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Learning experience design for augmented reality

Betül Czerkawski[a] and Margherita Berti[b]*

[a]*Department of Applied Technology, University of Arizona, Tucson, Arizona, U.S.;* [b]*Department of Second Language Acquisition and Teaching, University of Arizona, Tucson, Arizona, U.S.*

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Recent years have seen a growing interest in augmented reality (AR) technologies due to their potential for simulating real-life situations and creating authentic learning tasks. Studies have shown that AR enables engaging and interactive learning experiences (e.g. Bressler and Bodzin 2013; Klopfer and Sheldon 2010) and can benefit student learning (e.g. Bonner and Reinders 2018; Siegle 2019). However, although research in AR for education is not scarce, educators often do not have a learning experience design (LXD) approach that is supported by the recent findings of learning sciences and instructional design models. To bridge this gap, the present study introduces an AR-learning prototype developed by using *SAM I* (Successive Approximation Model I), and the *Threshold Concepts Framework*, employed for meaningful integration of AR into the learning process. A pre-survey and a post-survey method were utilised in the data gathering process to gauge students' experience with the AR module. The findings show that the majority of students have not had educational experiences with AR prior to the study, and they struggled to find ways to incorporate this technology into their content areas in a meaningful way. Nonetheless, participants realised the value of AR and stated that they most likely would use this technology in the future. Based on the findings, the authors present a set of suggestions for instructors and LXDs, and provide recommendations for future research.

Keywords: successive approximation model; emerging learning technologies; online learning; mixed reality

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Introduction

Today, educators have many opportunities to engage their students with emerging learning technologies. Such tools enable participation in complex problem-solving tasks and the achievement of learning outcomes. To evaluate and select the technologies that best fit educational environments, educators can utilise instructional design principles, the design thinking framework and evidence-based guidelines developed by the learning sciences. These models can aid in creating experiences that are learner-centered, interactive and support the mastery of content knowledge.

*Corresponding author. Email: berti@email.arizona.edu

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Augmented reality (AR) is among those emerging technologies that show significant potential for education (Barrett *et al.* 2018; Birt and Cowling 2017; Cheng and Tsai 2013; Godwin-Jones 2016; Liu and Tsai 2013; Quint, Sebastian, and Gorecky 2015; Wang 2017). AR can be defined as 'a means with which to supplement the real world with digital information through a visual interface' (Richey 2018, p. 11). The significant emphasis on experiential and immersive learning has made AR a strong candidate to be used across many disciplines, and its growing popularity has led to an increasing number of university labs and centers to focus on its potential for teaching and learning (Brown *et al.* 2020). The 2020 EDUCAUSE Horizon Report explains that this new emerging technology is proving to be an effective way to augment traditional pedagogy while also providing new kinds of access to learners with different abilities. Institutions like Penn State University and North Carolina State University have gathered augmented, virtual and extended reality teaching resources on individual sites to facilitate the integration of immersive experiences in the classroom. Over the past 3 years, scholars have found that these immersive technologies can support skill-based and competency-based pedagogies, and expand the range of hands-on learning experiences (Hayes, Hardin, and Hughes 2013; Ke, Lee, and Hu 2016; Liarokapis and Anderson 2010).

This study sought to describe the development and implementation of an AR-based learning prototype in two, online graduate courses through a learning experience design (LXD) approach. This paper is divided into four sections. Part one provides an overview of AR uses in education, and describes the selected instructional design model and framework. Part two deals with the research process, including participants, materials and data collection procedures. In section three the results are discussed. Finally, section four offers suggestions and recommendations for educators and future research studies.

