application

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Abstract. The increased ubiquity of technology in everyday life, as well as the value placed on technology skills, has resulted in increased use of technology in the classroom. STEM education has become a focal point in modern K-12 classrooms, with educators seeking ways to create technology-rich learning spaces. We propose that pedagogical design around Augmented Reality (AR) technology can be used to provide students with novel learning opportunities that take advantage of tangible printed materials and mobile technology that is readily available at home. As a learning resource, augmented reality (AR) has shown its versatility at all levels of education (C. H. Chen et al., 2015, T. Bratitsis et al., 2017, A. M. Amaia et al., 2016). In this paper, we present FLCARA; the Frog Life Cycle Augmented Reality Application, which presents the frog life cycle stages to students as a complete three-dimensional model placed in front of them. Using printed cards representing the various stages of the frog's life cycle, the students organize the cards to reflect the correct order of the cycle and then use the application to check if the order is correct. The application's design can be mapped easily onto other subjects, providing teachers with additional pedagogical tools to utilize in the classroom. The results of our initial study on the usability of the application are quite promising and reflect positively on this application's usability for the intended educational purpose. Overall, 90% of our participants agree that the application is effective; they were satisfied with the application's educational content (mean = 4.56, st dev = 0.76).

Keywords: Augmented reality · Educational application · Science · STEM

1 Introduction

Educators have a difficult task to prepare learners to become a productive part of the workforce in an ever-changing digital world. This global phenomenon has resulted in contemporary teaching being tangential to learners. Although technology can help resolve this conundrum, educators must have an understanding of how technology can be integrated into the curriculum to support learning outcomes for learners. Teachers harbour certain concerns, the most prominent being the displacement of the role of teachers in the classroom by technology. However, this concern is unfounded as the teacher's role

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has progressed to facilitating technology use in the learning process and giving students a basis for how they can strategically use the technology. There is consensus amongst educators around the globe that the integration of technology in the learning process is vital in contemporary society (Gallou and Abraham 2018). Therefore, educators must create a learning environment where every learner can learn to use technology effectively. This involves integrating technology into the curriculum, which inadvertently helps educators develop their teaching skills. This development is attained by revamping the class environment with technology-based learning that supports learners who have been familiarized with technology in the digital age. The right of learners to access the most advanced pedagogical practices is tied to their success in an ever-changing job market.

As a learning resource, augmented reality (AR) has shown its versatility at all levels of the educational field and is a relevant step towards a technology-based learning environment primarily due to the features that differentiate it from other learning resources (Petrov and Atanasova 2020). The ability to interact with AR pedagogical technologies provides the student with a different perspective from which to scrutinize information and ideas. Furthermore, it allows teachers to incorporate a variety of materials and utilize different formats, such as URLs, videos and text (Cabero and García 2016). More importantly, the peripherals required for AR use, such as smartphones, are sometimes readily available to learners as they have become commonplace (Yáñez-Luna and Arias-Oliva 2018), although we acknowledge that such access is depending on socio-economic status.

This ubiquity is vital as we look towards the literature of technology in educational fields. AR, as an emerging technology, has been swiftly adopted and incorporated into educational areas not only due to the diverse possibilities it offers (Johnson et al. 2016, Villalustre and Moral 2017, Bacca et al. 2014) but also due to the accessibility of smartphones/ tablets. The characteristic of AR having supporting peripherals that are already in conventional use bodes well for its continued use in the educational sphere (Cano and Sevillano-García 2018). Educators have an opportunity to help students develop 21st-century skills by introducing AR in the classroom. Prior research suggests that there is sufficient evidence to support the implementation of AR-based technologies in education to encourage interest in a variety of subjects and provide a holistic learning experience to learners by linking outcomes in the virtual and physical world (El Kouzi, Malek et al., 2019).

Forbes described AR as one of the dominant technological advances that could bring about a shift in the educational landscape over the next ten years (Forbes 2019). The characteristic of AR is its capablity of augmenting real world items with digital assets makes it stand out among other technologies. Furthermore, the scrutiny and consumption of media in real-time in AR using accessible technologies such as smartphones places it in a promising position to bring about a paradigm shift in the use of technology in education (AASA 2014). From the perspective of educational technology or EdTech, AR can offer a more personalized educational experience due to the embracing of audio-visual elements in its use and because it engages the kinetic senses of the user. This can pique the interest of learners and give them greater enthusiasm for the learning experience. Moreover, AR offers a memorable experience to learners as it is a relatively novel technology that can bring about an emotive undertaking for learners.

