

AUGMENTED REALITY INFORMATION OVERLAY MAPPING: BRIDGING THE  
GAP BETWEEN VIRTUAL AND DIRECT LEARNING EXPERIENCES

by

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(Under the Direction of Michael A. Orey)

ABSTRACT

This mixed methods study examined the use of Augmented Reality (AR) information overlay mapping in online instructional design courses, and the impact on participant's working memory. Novel AR technological expansions, and the rapid proliferation of powerful computing tools embodied by emerging mobile and wearable computing devices, illustrates a significant shift in 21<sup>st</sup> century learning strategies. This study may help to increase the body of knowledge on effective AR integration plans, adapted working memory utilization in technology-enhanced classrooms, and the viability of AR assistive devices in online learning domain studies. The influence of information overlays, outside industry specific domains, is relatively under-examined in the literature. AR screen reading applications may have the potential to 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. Applying AR learning technology in online electronic learning environments remains emergent, and yet there are indications in the literature that AR classroom integrations may assist learners to acquire, and to express, knowledge more readily than traditional

online learning techniques alone. Through initial pilot studies, and based on surfacing evidence from the literature, this study investigated whether AR systems provided a uniquely beneficial learning context due to AR's native function to overlay information onto manifold electronic and physical domain settings. While the quantitative data collected in this study was limited due to a minor sample size ( $n=27$ ), the qualitative results indicated that AR users were exceedingly engaged, and recalled content readily; indicating greater student engagement, perhaps due to the novel nature of AR application being implemented in participants online learning classes. The results of the study indicated several qualitative data points that posit something affirmative happened in regards to recall and memory with the AR only group. However, the general combination of qualitative and quantitative data to triangulate a discernible relationship between AR and working memory gains remained inconclusive overall, with very minor to no discernable statistical differences. Future studies with mobile AR implementations are recommended with larger statistically significant participant sample sizes to measure AR's ability to increase working memory and knowledge recall.

INDEX WORDS: Augmented Reality, Mobile Learning, e-Corsi, TLX Cognitive Load Assessment, Working Memory, Cognitive Systems, Mixed Methods

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## DEDICATION

This dissertation is dedicated to William G. Squires Jr., Mary E. Squires, and William D. Squires. Thank you for your encouragement, affection, and support.

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## **Chapter I**

### **Introduction**

Established AR researchers define AR as a technology that allows computer-generated virtual imagery information to be overlaid onto a live direct or indirect real-world environment in real time (Azuma, 1997; Zhou, Duh, & Billinghurst, 2008). AR as a definition combines interactive virtual and programmable content with physical locations, images, learning artifacts, digital spaces, and digital objects represented via a personal computer, or second screen device. 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). Augmented Reality is a collective term that encompasses the integration of digital information with an environment in an instantaneous, or nearly instantaneous manner. Unlike virtual reality, which creates a totally artificial environment, Augmented Reality uses the existing environment and overlays new information.

#### **AR Uses the Existing Environment and Overlays New Information.**

While AR technology may seem relatively new, it has in fact been around for decades in various iterations: “It has been used in fields such as: military; medicine; engineering design; robotic; telerobotic; manufacturing, maintenance and repair applications; consumer design; psychological treatments” (Mehmet, Yasin, 2012). That being said, AR is also constantly evolving and is now at the forefront an innovative tool that can enhance educational content, and can create new types of automated applications

to enhance the effectiveness and attractiveness of teaching and learning for students in multiple pedagogical situations. While educational studies on AR are indeed comparatively limited in the field of education, the technology has finally reached a scalable possibility that its propagation can be used and acquired by educators and learners with relative ease. Similar studies have been conducted with “Quick Response Codes”. These QR codes studies 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, Chiu, 2011).

Augmented Reality takes ‘tagging’ and interactions to a new level according to behavior science studies conducted with AR: Augmented Reality augments virtual information onto the real world with continuous and implicit user control of the point of view and interactivity (Mehmet, Yasin, 2012). As Mehmet and Yasin (2012) point out, AR provides a composite view for the user with a combination of the real scene with overlaid computer generated virtual scenes. This augmentation of the real world occupies an ordinary place, space, thing, or event in a way that is partly unmediated, creating a new approach that enhances the effectiveness and attractiveness of teaching and learning: The ability to overlay computer generated virtual artifacts onto the real world changes the way students interact with content and training becomes real, that can be seen in real time, rather than a static experience (Mehmet, Yasin, 2012). In other words, AR brings virtual content, through a smartphone (most smartphones now have this capability) or any relevant device, and can host virtual content onto a physical space (See figures 1 and 2).