Background

Augmented reality

Although AR is not a new technology, it is only in recent years that it has become increasingly popular in education. While it is clear that AR technologies overlay digital content onto the real world, it is rather challenging to find agreed-upon definitions regarding types of AR. Nevertheless, a simplistic categorization of AR includes three types based on the features and capacities of the technology: markerless, marker-based, and location-based (Wojciechowski and Cellary 2013). The first type, markerless AR uses the 'tracking physical objects' features, present in the real environment and does not require markers. On the other hand, marker-based AR uses a marker as a trigger. The marker can be a QR code, a specific symbol, or some other type of artificial marker that prompts the augmented experience. Thirdly, location-based AR uses 'data about the position of mobile devices, determined by the Global Positioning System (GPS) or WiFi-based positioning systems' (Wojciechowski and Cellary 2013, p. 572). This type of AR technology enables users to move in the real environment and observe computer-generated information on their mobile devices depending on their location. The AR technology type selected for this study, HP Reveal, is marker-based, as participants developed AR experiences based on the trigger images, or the elements they created.

HP Reveal was a popular educational application (app), formerly known as Aurasma Studio, free to use and accessible on mobile devices at the time the research was carried out. The creation of AR experiences through HP Reveal occurs in three steps. First, the user identifies a trigger element (e.g. a printed graphic, a text) and takes a photo of it through the HP Reveal app. After taking the photo, the app prompts the user to select a digital overlay or to upload her/his own overlay. The overlay is digital information that will appear when the trigger element is scanned. Third, the AR experience is given a title and saved within the app. Following it is possible to view the created AR experience simply by opening HP Reveal and pointing the camera of the mobile device toward the trigger element of which a photo was taken in step one.

The HP Reveal app has shown great potential for educational purposes. For example, Plunkett (2019) discussed how HP Reveal was used to develop notecards based on organic chemistry reactions. When scanning the trigger elements, users saw the product of the reaction as well as a real-time, hand-drawn mechanism of how the product is formed. The app was also used to create a virtual guide on how to use and set up equipment in a chemistry laboratory. In another study, Bonner and Reinders (2018) presented suggestions for AR uses in the language classroom. They explained that students could create videos within HP Reveal illustrating how to go from one place to another on campus. Using HP Reveal and following the directions in the studied language, groups of students would work their way to the final point. Alternatively, within the classroom walls, the teacher can create additional information for students by developing AR experiences using texts and images in the language textbook as trigger elements. By scanning such elements, learners can access further information and online resources via links and videos embedded into the text itself. A third study addressed how HP Reveal and AR technologies can enhance student learning (Siegle 2019). The author reported that many schools use these technologies to display student art. Students could record short videos describing their art and the videos could pop-up when students' art pieces are scanned with the HP Reveal app.

Overall, numerous studies have explored the potential applications of AR and HP Reveal in a variety of fields, from the sciences to the humanities. Nonetheless, although studies have looked at the integration of AR in diverse courses, there is limited research investigating the use of this technology in online graduate courses with students being the creators of AR-based activities for learning and teaching purposes. This paper addressed this gap by introducing an AR-learning prototype/module developed using *Successive approximation model I* (*SAM I*) and the *Threshold Concepts Framework*. Through these models, the AR prototype was developed and integrated into two graduate courses, which required students to step into the 'teacher shoes' and develop experiences in their own content areas.

Successive approximation model I

Instructional designers have been using the well-known ADDIE (Analysis, Design, Development, Implementation and Evaluation) model for many decades. ADDIE is an easy to follow, simple framework that can be applied to all types of learning situations. *Successive Approximation Model or SAM I* is a contemporary alternative to ADDIE model. Similar to ADDIE, SAM I could be used in many learning situations, but it is also significantly different from ADDIE. Unlike ADDIE, SAM I is iterative, flexible, collaborative, quick, and therefore considered to be an *agile* approach (Allen 2012). SAM is a fitting approach for small teams and projects. It offers opportunities for team

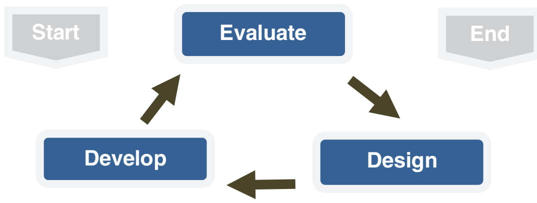

Figure 1. Integrated design in SAM I (Allen 2012).

members to provide feedback to each other while creating a prototype that will be tested frequently until design directions are tried. Due to its short work cycles, SAM I is a fast approach that uses prototyping as the base of creation. According to Allen (2012), the creator of both SAM I and SAM II models, prototyping is 'a core component of SAM and is an indispensable means of sharing information among key stakeholders and leads to more creative designs' (p. 83). Figure 1 shows a visual representation of SAM I. When the projects are more complex, Allen describes another framework called SAM II, which is an extended and more comprehensive version of SAM I.