2 Literature Review

Consensus on how technology should be used in education is moving towards creating learning experiences that promote better learning outcomes and improve accessibility to all students, rather than the previously held reservations on whether technology should be used at all (AASA 2014).

This requires that educational content be designed in a way that improving learning outcomes becomes a priority. Research by Park et al. (Park et al. 2015) indicates that learning outcomes can be enhanced when interactive or illustrative teaching tools and methods are used under low working memory conditions such as narration. Their findings further posit that due to the cognitive processes, selecting and organizing information into logical models can be supported by these illustrative tools and methods if implemented correctly. This has been established through fresh developments in learning sciences, which has given a new understanding of how technology can reshape and vitalize learning experiences (Bransford et al. 2000).

Implementing technology use in education has offered learners and educators the prospect of accessing resources and expert knowledge unbound by geographical limitations. It also allows communities to become educational hubs as they can still access resources related to a variety of subjects through virtual connectivity, almost matching the in-person school experience (Office of Educational Technology 2016).

Furthermore, developments in computing technology have created new avenues for cooperation on a global scale while allowing for the creation of self-adaptive systems that facilitate real-time academic appraisal. These developments could make the learning process more user-centric, allowing students to have a curriculum based on their strengths and limitations (Zhu and Tang 2017).

When evaluating AR learning applications in the classroom, developers and educators must be aware that initial findings may be subject to novelty effects, especially when considering the level of exposure in particular age groups. Young children are exposed to 3D interactive graphics through games, but their lack of exposure to newer technology such as augmented reality can take away interest from the subject matter. This novelty effect brings about curiosity in the technology itself rather than effectively delivering educational content through AR. Such considerations should be made when attempting to integrate AR in education (Seo et al. 2006).

Given that most technologies introduced in education have their benefits and drawbacks, research highlights that AR is not exempt from this phenomenon. A literature review on the positive and negative outcomes of AR in education by Radu (2012) highlighted that AR provided a more holistic understanding of content requiring spatial awareness such as geometrical objects, astrometry, geometrical profiling and in understanding how words can be symbolically associated with other phrases. On the other hand, the negative learning outcomes were evident in need for greater scrutiny and deliberation, which, at lower and intermediary levels of education, can be challenging. This might result in some students not concentrating fully on the content and adversely affect team-related contributions.

Over time, research has provided evidence that virtual environments and related games can have positive social outcomes such as improvements in compassion, emotional control and social consciousness (Chen et al. 2015; Li et al. 2017). Virtual environments can also improve individual learner outcomes such as problem-solving, improved collaborative instincts, and abatement in behavioural issues and suspensions from school (Hanna et al. 2014).

Comparisons to traditional learning content are essential to examining the net benefit of AR use. Diaz et al. examined these comparisons, pitting static content against dynamic AR content. Their discovery was that 90% of students surveyed indicated that comprehension of new topics was made easier with AR content, and 80% favoured interactive animations to understand new learning concepts (Diaz et al., 2015).

Hands-on aspects of STEM notwithstanding, learning these subjects from texts can be daunting for learners. Research highlights that activities outside of the usual syllabus can incentivize students to take more interest (Fortus and Vedder-Weiss 2014) UNESCO recommend that providing a context of how science can be used outside the classroom can help motivate learners. By highlighting the impact of science-based application in society, AR in education can enhance the real-world use of science (Fensham 2008). AR has the potential to overlay relevant information in these very same texts, pre-senting animated simulations and interactive digital content that engages users while being situated in the context of curriculum-approved texts.

Dunleavy and Dede assessed 14 AR-based games and interactive applications related to science. They discovered that AR provides the best outcomes when used in extracurricular activities that entail in-depth examination, immersion and investigation. Smart devices and AR-based devices offer a platform where complex scientific concepts can be explicated through simulations and combinations of real and virtual object assessment (Dunleavy and Dede 2014).

In-class projects promote positive learning outcomes through developing relevant skills needed in the modern-day in areas such as ingenuity, cooperation and leadership if suitably implemented. Furthermore, critical thinking skills can be developed through project-based activities. Digital games give learners an opportunity to vary their choices, use their judgment and respond to outcomes in a nurturing environment (Reardon 2015).

Freitas and Campos assessed how AR could be used in 2nd-grade level subjects such as transportation means, animal classifications and similarities in semantics, as used by Kerawalla. The design of these scenarios and how they are to be evaluated were also considered in their assessment. The results showed that AR could help sustain significant levels of motivation in 2nd-grade learners while also providing positive outcomes for underperforming students by improving their learning experiences (Freitas and Campos 2008).