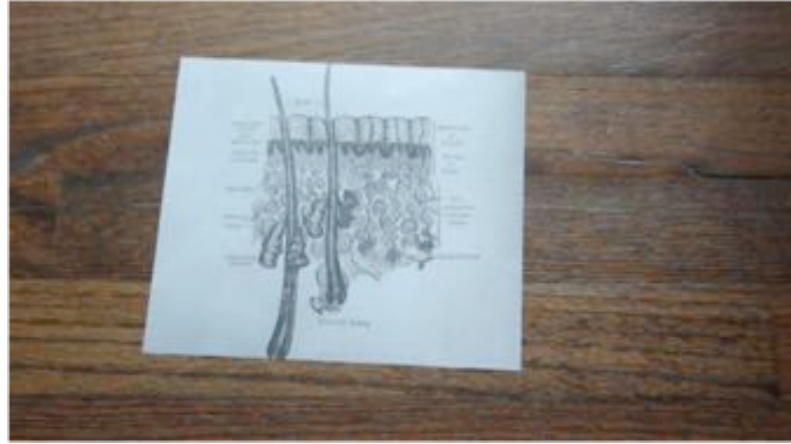


FIGURE 1: EXAMPLE OF A SKIN CELL PRINT OUT FROM A HUMAN ANATOMY PHYSIOLOGY ONLINE TEXTBOOK



FIGURE 2: EXAMPLE OF AN AUGMENTED REALITY APP BEING POINTED AT THE STATIC IMAGE AND A 3D MODEL BEING OVERLAID (iTUNES APP STORE AREDUCTION).

The above figure is an example of an AR overlay hosting that illustrates and conjoins electronic online learning with mobile learning. Namely, by hosting content online via a personal computer, then accessing the content via a mobile device, this interaction arguably enriches the user experience fulfilling a completely novel level of user interactivity. Thus, the possibilities for AR technology combined with education and learning are potentially limitless, tagging static content with audio, video, web links, 3D graphics, and more recently, to enter the collective consciousness: Pokémon. While the

novelty factor and gaming components of AR are well documented, burgeoning research conducted with handheld displays and mobile technology illustrate how AR can potentially revolutionize the way humans interact and absorb learning content in day to day life, and in learning environments (Mehmet, Yasin, 2012). While as researchers, we must be careful not over evangelize innovative technology; that being said, there are strong indicators that AR can be applied, and in many cases, is being applied to learning and edutainment by enhancing a user's perception of and interaction with the physical world. Learners interact with three-dimensional virtual images 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, Yasin, 2012). That is, the notion of a 'Tangible Interface Metaphor' and is one of the important ways to potentially improve learning and make what may have been seemingly impossible possible, such as viewing a skin cell up close without a microscope.

### **Bridging the Learning Gap with AR**

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 3D 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). AR technology can now service as the input device retrieving hosted content from an online learning management database and displaying this content for a learning to digest, interact, and engage with in real-time. AR systems are a powerful tool that can help bridge the gap between student

enjoyment, 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 that is a direct, non-reflective” (Winn, 1993). Ultimately, AR is a direct response to first person content that ties fundamental virtual subject matter to the real learning objects, images, and locations.

Current research indicates that Augmented Reality 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 AR and cognitive learning models may help illustrate how assistive and mobile devices are facilitating learning, potentially increasing learners working memory, and autonomous help-seeking behavior in technology-enhanced learning environments. Previous longitudinal pilot studies utilizing Augmented Reality screen reading applications shows how AR mobile tools 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 results previous pilot research studies show that Augmented Reality applications may offer a uniquely beneficial learning context compared to a traditional computer lab setup due to the nature of the AR application's ability to unlock content anywhere and anytime versus traditional electronic learning methods.

While only a limited amount of information can remain in working memory, AR can potentially help increase this amount through information overlay mapping. Miller’s

theory of working memory when applied to AR may shed light on 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 (Tang, Owen, Biocca, and Mou, 2004).

### **Potential for AR in Education**

Augmented Reality screen reading applications may have the potential to 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. Therefore, the question emerges from the literature whether Augmented Reality applications can provide a uniquely beneficial learning context due to AR's flexibility and ability to 'unlock' content versus traditional eLearning methods. Novel AR technology and the rapid proliferation of powerful computing tools for the next 10 to 15 years, embodied by emerging mobile and wearable computing devices, illustrate a significant shift in learning technology that indeed necessitates more research with AR specific technology. While, Augmented Reality is only as suitable as the instructional design and pedagogical constructs used to sustain instruction, the permutations of this comparatively novel teaching and learning tool are indeed thought provoking.

### **Research Questions**

- Does Augmented Reality have an impact on effective utilization of working memory?
- Is there a predictable correlation between Augmented Reality visualizations and working memory?

- How do participants think or feel about Augmented Reality's use in online learning environments, and if AR is an effective medium for teaching and learning?
- How do participants in the sample explain Augmented Reality's impact on classroom engagement, associative information processing, and working memory?
- Does the quantitative data and qualitative data converge to support a conclusion that Augmented Reality can positively impact associative information processing and working memory?



