AUGMENTED REALITY APPLICATION CLASSROOM DEVELOPMENT: NEW TECHNOLOGY AND NEW MEDIA, EDUCATION AND INTELLIGENT CLASSROOMS

By

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ABSTRACT

Mobile technology is one of the fastest developing communications tools in the history of humankind. Perhaps now more than ever, one of the biggest questions educators and instructors face is how to engage learners in the digital age as mobile technology rapidly evolves. Current research indicates that Augmented Reality (AR) mobile learning applications, when functioning as electronic performance support systems, can increase student's spatial and working memory, response times, and has a significant impact on student engagement. With pedagogically enhanced support systems, AR-enabled courses increase learner's cognitive ability, their response to behavioral demands, and overall positively influence learner's working memory. The significance of this study will help illustrate how assistive and mobile devices are facilitating learning and autonomous help-seeking behavior in technology-enhanced learning environments. The longitudinal study utilizing Augmented Reality screen reading applications indicates that mobile AR technology can function as assistive and help-seeking instruments to increase user visual and spatial memory recall while simultaneously providing learners with tailored and systematized learning content. The study applies mixed methodologies, utilizing quantitative and qualitative data to aid in triangulation. The results show that Augmented Reality applications offer a uniquely beneficial learning context compared to the traditional computer lab setup due to the nature of mobile application's ability to unlock content anywhere and anytime versus traditional electronic learning methods.

Keywords: Augmented Reality, Mobile Learning, Just-In-Time-Learning, Working Memory.

INTRODUCTION

Perhaps now more than ever, one of the biggest questions educators and instructors face is how to engage learners in the digital age as technology rapidly evolves. However, the idea of adding mobile learning to the classroom, thereby allowing students the anywhere-anytime access to content, is becoming an emerging trend, and an essential tool for some educators: The rapid spread of mobile learning is due to its ease of use and learner engagement benefits (Caballe, 2010). Mobile technology has evolved to include capabilities that can allow instructors to monitor both individual and group performances irrespective of the end-learning environment used to gain insightful analysis from scaled-data collections (Zaki and Meira, 2014). Furthermore, functionality as a mobile learning instrument supports facilitating a rapid transferability of feedback, knowledge, and adaptive content through a learner-based environment. Increased access to mobile devices, and lowered costs, enable learners worldwide to access content and information that would be unavailable through conventional methods. Applications, such as Augmented Reality, bridge digital content from the Internet, by overlaying virtual content onto images, learning artifacts, digital spaces, and digital objects represented via a personal computer, or second screen device. AR is typically utilized through a mobile device. Most smartphones now have this capability, however wearable devices such as Google Glass and other emerging wearable tools also facilitate AR overlay transmission. AR technology bridges the gap between the physical and digital world by removing the desktop or laptop personal computer setup as the sole mode of engagement with the Internet, and opens a world of audio, video, photos, three-dimensional objects, animations, and websites overlaid in real-time on tangible locations. Thereby, substituting the personal computer with a just as powerful handheld mobile device, wearable device, and the affordances that these robust handheld technologies offer through instantaneous interactions, and experiences with a networked connection facilitated through a globalized Internet community (Azuma, 2004).

1. Background of Study

The existing literature combines mobile adaptation and engagement with a rapidly developing technology that is collectively defined as Augmented Reality. The literature suggests that AR technology can reduce training costs, increase "just-in-time" asynchronous learning, and potentially increase working memory. There are several ways AR can be successfully developed for mobile learning applications. AR technology has reached a scalable possibility that its proliferation can be used and acquired by educators and learners with relative ease. Studies conducted with "Quick Response Codes" (QR) have illustrated that, the "strength of mobile learning is to link e-learning content with specific locations in which that information will be applied" (Macdonald and Chiu, 2011). Augmented Reality adapts the concepts of 'tagging' overlays and interactions according to behavior science studies conducted with AR: "This new approach enhances the effectiveness and attractiveness of teaching and learning. The ability to overlay computer generated virtual things onto the real world changes the way we interact, and trainings becomes real that can be seen in real time rather than a static experience" (Mehmet, K., & Yasin, O. 2012).