Based on the review of literature, there is enough evidence to support the implementation of AR-based technologies in education can be useful in encouraging interest in a variety of subjects and providing a holistic learning experience to learners by linking outcomes in the virtual and physical world. This linkage allows for a better understanding of abstract concepts and topics that make their real-world application more relevant for learners.

This work builds on preceding theory and research to an additional perspective of how AR technology in an educational context can be used predominantly by approaching AR as a supportive tool for teachers and examining the impact on learners' academic achievement, usability/satisfaction and motivation.

3 Motivation

In our review of the literature presenting STEM-based AR applications, we noted a lack of augmented reality applications as an emergent technology which are developed for classroom science text books specifically for the Animals Life Cycle. Our first stage was to create and application which addresses the Frog Life Cycle dedicated to primary school students. the Frog life cycle for primary school students. To this end, we developed FLCARA to improve the student's memorizing this lesson through an interactive AR application. In this study, we present a preliminary usability analysis of this application using heuristics presented in the PREMEGA framework (Shoukry 2015). FLCARA encourages a self-driven approach to learning by introducing textbook material as an immersive, 3D model that can be uncovered by discovering the parts of their school textbooks using our application.

The FLCARA application takes the frog life cycle stages out of a two-dimensional textbook and presents it to students as a complete three-dimensional model placed in front of them. Using the application, which runs on a smartphone or tablet, students can develop a visual understanding of each stage by tilting, rotating, and panning the camera around the 3D virtual content. Not only the application presents 3D virtual content (EL Kouzi et al. 2019) also it poses students with interactive buttons that allow them to check if they have placed the markers in the correct stage place. This is a novel application for several reasons:

- To the best of our knowledge, this is the first Augmented Reality application to visualize the frog life cycle. It enables students to look at each stage and memories the correct sequence.
- This application is easy to use. And the activity which the users will be doing is fun.
- The markers of this application are intentionally made simple so that the participants will
- expect what to see as AR above each figure.
- The presence of the button allows participants to test for unlimited trials if they have placed the stages correctly without worrying about failing or being judge by other students.

4 The Application

The development tools that have been used for this application are Unity editor 2019.3.14f1 and Vuforia Software Development Kit (SDK) for Android. The Android SDK is also required for compilation. The Unity engine supports the development of applications for PC, Android, and IOS using the Unity graphics engine. Vuforia is an Augmented Reality SDK for mobile devices that uses computer vision to recognize markers, allowing developers to link virtual content (e.g., pictures, movies, 3D models, audio files, etc.) to real-world objects. The Vuforia SDK is available for Android Studio, XCode, and Unity, which was selected for this application.

The application was developed to recognize specific markers to display the 3D model on top of it. The 3D model consists of five stages of the frog life cycle. The users should put the stages correctly organized in the life cycle diagram, as in Fig. 1. Then they check if they have put them correctly by pressing the “check” button. After that, the student will be informed if they have put it in the right order or not by a text appearing on the screen. In case they have placed them incorrectly, they will be able to change their order until they are ordered correctly.