## **Chapter II**

### **Review of Literature**

The structure of the literature review features the current trajectory of Augmented Reality in the field including the current literature detailing how Augmented Reality has been applied in educational environments; how Augmented Reality has been applied in training environments; how Augmented Reality has been used to measure cognition and the specific instruments used to measure cognitive load with AR; previous working memory testing and foundational working memory practices that might be adapted in order to measure AR's potential impact on working memory; and how AR technology might be adapted to support working memory in future studies. There is evidence in the literature to support the assertion that AR technology can impact working memory and can be adapted to longstanding testing and foundational practices measuring cognitive load, novel iterations of AR in education can also be updated to be mobile friendly, aid in enriching student feedback and provide information on the overall learning experiences of the student. According to Dunleavy and Dede, (2013) AR is an instructional approach looking for the context where it will be the most effective tool amongst the collection of strategies available to educators. While AR's commercial aspects have recently become well documented with appearances of AR in popular mobile games such as Pokémon Go - reaching a collective download user total never before seen via Apple's mobile app distribution platform iTunes (Roman Dillet, 2016). The educational affordances of

Augmented Reality are still emerging in the literature as an encouraging instructional permutation for the future of learning.

### **Augmented Reality's Trajectory**

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). Although there has been much speculation about the potential of Augmented Reality (AR), there are very few empirical studies about AR's effectiveness in regards to online learning and conventional learning spaces. Researchers posit that while relatively few empirical studies, and development teams, are actively exploring how mobile, context-aware AR could be used to enhance teaching and learning an AR review of studies research team reported that AR implementations can result in substantial student motivation (Dunleavy and Dede, 2013). The MIT Scheller Teacher Education Program, the Augmented Reality and Interactive Storytelling (ARIS) Group at the University of Wisconsin at Madison, the immersive learning group at the Harvard Graduate School of Education, and the Radford Outdoor Augmented Reality (ROAR) project at Radford University have all used AR in some form of design-based research (DBR) approach to explore the feasibility and practicality of using AR in an environment for teaching and learning (Dieterle, Dede, & Schrier, 2007; Klopfer & Squire, 2007; Dunleavy & Simmons, 2011; Martin, Dikkers, Squire, and Gagnon, 2013).

### **Augmented Reality in Education**

AR technology in schools is an important factor to consider because AR integration in academic environments have revealed learning experiences that are

associated with directly relevant content (Bujak, Radu, Catrambone, MacIntyre, Zheng, and Golubski, 2013). Student motivation and the novelty effect of AR is a component that can also impact AR integration, if AR is effectively adapted to student learning environments by allowing slower students more time, and usually providing them with tutoring or other special assistance (Wentzel & Brophy, 2014). Researchers have striven to apply AR to classroom-based learning within subjects like chemistry, mathematics, biology, physics, astronomy, and to adopt it into augmented books and student guides (Lee, 2012). Furthermore, studies have also document that learners are highly engaged while playing mobile Augmented Reality learning games (Chang, Morreale, and Medicherla, 2010; Bressler and Bodzin, 2013). On the other hand, researchers estimate that AR has not been much adopted into academic settings due to limited financial support from government funding and the general lack of awareness of AR in academic settings (Shelton, 2002; Lee, 2012).

AR may help enable elaborate rehearsal of learners' related prior experiences and knowledge with superimposed information (Estapa & Nadolny, 2015). Researchers 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: The result supports prior research showing that the use of AR in classroom contexts can increase motivation (Estapa & Nadolny, 2015). Interacting with AR-based learning experiences, documented by Bujak, Radu, Catrambone, MacIntyre, Zheng, and Golubski (2013), noted that AR experiences leverage situated cognition, by allowing the student to connect to the virtual educational content by simply pointing a camera at their environment, whether inside or outside the

classroom. This ease of access is highly beneficial to students because contextually relevant information can be procured to satisfy the student's interest. Johnson, Smith, Willis, Levine, & Haywood, (2011) specified that Augmented Reality implementations have a strong potential to provide both powerful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world.

Other instances of AR applications in the education domain are the increased motivation, engagement activity of learners, and the overall cost and safety. According to Wojciechowski and Cellary, (2013), AR environments allow learning content to be presented in meaningful and concrete ways including training of practical skills. AR technology has been documented in trial and Project Based Learning environments, where complex chemical reactions and expensive materials can be substituted for simulations and image-based AR environments can be used for a broad spectrum of chemical experiments without having to make changes to the physical configuration of the installation. According Wojciechowski and Cellary, (2013) an AR application takes up much less space and costs less than a typical workbench for chemical experiments, and does not require any special chemistry laboratory infrastructure. The advantages of using Augmented Reality to improve training versus Virtual Reality and other web based tools, is the time and cost for developing virtual scenes is removed because the scene is a real one where content is overlaid onto the scene and the participants can see the environment around them; whereas VR removes the learner from the context and only simulates the experience (Azuma, 2007).

Furthermore, studies investigating learners' collaborative knowledge construction performances and behavior patterns in an Augmented Reality simulation systems recorded that AR has the potential to markedly increased student knowledge gains (Chang, Morreale, and Medicherla, 2010). Studies have found that the AR supported students perform with increased proficiency due to the representation of the concept; attributing that the AR system may serve as a confirmatory tool and enable learners to respond quickly to the displayed results and support their knowledge construction processes (Lin, Duh, Li, Wang, and Tsai, 2013). The suggestion that AR can potentially increase motivation is also poignant catalyst to assist learners with elaborative rehearsal strategies and may aid in increasing working memory (Lin, Duh, Li, Wang, and Tsai, 2013).