Successful applications of Augmented Reality have been seen in numerous inquiry-based learning environments where the AR tool is used to unlock, investigate questions, scenarios and complex problems. Other advantages of AR applications in the education domain are the increased engagement activity of learners, and the overall cost and safety: "AR environments allow learning content to be presented in meaningful and concrete ways including training of practical skills" (Wojciechowski and Cellary, 2013, p. 570). AR technology has been documented in trial and project based learning environments, where complex chemical reactions and expensive materials can be substituted for simulation based AR scenarios: "Image-based AR environments can be used for a broad spectrum of chemical experiments without having to make changes to the physical configuration of this installation. The AR installation takes up much less space than a typical workbench for chemical experiments, and does not require any special chemistry laboratory infrastructure". (Wojciechowski and Cellary, 2013, p. 583). Studies investigating learners' collaborative knowledge construction performances and behavior patterns in an Augmented Reality simulation system recorded markedly increased knowledge gains. Studies have found that the AR supported students perform with increased proficiency due to the representation of the concept; attributing that the "system may serve as a confirmatory tool and enable dyad learners to respond quickly to the displayed results and support their knowledge construction processes" (Lin, Duh, Li, Wang, and Tsai, 2013, p. 319).

The findings from Juan, Mendez-Lopez, Perez-Hernandez, and Albiol-Perez working with Augmented Reality illustrate that learner's pre and post-test results with the tool show a striking amount of memory improvement (Juan, Mendez-Lopez, Perez-Hernandez, and Albiol-Perez, 2014). Studies measuring the result of an Augmented Reality enhanced mathematics lesson on student achievement and motivation found that "AR did capture the attention of the students to a greater degree than the website only group. This result supports prior research showing that the use of AR in classroom contexts can increase motivation" (Estapa and Nadolny, 2015, p. 10).

2. Objectives

Only a limited amount of information can remain in working memory, but AR can potentially help increase this amount through information overlay mapping. Miller's theory of working memory applied to AR promotes efficient learning and associative information processing (Miller, 1956). Due to the unique nature of AR image overlays, AR enabled online courses have the potential to enhance learner's cognitive ability, their response to behavioral demands, and increase learner's working memory. The use of AR allows the adaption of static objects into rich learning objects and enables movement in a physical environment with the appearance of virtual elements mixed in with the environment (Azuma, 2004). The emerging evidence of AR's influence on student engagement and increased working memory potential is a poignant catalyst to examine how these tools aid in increasing knowledge gains and mastery learning: Mastery learning allows students more time to learn independently, and frequently provides them with tutoring or other special assistance (Wentzel and Brophy, 2014).

3. Method

An exploratory sequential mixed methods design was used to collect quantitative data first, and then explain the quantitative results with in-depth qualitative data (Creswell, 2011). The longitudinal collection cycles took place through semester long collections beginning in the fall of 2014. The first quantitative phase of the study, embedded AR application software analytics and survey data, was collected from participants in an online classroom environment, where they downloaded an AR application to test working memory theory to assess whether AR content overlays relate to increased information processing, spatial cognition, and working memory capacity. The second qualitative phase was conducted as a follow-up to the quantitative results to help explain the quantitative results and the potential for pedagogical applications. In the exploratory mixed method data collection cycles, participants explored whether the dynamic nature of AR enabled environments and bespoke digital overlays have an impact on spatial cognition and working memory in online learning environments.

3.1 Sampling Used

Total participants included a convenience sample of 45 college level online learning students. Longitudinal collections took place from 2014 through 2016. The survey data collected was combined to include total participant cycles (n=42). Participants were selected for a 2015 phase two interview (n=3) that incorporated the emerging sample that had a median score typical of the average responses of the survey groups.

Exploratory mixed method designs typically do not include the same individuals who provided the phase one quantitative survey data because the purpose of the quantitative phase is to generalize the result to a broad population (Creswell, 2011). The participants (n=3) that were selected for the phase two of the 2015 collections were selected for their typicality among the open ended survey results, generalizability of their response data, their position as college students, their experience with novel instructional design concepts, access to a mobile iOS device, their comfort with using mobile AR application outside of a class, and using AR in an online learning environment. The phase two qualitative data consisted of three hour long interviews, and the analysis consisted of identifying useful quotes, sentences, coding segments of information, and the grouping of these codes into broad themes related to the participant's responses (Creswell, 2011). This selection was based on first reading though the interview transcripts, writing memos, conducting descriptive analysis, checking for trends, and developing a qualitative codebook (Creswell, 2015).