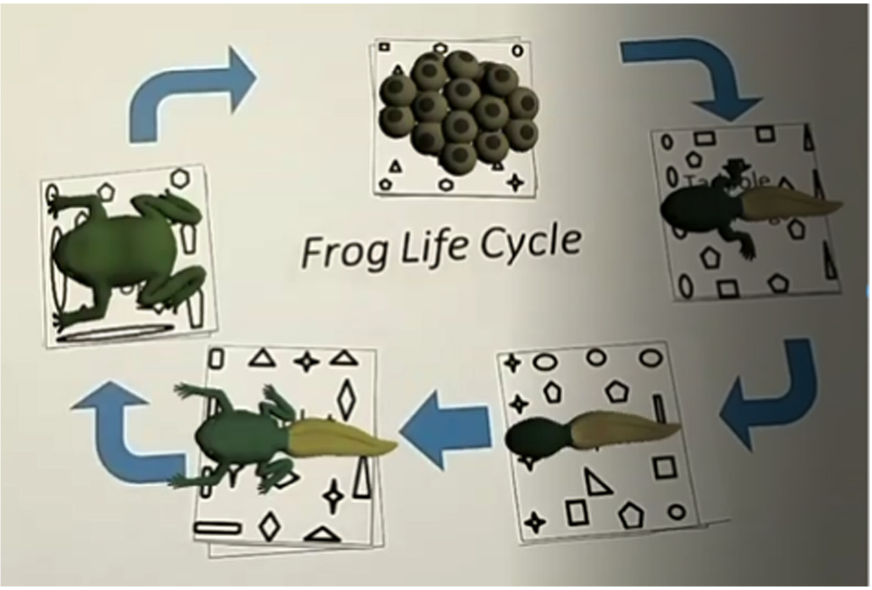

Fig. 1. FLCARA markers placed in correct order in life cycle diagram

5 Bloom’s Digital Taxonomy

In 1956, educational psychologist Benjamin Bloom developed a taxonomy of learning objectives, as a composition to recognize the learning procedure. He had divided his taxonomy into three psychological domains:

– Cognitive: processing information
– Affective: attitudes and feelings
– Psychomotor: physical skills.

His taxonomy advanced from Lower Order Thinking Skills (LOTS) to Higher Order Thinking Skills (HOTS). Later, Lorin Anderson and David Karathwohl revisited his

Taxonomy. They have used verbs instead of nouns, and they reorganized the order of categories. After that, Andrew Churches extended Anderson and Karathwohl's categories and developed it to become a digital environment (Churches 2010). We used Bloom's Digital Taxonomy to facilitate learning. Below how does the AR application follow this taxonomy:

1. Remembering: First, the students will view the 3D frog life cycle models above each marker. They will be able to match the name written on the marker with the figure above it. So the student will be able to visualize this stage.
2. Understanding: the students will be able to identify the 3D figure by looking at their physical parts from all sides. Also, they can compare the stages of the life cycle with each other.
3. Applying: In this stage, the students will display the markers in the empty life cycle picture. So, they will construct the life cycle and present it properly. The students will take their knowledge and understanding of different situations.
4. Analyzing: In this stage, the students will think critically and explore the best way to order the markers in the correct structure by organizing them correctly.
5. Evaluating: After placing the markers in their places, the students will press the check button to evaluate their work. They can judge by themselves if their work is correct by testing it. This will let them find effective solutions to the puzzle and justify conclusions while drawing on their knowledge and understanding.
6. Creating: After building the cycle and combining the markers in their correct place, the students will be able to view the elements which are put together to form a coherent or functional whole.

6 Methodology

The purpose of this project is to design a complementary learning application through the use of AR technology. This application will facilitate the mapping of interactive content into instructor-selected textbooks to support the curriculum. The incentive behind the development of this educational AR application is to provide an exhibition of the demonstrable benefits of AR integration in learning beyond novelty effects. This is in addition to the improvement in learner comprehension of complex STEM topics. In this paper, the usability of the application will be tested in the use case of a unit in a Biology course, with the corresponding study presented. Usability issues can significantly affect the effectiveness of this AR application, according to prior results in some studies (Akçayır et al. 2017; Radu et al. 2016). Hence the importance of assessing the application's initial usability in a learning setting. Future studies will help understand anecdotal usability issues for a target user group and evaluate the prospect of using the application in a real learning setting.

In this evaluation, we resolved to use the Pre-MEGA framework designed by Shoukry et al. (2015). The rationalization for selecting this framework is based on its provisions for detailed heuristics that facilitate the assessment of mobile-based pedagogical technologies targeted towards children. Despite some heuristics related to game mechanics and user-generated avatars being inapplicable in this paper, the framework addresses issues of usability, ease and functionality of interaction, and pedagogical content design. Addressing these issues provided a basis from which we could design our usability questionnaire.

6.1 Participants

Eighteen adults had participated in this study. The participants were between 18 and 45 years old. Although this group does not represent the target age group of the application, it is not uncommon in HCI to use low-risk populations to first evaluate the usability of an application before moving on to studies involving the target group (e.g., minors). Participants were recruited using convenience sampling and by advertising the study on the Carleton Research Participants Facebook page. They were told that they might withdraw at any time they wish. After they submit the questionnaire, they may not be able to cancel their participation since the data will be saved anonymously, so no name or code number was saved with the questionnaire. The participants had read the consent form and agreed to participate in the study. The consent form was sent by email to those who agreed to participate in the study.

6.2 Procedure

The participants who read the consent and accepted it had received an email containing the link for the application on Google Play Store and a pdf attachment with the required markers to print at home (markers are used by the application to interact with the AR experience), and a link to an online questionnaire. They installed the application on their devices. Then they've printed the two markers, M1 (Fig. 2) & M2 (Fig. 3).