Threshold concepts

There are various approaches and models available to educators who would like to integrate a certain emerging technology into the learning environment. When reviewing such approaches and models, Anderson (2016) mentions social constructivism, connectivism, heutagogy, complexity theory, network-based theories and threshold concepts as viable options. In this study, the authors employed the *Threshold Concepts Framework* to conceptualise the use of AR learning technologies.

This framework comes from Christensen's (1997, 2008) attempt to apply disruptive technology approaches into educational settings. The threshold concepts refer to the 'conceptual gateways' or 'portals' that were not accessible, or that were in some way previously problematic (Anderson 2016, p. 46). In other words, educators provide new opportunities for their students that were not accessible or possible before by using a new emerging technology. By doing so, educators transcend the challenges or disruptions created by the introduction of a new technology. They constantly question and reflect on their teaching experiences in order to overcome the challenges introduced by the new technology. Threshold concepts have four characteristics: *transformational*, *integrative* and *irreversible* experiences, and *troublesome* past practices that are challenged with the use of an emerging technology. 'Educators as both adopters and change agents need to overcome challenges to disruption and be ready to cross over their own "threshold concepts" as well as those of their colleagues and students, "resisting constraints of thought and action"' (Anderson 2016, p. 47).

Methodology

This descriptive survey study included a small group of graduate students enrolled in two online graduate courses in the fall of 2019. The courses, composed of various modules, included an AR-based module aimed at familiarising students with AR

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technologies and designing an AR activity based on their content expertise. Before the start of the AR module, students completed a pre-survey with the goal of understanding whether they had used AR in other courses or for other purposes, as well as the anticipated benefits and challenges. After the module, students completed a post-survey assessing their overall experience in using AR for educational purposes. Considering that the class sizes were small, the researchers did not utilise statistical procedures to compare the pre-survey and post-survey results. The findings were examined using frequency. The following sections go into further details about the methodology of this study.

Participants

The participants of this study were a group of graduate students (N = 16) of various majors enrolled in two courses, with eight students each, taking place online during a seven and a half weeks semester. The two courses, part of the Educational Technology Master's Program, addressed educational technology topics, and were titled Learning Technologies for the Digital Age and Designing Online Learning Environments. Of the 16 students, 15 took the pre-survey and 13 the post-survey. Participation in both surveys was voluntary; however, completing the activity in the online AR module was a mandatory component of the course. Students' fields of study included secondary education (N = 2), higher education (N = 4), educational technology and instructional design (N = 4), languages and linguistics (N = 3), environmental sciences (N = 1), and art and visual culture education (N = 1). Participants were a combination of master's and doctoral students.

Materials and procedures

Pre-survey and post-survey

The researchers in this study, the course instructor and the graduate assistant, developed the AR module, or prototype and the data collection instruments after conducting an extensive literature review on the topic. Both surveys were developed and completed online on the Qualtrics platform. The pre-survey included nine items while the post-survey had 13 items. Although most questions were close-ended, when appropriate, students were asked to explain their choices expressed in the close-ended items, as well as describe in their own words their attitudes toward AR in response to open-ended questions. The surveys included similar items. For instance, the pre-survey started with a demographic question about students' majors. Then it followed with three questions to explore students' familiarity and experience with AR technologies. The post-survey also included a demographic question, followed by three questions probing students' experience with the AR module activity and technologies used in the module. The post-survey also included two additional questions about how comfortable students would be using AR technologies in the future.