3.2 Procedure Collecting Data

Participants completed a researcher generated survey that examined their experience using the Augmented Reality application and its impact on working memory recall. This was based on viewing content that was not enhanced by the ARed application, and then enrolling in the AReducation course that included AR enhancement. Participants downloaded the ARed Augmented Reality program (see Appendix Figure A1), used the program to unlock overlay content, and reported on their reflections of its ability to related learning content and retention. Participants interacted with AR content and overlays using the Learning Management System (LMS) called Piazza. Participants completed survey questions (n=42), and engaged in interview follow-ups (n=3). The mixed method data analysis tool MAXQDA 12 was used for textual and lexical response coding. Data for each segment and AR overlay event triggers were logged and matched with the unique user identification using a commercially available analytics engines embedded in the AReducation app to match participant responses to the reporting device used to unlock the AR overlay content.

4. Results

Participants found that Augmented Reality and overlays had a positive influence on their understanding of the online material, and helped them to understand and remember content related to online learning. Participants noted that the experience was rewarding (e.g. I think AR Training in an online class environment would be ideal alternative to what could be found in a face-to-face environment). Only a few participants (n=2) noted that they had issues with the technology working on their device. The majority of participants (Table 1) found that the AReducation program was engaging, helped them remember content information, and positively influenced their recall when compared to a static page, image, or reading (e.g. It increases the interaction and engagement to increase the transfer of knowledge). See Table 2, for qualitative response data.

5. Discussion

AR can be applied to online learning by enhancing a user's perception of, and interaction with, digital content. Learners interact with a three-dimensional virtual image, and view it from any vantage point, just like a real object: "The information conveyed by the virtual objects helps users perform real-world tasks" (Mehmet and Yasin, 2012). The notion of a 'Tangible Interface Metaphor' is one of the essential ways to improve online learning. By hosting augmented overlays and three-dimensional content onto learning management platforms and online hosting sites, users anywhere in the world can create and share their own digital tags and ideas: "By properly connecting these nodes with three-dimensional objects, one can animate (e.g., move) objects. Other sensors are useful in managing user interaction, generating events as the user moves through the world or when the user interacts with some input device" (Chittaro and Ranon, 2007). Mobile technology can now serve as the input device retrieving hosted content from an online learning management database and displaying this content for a learner to digest, interact, and engage within real-time. AR systems are developing tools that can assist in bridging the gap between mobile technologies affecting responses, and direct learning experiences: "When we interact with an environment, be this real or virtual, our type of experience is a first-person one

Item Description	M	SD
AR helped me recall content	4.57	0.49
I was more engaged in the course materials containing AR overlays	4.78	0.47
AR allowed me to understand the content more clearly	4.42	0.90
AR was useful for instruction and feedback	4.49	1.12
It helped facilitate learning	4.55	0.92
AR is useful in online learning environments	4.42	0.94
It helped me remember the content	4.65	0.80
It positively influence my memory of the content	4.58	0.57

Scale: 1 Strongly Disagree–2 Disagree–3 Neutral–4 Agree–5 Strongly Agree

Table 1. Participant's Reactions to Augmented Reality enabled Online Course Content

Participant Feedback Responses
This will even be great in Early Childhood education. Being able to teach kids how objects look in 3D when learning the alphabets etc.
I can see it being beneficial in health care, engineering, or other fields where viewing an item in 3 dimensions would help increase understanding.
I think it definitely provides hands on experience
Useful for any instruction and or training
It would be beneficial in offering an alternative way to interact with a new concept in a similar way as one would if they could be physically (face to face).
I think it definitely provides hands on experience for visual learner
I would not think this appropriate without full explanation of how to use it. I have learned from doing online classes that there are a lot of non-tech people.
Definitely. Dissection of a brain/heart, etc. I believe that AR should definitely be used during online training.
It increasing the interaction and engagement to increase the transfer of knowledge
It facilitates learning
limitations on devices
It help learner to see exactly what the instructor is explaining
Anything that allows for more engagement between the student and the computer screen is a benefit.
I think it would be beneficial.
Online would be the BEST place to use it! I think it would be easier to use online; easier access to what you want to look at.
I think AR Training in an online class environment would be ideal alternative to what could be found in a face-to-face environment.