Researchers utilizing a mixed methodology approach to Augmented Reality in science education settings found that AR may result in different affordances for science learning (Cheng and Tsai, 2013). Cheng and Tsai (2013) note that image-based AR often affords students' spatial ability, practical skills, and conceptual understanding. Furthermore, effective 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 by probing learning processes through the methods of interviews, observations, or videotaping analysis, on how students structure the scientific thinking and knowledge in AR-related learning activities could be better understood. According to Cheng and Tsai (2013) these qualitative methods have been commonly utilized in AR-related studies, but there is a need to apply mixed method analysis to attain in-depth understanding of the learning process.

During a mixed methods assessment of students' flow experiences during a mobile Augmented Reality science integration researchers found that while AR may be a technology lacking in extensive research for education, it was determined that its potential as a scalable design for schools was very stable (Bressler and Bodzin, 2013). That is, AR minimized player frustration and may have increased enjoyment reducing cognitive overload (Bressler and Bodzin, 2013). Lee (2012) found that Augmented Reality lowers the barrier to entry for students engaging with virtual content, as it makes use of natural interactions that allow students to interact with educational content. It is highly likely that AR can make educational environments more productive, pleasurable, and interactive than ever before. According to Lee (2012) AR not only has the power to engage a learner in a variety of interactive ways, that have never been possible before, but also can provide each individual with one's unique discovery path with rich content from computer-generated three dimensional environments and models (Lee, 2012). That is, learners can select virtual objects by pointing to them, they can reach out to touch and move objects. Since AR permits these interactions, there is a reduction in the knowledge and skills required of users, increasing the transparency of the interface between students and the educational content (Bujak, Radu, Catrambone, MacIntyre, Zheng, and Golubski, 2013).

### **Augmented Reality and Workplace Training**

According to Neumann and Majoros (1998) AR can endow novices with some of the advantages enjoyed by experts: Such as an efficient retrieval of information from their working memory, regardless of the situation they may find themselves. Neumann and Majoros findings suggest that AR provides this expert status in two ways. The first is

simply the basic effect of AR triggering and recalling information with little user effort, by simply aiming the device. Maintenance and manufacturing experience is filled with evidence that people favor information that is easy to access and tend to use more salient data in decision making (Neumann and Majoros, 1998). Secondly, the researchers also found that AR's composite scenes are analogous to the spatial, graphical user interface (GUI) that is standard with personal computer use. The interface model became the standard expression for desktop use for at least two reasons: First, through direct manipulation metaphors, the GUI eliminated users' need to control functions via arcane textual language, and second (and especially relevant to AR), its desktop metaphor presented a spatial layout to the user icons and working spaces can occupy regions (often called "real estate") of a display. As Neumann and Majoros (1998) point out the GUI allows users to associate functions with spatial locations, it aids visual recognition (e.g., "similar look and feel" of various applications), and it elicits behavior, such as dragging and interacting with buttons" (Neumann and Majoros, 1998). AR's capacity to overlay new information through a very simple GUI allows subjects to recall and order items and integrate the meanings of multiple of items by only having a consistent spatial origin (Neumann and Majoros, 1998). Therefore, tasks that are normally guided by reference to some documentation may be excellent candidates for improvement with AR.

Tang, Owen, Biocca, and Mou, (2003), found that Augmented Reality in object assembly indicated decreased mental effort for participants that used AR, suggesting some of the mental calculation of an assembly task are offloaded while using Augmented Reality overlays. Participants reported that using Augmented Reality overlays were less mentally demanding: The findings are consistent with the model that AR may reduce the

amount of mental manipulation required. Tang, Owen, Biocca, and Mou, (2003) posit that since participants did not have to mentally transform objects, and keep a model of the relationship of the assembly object to its location in their working memory, they experienced less mental workload (Tang, Owen, Biocca, and Mou, 2003).

### **Working Memory**

Working memory is often described, since George Miller's publication in 1956, as seven plus or minus two chunks of information (Miller, 1956). Only a limited amount of information can remain in working memory, but AR can potentially help increase this amount through 'chunking'. George Miller's principle is still appropriate today and can be applied to AR to promote efficient learning and long-term retention (Miller, 1956). It is generally believed that baseline human working memory capacity is limited (Clark, 2008). When information is first presented to an individual, it is retained almost intact for a brief period in the person's sensory store: Information is then read from the sensory store into the short-term store or working memory (Proctor and Van Zandt, 2008).

Information in the working memory decays very rapidly unless it is kept active through rehearsal or covert repetition of the items read from the sensory store (Wang and Dunston, 2006). For many tasks, precise performance requires not only that relevant information be recollected in the short-term store, but also that the information be acted upon quickly. Therefore, the limited capacity of the short-term store has implications for any task or situation in which successful achievement of a task requires the learner to encode and retain information accurately for a long period of time (Wang and Dunston, 2006). Cognitive psychology reveals that the accuracy of retention can be increased by increase actives that allow for rehearsal with new information (Kaufman, 2010). It is also



recognized that the more items that are stored in working memory, the longer the time a person needs to retrieve a desired item of information. Minimizing the reliance on memory focuses the use of cognitive resources on other tasks. This is important, largely because cognitive overload can result in a significant increase in the number of errors on a given task (Kaufman, 2010).