Designing the online AR-based module

In the Spring 2019 semester, the researchers pilot tested the pre-survey and post-survey as well as the online AR module with a small group of graduate students (N = 6; the course was titled Designing Online Learning Environments). Prior to this pilot study, the researchers also obtained approval from the Institutional Review Board (IRB) to begin the research. During the summer of 2019, the researchers revised the module and the surveys multiple times using the SAM I model.

In order to integrate the SAM I model, the researchers used the following steps:

Design of the AR prototype module and preparation for its use in two graduate educational technology courses (Cycle 1)

- Creation of pre- and post-surveys to gauge student experiences with the emerging technology
- Selection of AR software (HP Reveal)
- Secure IRB approval for the study

Revision of the prototype after analysing data for Cycle 1

- Implementation in two graduate courses
- Analysis of pre- and post-surveys results and review of students' products
- Revision of the existing prototype

Development of a new prototype to further improve Cycle 1 (Cycle 2)

- Selection of new software (Metaverse)
- Development of samples for Cycle 2

It should be noted that after the two courses concluded, HP Reveal was not available anymore, so the new iteration included a new AR software, Metaverse. The Cycle 2 of the design process has not been implemented yet.

The two fall-2019 courses used the same prototype taught by the same instructor and graduate assistant. Both courses had a technology integration component and the instructor situated the AR module experience within this component. Once the module was integrated into the researchers' university learning management system, the same module was copied onto the other course. Therefore, the module in one course was identical to the one in the other course.

In the development of the module, the researchers used the threshold concepts in the following ways. First, the instructor and the teaching assistant designed the learning environment by constantly reflecting and wrestling with the design of the new module to provide the best novel experiences to the students (i.e. *transforming*) using AR technologies. The importance of the learner-centredness of the experience was discussed in depth. Within the module, the instructor served as a facilitator throughout the development of the AR activity, thus giving students an opportunity to lead their own experiences. Then the researchers provided new opportunities that were otherwise not possible by integrating the activity into the students' major disciplines and asking them to situate their projects into real-life problems (i.e. *integrating*). To this end, students were given a template to work with, but they were free to select their own activities with the AR app. The virtual, real-time class meetings included extensive discussions about ways to integrate AR in various contexts. During these meetings, the instructor showed many AR examples from different disciplines to stimulate thinking and further discussion. These discussions offered many learning and re-learning experiences for the instructor and the students (i.e. *irreversibility*), as the group considered the previous ways the emerging technologies were used and the reasons and causes of past troublesome experiences (i.e. *past experiences*).

Description of the online AR-based module

This module started with a voluntary pre-survey to gauge students' prior experience with AR technologies. Following the pre-survey data collection, students were introduced to AR using text and video-based instructions, web resources including articles and videos explaining the use and integration of AR in education, and a voice-over presentation created by one of the researchers that summarised the content of the module. As part of the module, students were asked to fill out the following sheet (Figure 2) for their project:

Weekly meetings were held by the instructor throughout the semester, including during the AR module. To support students further in the use of HP Reveal, the instructor and the teaching assistant conducted a real-time videoconference via Zoom to provide students with an overview, respond to their concerns, and showing examples of AR uses. Although HP Reveal was the selected software for the module, the instructor shared other examples of AR technologies with students. Once the module was completed, and the AR activities were developed, students were asked to complete the post-survey. The online module took place simultaneously in both courses to minimize teaching-related differences.

Results and discussion

In the pre-survey ($N = 15$), about half of students ($N = 8$) reported that they had little or no confidence about AR technologies, since they had never used them prior to the class. Only one student had a previous AR experience and felt highly confident about using any AR tool presented in the course. When asked about how much they knew about AR, four students said that they have heard of Pokémon Go, six read articles or watched videos about AR technologies, and five never heard of AR before. While some students knew what AR was, 14 of them had never used it before.

Augmented Reality Activity Sheet	
Course Name	
Subject Matter	
Target Audience	
Activity Description	
Goal(s)	
Description of AR	
Technologies Used	
Learning Outcomes	

Figure 2. Augmented reality (AR) activity sheet.