Table 2. Participant Textual Responses: Is AR beneficial to learning?

that is a direct, non-reflective" (Winn, 1993). The results of the study illustrate that AR is a direct response to first person content that ties fundamental virtual subject matter to the real learning objects, images, and locations with the potential to further increase student engagement, memory recall, and feedback.

5.1 Limitations

A major limitation of this study is the small amount of participants and sample size. Participants were selected for their initiation with mobile devices and already familiar with online learning and mobile devices. Will the results reflect a positive correlation with Augmented Reality and online learning this may not broadly represent a population that is unfamiliar with the tool itself and may require another step in the design process to bridge the content and knowledge gaps. Further, the nature of the AR experience, course creation, and knowledge recall is only as good as the pedagogical construction behind its creation. While many free Augmented Reality tools exists and are rapidly advancing and single "Internet Explorer" of AR or unifying content database does not exist. While the spectrum of the AR-browser is evolving it may be difficult for streamlined adoption without resorting to creating custom content.

Conclusion

AR technology is not a new technology, and yet the affordances AR can engender to an instructional setting are continuously evolving. As Kesim & Ozarslan noted (2012) AR has been around for a long time, and is used in fields, such as the military, medicine, engineering design, robotic engineering, manufacturing, and consumer design. However, more research is needed to help elucidate AR's role within intentional online learning spaces. Namely, effective Augmented Reality technology adoption for classroom instruction shares the common theme that it is pedagogically driven, learner centered, systematic, sustainable, accounts for instructor preparation, and considers the environment of adoption along with the practicality of implementing the technology. While there is no one size fits all solution for new technology an effective technology implementation is contingent on learners' pre existing knowledge, and the instructional goals of the appropriate stakeholders. Nevertheless, novel AR technology and the rapid proliferation of powerful computing tools for the next 10 to 15 years, contained in mobile devices, illustrate a significant shift in learning technology that indeed necessitates more research with AR specific technology. While some benefits and drawbacks have been documented, Augmented Reality is only as suitable as the instructional design and pedagogical constructs used to sustain instruction. Therefore, the permutations of this comparatively novel teaching and learning tool are indeed thought provoking in so far as what the future of mobile computing portents.

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Appendix

Examples applied within Learning Module

Lesson:

Open the AReducation app and point the viewfinder at the programmed Artifacts:

Example Mock-up for an AR "trigger" based content demonstration:

- AR working memory training involves pointing the device's camera at a designated object, and "triggering" a database recall interaction that begins an the AR training.

Mobile Application: iOS

- User feedback is collected based on users that have used the application to complete their classroom work on the LMS site and website for the survey analysis. Participants have the option not to use the application, or use a blended strategy to measure, if AR helps with assessment questions. Google Analytics data is also collected. All data stored on cloud servers is encrypted, and only the researchers have the admin login credentials for the analytics database.
- Google analytics data includes: mobile devices used (what type of phone, tablet being used, model & make, geographic location), time that the application was used and duration, what Augmented Reality interactions were unlocked and for how long.
- Updates are downloaded through a combined application programing interface implementation with the Google Analytics API and software development kit, consent from the participants is required for all data collection, follow-up interviews, and for the AReducation application to be downloaded to any personal iOS device.

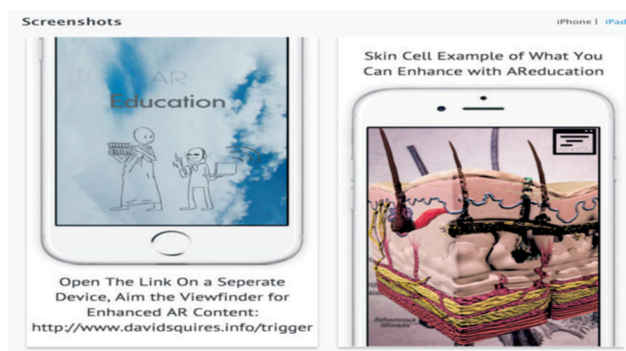

Figure A1. AReducation Application and Learning Module (iTunes App Store) Delivery System

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