### **Working Memory Measures**

Working memory involves processes such as attending to, holding, and mentally manipulating information (Lawlor-Savage, and Goghari, 2016). Studies reporting performance based working memory gains in tasks such as digit span, Corsi block tests and reading span, indicate that a variety of tasks have been used as measures of working memory, but some of the most widely used measures within cognitive psychology are the complex span tasks (Foster, Shipstead, Harrison, Hicks, Redick, and Engle, 2014). Using three established complex span tasks Foster, Shipstead, Harrison, Hicks, Redick, and Engle (2014) measured working memory where subjects are given a sequence of ‘to be remembered items’ such as a sequence of letters, while the subjects must also complete a distractor task, such as solving a math problem, between the presentations of each ‘to be remembered item’ in a sequence (Foster, Shipstead, Harrison, Hicks Redick, and Engle, 2014). Foster, Shipstead, Harrison, Hicks Redick, and Engle, (2014) describe a number series task as sequence of numbers that follow a logical pattern (1, 2, 3, 5, 8, 13, 21), then the subject’s task is to choose from five available options the next number in the sequence. Working memory task procedures require participants to remember numbers, objects, or symbols in a row often matching (Lawlor-Savage, and Goghari, 2016). In this way, working memory testing might also be applied to Augmented Reality applications,

where participants are asked to aim a device viewfinder at AR triggers in a succession and report on the tagged content that is overlaid. Symbols in working memory procedures are often presented as self-paced, and once a response is recorded the next symbol appears (Lawlor-Savage, and Goghari, 2016). In theory, this procedure could be adapted to an AR system where participants aim at the tagged content and then move on the next image in a succession.

Studies based on increased memory load during task completion, when procedures are presented on mobile screens, founded that the National Aeronautics and Space Administration's Task Load Index (TLX) evaluation instrument indicate some advantages and disadvantages of mobile devices impact on working memory, procedural task performances and information flow among NASA technicians (Byrda and Caldwellb, 2011). Subjects in the study began the session by completing a participation consent form, and a participant Pre-evaluation and demographic questionnaire (Byrda and Caldwellb, 2011). The purpose of the questionnaire was to collect general demographic information and the experimental task for the study was adapted from a task used in summer educational programs introducing K-12 students to science, technology, and engineering and mathematics experiences (Byrda and Caldwellb, 2011). Before the experiment began, a window area of a Dell desktop monitor was adjusted to simulate one of the three screen sizes mobile, tablet and desktop (Byrda and Caldwellb, 2011). The document window size was adjusted after each task section and the screen resolution remained constant throughout the experiment; however, the procedure was specially formatted for each of the three window sizes for ease of viewing (Byrda and Caldwellb, 2011). The same monitor was used in each screen size condition, to control for

preferences that might result from distinct features or characteristics of using three different small-screen devices (Byrda and Caldwellb, 2011). The National Aeronautics and Space Administration's Task Load Index test, adapted from Hart, and Staveland, (1988) was administered to measure the multi-dimensional rating procedure and to derive an overall working memory workload score based on an average rating of six subscales: mental demands, physical demands, temporal demands, own performance, effort and frustration (Byrda and Caldwell, 2011). This study is noteworthy because it offers a bridge that may also fit into AR research. Specifically, in AR related tasks participants often use a mobile device with limited screen size. However, this study does differ in the sense that instead of using a computer and then performing a task, participants would be aiming the mobile device's view screen while also performing a task with the device. Nevertheless, the TLX working memory procedures involved has been effectively adapted to an AR environment, as Tang, Owen, Biocca, & Mou, (2003) have illustrated.

Further studies based on span tasks and measuring working memory during task completion include the Corsi Block Test. The Corsi Block Test is now a widely-used assessment used in clinical and research contexts to measure visuospatial attention and working memory (Corsi, 1972). The Corsi Block Test requires participants to reproduce a sequence of movements by tapping blocks in the same serial order an examiner did on a board containing nine blocks at fixed, and random positions. As the test procedure progresses, the number of blocks in the sequences progressively increases. Moreover, the Corsi Test also requires participants to remember the serial order of the blocks in the sequence. Current literature indicates that there is no difference between an online e-Corsi Block Test and a traditional block test (Claessen, Van der Ham, & Van

Zandvoort, 2014). Findings suggest that a computerized version of the Corsi Block Test using an Internet capable mobile device or personal computer and then comparing performance on this task to the analogous scores on the standard Corsi Task among participants. In fact, because computerization of the Corsi Task leads to a more standardized administration, as compared with the standard version: Practical advantages of the computerized Corsi Task include strict application of the presentation duration of the block sequences and automatic scoring (Claessen, Van der Ham, & Van Zandvoort, 2014). As the computer takes over both the stimulus presentation and scoring procedure that were previously carried out by an examiner, using the e-Corsi instead of the standardized version results in a shift of the researcher's role in this task: from administrator to observer (Claessen, Van der Ham, & Van Zandvoort, 2014).