In the pre-survey, although students lacked hands-on experience with AR, they were able to reflect on and report potential benefits of this emerging technology such as increased interaction, engagement, motivation and visual learning. They also stated that AR could provide authentic and dynamic learning opportunities for learners. When asked about the potential issues involving the use of AR technologies in education through an open-ended question, students expressed many difficulties. For instance, one student expressed that AR could be time-consuming for the creation of educational content, while another one pointed out the difficulty of planning an AR experience from beginning to end. Three students confessed their lack of knowledge with AR and the fact that they did not know what to do with it. Two of the students stated that while highly engaging activities could be created with AR, students in schools might not have access to the right hardware or software. Finally, two students expressed physical difficulties such as running into objects in real space when using AR, as well as potential eyestrain.

After students completed the AR module, in the post-survey students reported being much more comfortable with using AR technologies. However, they also said that they encountered technical issues ($N = 8$) and had difficulties in incorporating it into various content areas ($N = 3$). When asked about whether they would need any support to use AR in the future, they said they would need to know strategies to better integrate AR ($N = 11$) in teaching and learning, troubleshooting support ($N = 8$), how to use AR tools ($N = 7$) and better explanation of the value of AR in education ($N = 4$). Students also stated that they intend to learn more about AR in the future ($N = 6$), and they would definitely use it ($N = 5$). Only two students said that they would not use AR at all. Similarly, six students would recommend AR to others, five were not sure, and two students said they would not.

Another question in the post-survey was about the AR teaching and learning activity participants developed for the course. Four students applied AR to an English as a Second Language (ESL)/English activity, one student to Social Studies, two students to Science, three students to Math, and five to other topics such as leadership and professional development. When asked about the potential and challenges of AR technologies, students expressed much more detailed and nuanced responses to the same questions asked in the pre-survey. For instance, students mentioned that AR technologies get students excited about learning ($N = 10$), enhance attention ($N = 9$), creativity ($N = 9$) and students' spatial ability ($N = 9$). According to students, the improvement in academic performance, collaboration and effective learning (each $N = 9$) were also major benefits. Concerning the challenges, some students stated that AR technologies are difficult to learn and use ($N = 9$), distracting ($N = 6$), expensive ($N = 6$), hard to manage for the instructor ($N = 5$), and may cause headaches and other physical issues ($N = 5$).

One limitation of the study that should be noted here is that HP Reveal, the selected AR app, presented technical issues that resulted in poor software function on mobile devices. The following semester, HP Reveal shut off their services and it is no more accessible on portable devices.

Conclusion and recommendations

This paper presented a study addressing the development of an instructional prototype using AR technologies. The *SAM I model* was used in the design of learning experiences, because of its agile and flexible approach to the design process. Christensen's (1997, 2008) *Threshold Concepts Framework* guided the study in the use of AR activities in two graduate-level courses. The authors focused on transforming the learning environment while providing new experiences for students with the use of AR technologies. They also questioned their teaching practices at every stage to adapt properly to the emerging technology.

The findings of this study showed that participants positively responded to the AR module by citing various benefits including getting their own learners excited about content, spatial ability, increased attention and creativity. However, participants were also mindful about challenges related to AR use, because as shown in the post-survey, they expressed their concerns about the difficulty of integrating AR in content areas, while also emphasizing the risk of not achieving learning outcomes. Students also expressed difficulties with the AR technology, but the main concern revolved around how to better incorporate this technology to foster learning and reach the learning outcomes. As stated by Richey (2018) 'before adopting a new technology, one should always identify the ways in which that technology can be used to improve learning outcomes' (p. 10) and students seem to understand this key point. This study was small in scale and therefore the results cannot be generalised to the larger student population. As a matter of fact, a systematic review of AR-based research in education conducted by Bacca *et al*. (2014) identified small or medium size samples of most studies an important issue. However, considering the diverse graduate students who participated in this research, it may be likely that similar results are true for other student groups. As shown in this study, more research is needed to provide a detailed description of learning and teaching activities when AR is incorporated into educational settings.