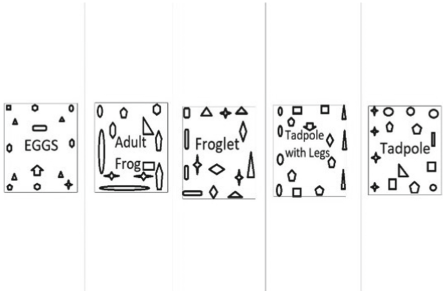

Fig. 2. FLCARA square markers M1.

The marker M1 contains 5 square markers; each marker has the name of the frog life cycle stage. They looked from the device at that M1. The augmented reality figures appeared floating above the five markers found on M1. After that, the participants cut and removed the markers from M1 and place them on M2. They looked through their devices and checked if they have placed them correctly by pressing on the "check" button. If they set it incorrectly, they would get "incorrect, try again" else, they get "correct." After placing the markers in the correct places, the participants had to answer the provided questionnaire.

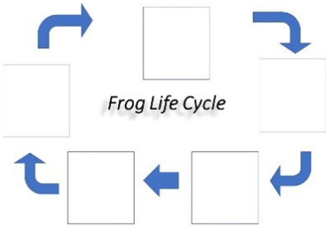

Fig. 3. FLCARA empty life cycle diagram M2

7 Results

7.1 Results from the Questionnaire

67% of the participants were ones in the age range 40 – 40 + and 33% were in the age range 18–28 years old. When asked how comfortable they are when using a mobile device on a daily basis, 83% said that they are very comfortable, and only 17% were neutral. 61% of the participants describe their overall experience after using the application as "very good," while 39% described it as "good." When asked if they used augmented reality before, 56% said yes, and 44% didn't use it before. Only 33% of the participants have used an AR application before playing this App.

7.2 Heuristic Evaluation

Next, mobilizing heuristics from the PreMEGA framework (Shoukry et al. 2015), we evaluated participant feedback on the usability of our application.

Efficiency:

- The application started quickly.
- The application enables independent use after first use.
- The application consistently responses to user actions.
- The application has clear, fun actions to reach educational goals.

Effectiveness:

- The application makes connections to learning content.
- The application is supportive rather than distractive.
- The application show figures based on real-life experiences.
- The application uses a theme meaningful to children.
- Augmented Reality is a good tool to be used for educational games.

Satisfaction:

- I felt satisfied with the educational content found in this AR application.
- It was easy to understand the differences and similarities between the two cells in this application.

- The elements of the application the interface was easy to identify.
- I felt comfortable to hold the device and press the virtual button.

Efficiency. We used the heuristics of the PreMEGA Framework to evaluate the efficiency of the application design. Heuristics were presented as positive statements on usability using a 5-point Likert scale where high values indicate agreement with the heuristic. Efficiency here refers to the overall responsiveness of the application (e.g., content loading time, response to user inputs, etc.). System efficiency relates not only to the computational power of the device running the application but also coding choices that can impact system responsiveness and lag. Overall, FLCARA scored very well on efficiency heuristics. Participants indicated that the application started quickly (mean = 4.6, st dev = 0.90). Regarding User Interface (UI) design and ease of use, participants indicated that the application design enables independent use after first use (mean = 4.83, st dev = 0.50). When asked about the consistency response to the user actions of the application, participants noticed that the application response well to user actions (mean = 4.83, st dev = 0.37). Overall, participants indicated that the educational goals of the application were clear (mean = 4.67, st dev = 0.58). Participant feedback on the efficiency of the design was consistently high. We assert that these preliminary results reflect positively on the usability of this application for the intended educational purpose.

Effectiveness. Where efficiency heuristics are linked to general usability, effectiveness heuristics assess the ease of use of the application regarding the interactivity of educational content. We asked participants to reflect on whether the application makes a strong connection to learning content. participant feedback on this heuristic was positive (mean = 4.72, st dev = 0.45). Most of the participants found the application supportive of learning goals rather than distractive (mean = 4.61, st dev = 0.76). The participants also evaluated the content delivery and presentation of the interactive 3D AR models as appropriate to the subject matter (mean = 4.94, st dev = 0.23). Participants also indicated that the application design seems meaningful for the target age group (mean = 4.94, st dev = 0.23). The application will be considered effective if it has a high degree of success in increasing the learner's interest in the subject matter and if it provides a fun and engaging way to interact with educational content. Overall, 90% of our participants agree that the application is effective, which does reflect positively on the usability of this application for the intended educational purpose. we were further interested in learning whether or not our participants felt as though AR would be a useful pedagogical tool – beyond the initial novelty effect. Although the duration of the study does not allow us to accurately assess novelty effects, we note here that participants agreed that AR is a good tool to support traditional classroom teaching (mean = 4.94, st dev = 0.23).