### **Working Memory and AR Instrumentation**

Tang, Owen, Biocca, & Mou, (2003) employed the cognitive workload measurement adapted from NASA TLX, whereby they utilized the TLX instrument to specifically measure an Augmented Reality object assembly task. By adapting the TLX instrument to object assembly and having students' rate categories to measure working memory and overall cognitive load Tang, Owen, Biocca, & Mou, (2003) were able to gather data on Augmented Reality's impact on cognitive load and its impact on working memory. According to Tang, Owen, Biocca, & Mou, (2003) working memory and cognitive load measuring instruments can be adapted and applied to AR tools allowing, in the NASA TLX example, users to self-report on their cognitive load by detailing their use with the AR enabled device, and their overall interactions in the enabled contexts. The TLX instrument measures cognitive load and the impact on effective working memory

utilization (Hart, and Staveland, 1988). As Cheng and Tsai (2013) illustrate, the learning experience has only been discussed in relatively few AR-related studies, especially in image-based AR applications: Following the issues of learning experience, an investigation of learners' responses to cognitive load and working memory could be incorporated into image-based AR studies in the future.

### **Augmented Reality & Working Memory**

The findings from Juan, Mendez-Lopez, Perez-Hernandez, & Albiol-Perez (2014) working with Augmented Reality illustrate that learners' Pre-and posttest results with AR displayed a pronounced amount of memory improvement providing evidence to support the proposition that AR systems may improve task performance and can relieve mental workload. Outcomes demonstrated age-related spatial memory improvement when the researcher's setup boxes distributed in a circle where the different learner groups could travel to each box and point the device inside where some AR content was programmed and in others where it was not, then the learner would recount what was inside and the location after aiming the handheld AR device inside (Juan, Mendez-Lopez, Perez-Hernandez, & Albiol-Perez, 2014). According to Juan, Mendez-Lopez, Perez-Hernandez, & Albiol-Perez, (2014) AR systems have already proven their potential in the education field with the ability of AR enabled courses to potentially enhance learner's cognitive ability, their response to behavioral demands, and increase working memory.

Studies conducted with Augmented Reality tools to specifically measure working and spatial memory have suggested that AR enabled environments have a positive impact on participant's memory recall ability (Tang, Owen, Biocca, and Mou, 2003). Assistive devices, with the capacity to access a worldwide compendium of knowledge from the

Internet indeed facilitate human's abilities to recall knowledge and aid memory by assisting and easing cognitive loads via overlaying content access with instantaneous content that can now, via a mobile device, display information visually, three-dimensionally, and with audio visual properties (Jaeggi and Buschkuhl, 2008; Caballe, 2010; Cheng and Tsai, 2013). AR technology can attach required information to the learner's physical worldview of a task, releasing part of the working memory to support user tasks in newly experienced or complex environments (Proctor and Van Zandt, 2008). An AR system can also help build up an enduring cognitive map and support a human's ability to comprehend spatial relationships (Proctor and Van Zandt, 2008). AR technology attaches the required information to the user's worldview of the task, releasing part of the working memory occupied by the information items, and therefore facilitate efficient retrieval of information that must be obtained from memory (Proctor and Van Zandt, 2008). Placing virtual objects in the context of real locations makes the objects subject to particular human abilities, and one of the most critical of those abilities is according to Proctor and Van Zandt, (2008) spatial cognition. By spatially relating information to physical objects and locations in the real world, AR technologies can support working memory (Proctor and Van Zandt, 2008). It is suggested that an experimental design for examining students' learning experience (e.g., working memory) by different instructional designs, either in location-based AR or in image-based AR studies, be developed in future studies (Cheng and Tsai, 2013). While the literature points to possible uses of Augmented Reality as tool for engagement, motivation, training, and working memory aid, the future for AR as an instructional platform remains to be conducted in AR studies in the future (Cheng and Tsai, 2013).

### **AR Learning Experiences**

Effective cognitive load reduction frees up more processing power to focus on learning tasks. While additional research is needed with Augmented Reality specific implementations in education and learning environments in general, it is possible to hypothesize that a user response to simulated AR environments and customized trigger effects may reduce cognitive load, and promote effective working memory utilization potentially positively impacting associative information processing and working memory in the process. For students to effectively adapt to procedural knowledge in near transfer, and changing knowledge scenarios in far transfer, cognitive load measurements help to shed light on Augmented Reality's impact on effective utilization of working memory. By examining students' learning experiences, working memory, and cognitive load with AR applications, the study herein measures if learners remember what they learned, if they can recognize and apply what they learned more effectively while using AR overlays in online classrooms, and if learner's utilization of AR has an impact on their working memory based on e-Corsi measurements. Grounded by a review of the literature, this AR study incorporates multiple methods and strategies in an attempt to elucidate what impact, if any, Augmented Reality may have on working memory utilization in higher education.