Regarding recommendations for instructors and LXDs, the authors identified the following:

Technical issues

AR refers to a wide range of technologies that have little in common in terms of data architecture. For those who develop AR software, a lack of such standardisation may be a problem for speedy and sequential developments. For AR, the only available standard is the Augmented Reality Markup Language (ARML) (Bekele *et al*. 2018). Although the present study used a free AR software, for those who are designing their own software, this kind of standardisation is much needed. Dunleavy, Dede and Mitchell (2009) also argue that the most significant limitation with AR derives from the nascent software development stage and managerial complex of the implementation process. It is significant to note that managing and debugging the AR technology is a key role for all instructors who would like to implement AR in their classrooms. More research is needed to better understand the technical support instructors need for successful implementation of AR.

Accessibility

The number of free and quality AR software is still limited. In addition, the compatibility from one mobile device to another is still an issue for certain AR apps. Only a few high quality and content specific AR software are available, but they are also costly. Since most AR apps require a smartphone or tablet, higher education instructors might assume that all of their students have access to such mobile devices; however that is not always the case.

Pedagogy

Wu *et al*. (2013) cited a variety of instructional methods being employed in the design of AR-based learning environments, including game-based learning, place-based learning, participatory simulations, problem-based learning, role playing, studio-based pedagogy and jigsaw method. However, AR use in education still lacks 'a clear focus on establishing their efficacy in educational contexts' (Lindgren and Johnson-Glenberg 2013). More examples and case studies should be developed for educators to see the value of AR technologies, while also trying to create a theoretical basis that is mostly lacking in the use of augmented and virtual realities (Chen 2009). In regard to pedagogical illustrations of AR, educators also need to see examples and case studies that support AR-based learning activities. Subject-specific examples are helpful for educators to see the potential of AR in their own fields. When Klimova, Bilyatdinova and Karsakov (2018) conducted a survey of existing AR programs and studied in detail what the AR curriculum around the world looked like, they were surprised to see that teaching methods and assessments remained very traditional. Illustrative and detailed curriculum design and activity development procedures, as shown in our study, could lift the veil off the implementation processes for instructors and pave the way for further design-oriented research. Finally, Dede and Richards (2017) argue that the priority for mixed reality researchers is 'to design and study high-quality educational environments that promote situated learning and transfer areas where the immersion can make a difference in student outcomes' (p. 238). This kind of research favours those experimental design methodologies that are not strictly controlled, but LXD methods that explain in detail what works, what does not work, for whom, and how.

Learning experience design

Cuendet *et al.* (2013) state that the incorporation of AR 'into school ecosystems produced design considerations that go beyond pedagogical criteria–whether this activity will trigger learning outcomes and take into account the diverse constraints of classrooms, such as time, space, discipline, or curriculum' (p. 557). These researchers identified four design criteria for AR. *Integration* refers to the AR activity that is seamlessly integrated into the workflow of all learning activities, including the existing ones. *Empowerment* happens when the teacher leads the AR activity to manage potential classroom management issues. *Awareness* is about being aware of the learner dynamics; both learners as individuals and learners as part of a group. *Flexibility* enables the teacher to adapt the AR activity to the circumstances, conditions and dynamics of the learning environment. Finally, *minimalism* requires keeping the AR activity simple and not complicating it with bells and whistles of software functionalities (Cuendet *et al*. 2013). What Cuendet and his colleagues offered here are relevant guidelines for successful integration of AR, but in addition to these criteria, a broader instructional design and development approach that will guide instructors is needed. In this regard, agile instructional design approaches are key to design learning prototypes to be tested, so that the best approaches to integrate AR into learning processes can be identified. However, there are many design approaches and further research is needed regarding the models, and approaches that best work for different circumstances. Learner experience design, as a discipline, could be crucial to create experiences that are learner-centric, effective and meaningful. Cuendet *et al*. (2013) acknowledged that the scientific status of their principles is not yet tested. The present study provides a very small contribution in this regard by demonstrating the design process for other educators.

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