Satisfaction. The final set of questions was used to assess the features that were unique to this application. specifically, we were interested in whether or not the educational content of the application was easy to understand, if the differences between the cell types were presented effectively, and how participants felt about the interactive content and virtual buttons. Overall, participants agreed that they were satisfied with the educational content of the application (mean = 4.56, st dev = 0.76). The participants also agreed that it was easy to understand the differences and similarities between the two types of cells presented in this application. None of the participants disagreed about the easiness of it. The results were (mean = 4.89, st dev = 0.31). The participants also noted that the elements of the application interface were easy to identify (mean = 4.89, st dev = 0.31). This application required the user to hold the device and point it to the marker; then, the user has to press on the virtual button found on the marker (paper). Although participants indicated that they were comfortable viewing and interacting with the virtual button for the duration of the study (mean = 4.83, st dev = 0.37), some participants indicated some fatigue in performing this type of interaction over extended periods of time, which could introduce problems in-classroom use, where students would likely be using the application more frequently and for longer periods of time. Overall, the results of our initial study on the usability of the application are quite promising. User feedback was overall quite high, and the design of the application seemed to spark our participants' interest in learning more about the subject matter. Using these results going forward, we plan to modify the application to take some of the usability concerns into account before launching a longitudinal study in our local schools. also, we hypothesize that the design of FLCARA can be mapped easily onto other applications in science topics, especially when there is a certain sequence that should be organized in a specific way.

7.3 Participants Subjective Feedback

Assessment determines the learning and appropriate assessment practices are used to stimulate required knowledge. The purpose of the assessment is to help the students gain a better understanding of what it is they are learning, improving the efficiency of what the student can absorb (Anderson 2007). Some of the participants were glad to share with us some of their comments after using the application. Following are some of their feedback:

- "AR can plays a constructive roles in helping students grasp complex concepts and make it attainable not only for above average student but also for the majority of student who may have difficulty realizing these concepts otherwise."
- "I would highly recommend the use or AR in classroom since it is simple fun and has a great potential to simplify and attract the attention of future generations."
- "Due to different types of student's learning abilities I think this is type of learning could help support and improve the process of learning."
- "AR would enable the students to link abstract concepts to real life contexts and this is very beneficial since our kids are becoming more and more visual learners."
- "This applications is like a self study because the kids can know the correct answer after the picture appears."
- "It is really easy to use this application. Some kids don't like to read books and listen to the teacher so this is a very good alternative to normal boring learning."
- "With such applications the students will learn while enjoying technology."

8 Conclusion and Future Work

Prior research indicates the effectiveness of AR in improving the impetus to learn in classroom situations. In this project, the authors demonstrated an educational application called FLCARA with the intention of promoting STEM-related subjects in a classroom setting. The initial evaluation presented in this paper addressed a specific unit in biology, with future evaluations providing an exploration of how heuristic sets can be generated for purposes of educational AR. The application was designed to take advantage of 2D content present in textbooks and overlay interactive 3D content over them, providing students with supplementary pedagogical tools for scientific practice. The application uses the Frog Life Cycle topic, providing visual contexts that improve comprehension. Participant feedback from using the application was largely positive, which gives us further guidance on how to approach the next phase of development and evaluation. The research study corroborates the author's assumption that the AR application supports individual student learning, and the underlying technology enhances enthusiasm in STEM-related subjects. It is the opinion of the authors that AR technology use will burgeon as an educational tool.

One of the drawbacks of this study was it used adult learners as usability testers of the application. Although it is customary practice to do so in preliminary usability studies, there is a possibility that the outcomes obtained in this study may slightly differ from the outcomes using the target population as subjects. To overcome this, future work will include usability studies from the target age group and comparisons will be drawn to pinpoint differences in some aspects of usability, such as cognitive differences. This will be done before longitudinal studies on the learning effects of AR are conducted. The results of the participant questionnaire provided assurances that future work on educational AR applications in STEM learning can be productive. This research will also be applied in future work where the authors will examine the other areas of STEM-based learning using a similar methodology. Teachers and students in Grade Two classes will be a vital part of this stage as they will provide a better understanding of the application from a real-world, classroom perspective. With this in mind, the authors theorize that a co-design approach to AR pedagogical tools will be beneficial to researchers in surmounting the design challenges and novelty effects that limit progress in this area.

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