## **Chapter III**

### **Methodology**

The AR-education study sought to identify the effects of Augmented Reality information overlays applied within an online learning environment and the potential results of efficient information access on human associative information processing and working memory. The purpose of the study was to measure the outcome of assistive information and content overlays on information processing and working memory capacity. Due to the unique ability of Augmented reality to decipher and overlay digital content onto physical and virtual spaces it is reasonable to hypothesize AR can potentially prompt a learner's transition from novice to unaided expert by reducing potentials for error via efficient information access. This study followed previous studies conducted with Augmented Reality tools to specifically measure working and spatial memory (Tang, Owen, Biocca, and Mou, 2003; Juan, Mendez-Lopez, Perez-Hernandez, & Albiol-Perez, 2014). Previous research has posited that AR enabled environments may have a positive impact on working memory and learners recall ability (Tang, Owen, Biocca, and Mou, 2003; Juan, Mendez-Lopez, Perez-Hernandez, & Albiol-Perez, 2014).

The AReducation study followed previous research-based Augmented Reality methodological studies by integrating a mixed methods approach to Augmented Reality data collection in order to triangulate survey data, application analytics descriptive statistics and direct participant feedback (Bressler, and Bodzin, 2013). Due to the novel



nature of AR applications in learning applications the novelty effect often requires more detailed participant continuation than quantitative data alone can often elucidate (Bressler and Boszin, 2013). Therefore, the primary methodology for this study was based on Creswell and Clark's convergent mixed-method design to integrate descriptive quantitative and qualitative results to generate a larger picture for a phenomenon by comparing multiple methodological intensities within a single research study (Creswell and Clark, 2011). Furthermore, the convergent mixed-method design was employed in order to provide an inclusive degree of triangulation: Quantitative and qualitative results are combined into a more complete understanding of a phenomenon and assist in comparing multiple levels of a phenomena within a longitudinal study (Creswell and Clark, 2011). A convergent sequential mixed methods design will be used to collect quantitative descriptive statistic data first, and then clarify the quantitative results with in-depth qualitative data (Creswell and Clark, 2011). Previous longitudinal collection cycles have taken place through semester long collections beginning in the Fall semester of 2014 with IRB approval (See Appendix B). 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 increase information processing, spatial cognition, and working memory capacity. The second qualitative phase was conducted as a follow-up to the quantitative results with in the same semester to help explain the quantitative results and the potential for pedagogical applications in online learning, mobile learning and beyond. In the convergent mixed method data collection cycle, participants explored whether the

dynamic nature of AR enabled environments and custom digital overlays had an impact on their spatial cognition and working memory in online learning environments. These results appeared to support the hypothesis that AR does have a positive impact on working memory. These aforementioned procedures will be further refined and re-implemented with an updated data collection and design beginning Fall, 2016.

### **Research Questions**

#### **Quantitative**

- Does Augmented Reality have an impact on effective utilization of working memory?
- Is there a predictable correlation between Augmented Reality visualizations and working memory?

#### **Qualitative**

- How do participants think or feel about Augmented Reality's use in online learning environments, and if AR is an effective medium for teaching and learning?
- How do participants in the sample explain Augmented Reality's impact on classroom engagement, associative information processing, and working memory?

#### **Integration of Qualitative and Quantitative**

- Does the quantitative data and qualitative data converge to support a conclusion that Augmented Reality can positively impact associative information processing and working memory?

## **Research Design**

The framework developed in initial pilot testing (See Appendix B) suggests Augmented Reality may have an impact on working memory and students' ability to recall information in online learning environments. For detailed step-by-step instructions of the course design and overall schema for the conceptual AR triggers and interaction model see Appendix A and B. While there is limited research that has been conducted on Augmented Reality's influence on working memory in education settings, studies conducted with Augmented Reality on object assembly, manufacturing, and guided cognition have been done (Neumann, and Majoros, 1998; Tang, Owen, Biocca, & Mou, 2003; Azuma, 2007; Byrda and Caldwell's, 2011). Following the methodology of Tang, Owen, Biocca, and Mou, (2003), on intact groups task assembly I will adopt their methodology for comparative effectiveness of Augmented Reality in object assembly but for learning tasks in an online classroom. These methodological components include rendering tasks such as using an Augmented Reality overlay device to convey information, to aid in task completion, measure working memory perception, and to measure perceived mental workload that is observed by groups of participants. For example, the questions will consist of: "How Frustrated were you?" & "How hard was the concept to Learn"? A working memory base line test will be gathered using a web based e-Corsi block test memory plot, followed by retaking the e-Corsi at the conclusion of the study (Claessen, Van der Ham, & Van Zandvoort, 2014). Cognitive workload measurement adapted from the National Aeronautics and Space Administration Task Load Index (See Appendix F) will follow Tang, Owen, Biocca, and Mou's (2003) use of the same instrument to measure Augmented Reality in object assembly. Since

Tang, Owen, Biocca, and Mou (2003) used the instrument in task assembly the AR study herein will adapt two key questions from the instrument. The TLX instrument will be formatted in a responsive design to be mobile friendly and the applied instrument will be incorporated in a Master's level online learning classroom course specifically targeting cognitive load, and AR's impact on effective utilization of working memory through information overlay chunking.



FIGURE 3: SIMPLE HUMAN INFORMATION PROCESSING MODEL (ADAPTED FROM PROCTOR AND VAN ZANDT, 2008).

The information flow for performing AR tasks was illustrated by hypothesized processing subsystems (See Figure 3). This process may assist in identifying the mental operations that take place in the processing of various types of information from input to output with the AReducation application developed and hosted in the Apple app Store. Subjects will be directed to rate categories to measure cognitive load including: Mental demands and frustration levels based on the participants reported experiences and document their experience using a modified Likert scale (Hart, and Staveland, 1988). Initial piloted research designs suggest that AR systems can be shaped to minimize cognitive load by developing different working memory encodings and maximizing the efficiency of attention allocation (Dunston and Wang, 2006). The information-processing

scale provides a basis for analyzing the AR task components in terms of participants' cognitive demands and action processes by investigating how hard the concept was to learn with AR and without AR:

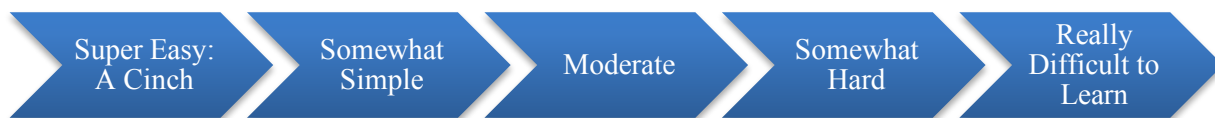


FIGURE 4: LIKERT MODEL EXAMPLE OF PARTICIPANT RESPONSE OPTIONS

### **Research Site**

Participants were recruited from two Fall 2016 three credit hour domain-specific Master's level technology courses under direct supervision of a faculty advisor. The sites characteristics are based on users who would potentially implement novel technology in an educational technology enriched learning environment. Access to the research site for this study was semester long, and followed collections for semester long sessions and three selected interviews with participants. Sampling included the entire registered students each course. The selection of participants and the criterion for interviews was based on survey feedback response questions and embedded Google Analytics SDK data showing user feedback timing and task completion rates.

### **Participants**

The study used a convenience sample, wherein the study's participants were chosen based on their pre-existing enrollment in two online learning courses (Patton, 2014). Participation in this case was voluntary and participants were further selected based on

several specific qualifying factors (See Appendix C). The courses selected for data collection were domain-specific technology courses, targeted towards working professionals and Master's students in Instructional Technology and Design who were also learning about technology integration strategies, with potential access to a mobile iOS device. Participants first answered an initial survey to determine qualifying and disqualifying traits to participate in each in two groups. Participants were placed in group 1 if they do not have an iOS device, and participants were selected for Group 2 based on their self-reported ability to obtain a mobile iOS device, along with participant's capacity to point their AR enabled device at learning content and answer knowledge transfer feedback questions in a succession. The survey instruments were designed with the mentioned discriminating factors in mind to limit participation in the AR group 2 to only those who had a mobile device and could download an iOS application from iTunes.

While the participants completed the initial surveys embedded software analytics recorded user's responses, timing, unique device identification, and time spent on each question. Group 2 had access to a visual companion AR course online ([piazza.com](http://piazza.com)), which contained AR visualization tasks involving the AR reader application's custom course content. This content was Instructional Design domain specific and after consent was granted by the participant triggered participants are prompted to download the app (if in group 2) and aim at the Augmented Reality enabled course content (See Appendix E for detailed descriptions of AR content and the Non-AR content). The AR course employed a variety of visual and cognitive variables, such as superimposed or "floating" 3D and auditory stimuli, that could only be accessed within the AReducation application framework, and when the handheld Augmented Reality reader's device camera was

pointed in the vicinity of the external content trigger image. The follow steps illustrates the guidelines for participation in the study:

- a.** All participants complete the Pre-survey and complete the e-Corsi block test.
- b.** Around half of the participants download an Augmented Reality application developed by the researcher published in iTunes:  
  
<https://itunes.apple.com/us/app/ared/id841114342?mt=8>
- c.** The application synchronizes with the research & development plan and provides access to a follow up survey instrument, and a working memory utilization metric to measure Augmented Reality's potential influence on cognitive load and effective working memory utilization.
- d.** All AR users completed an TLX cognitive load survey for non-AR and AR course work.
- e.** All AR users completed an open-ended AR survey
- f.** All participants and users completed a final e-Corsi
- g.** Three AR users were selected based on the AReduction app's embedded Google analytics SDK and initial descriptive statistical outputs helped to identify outlying and standard median defined responses. Narrative analysis was conducted that selected attitude statements and magnitude coded responses based on three AR users selected for the 45 minute interviews.

The rationale for the initial survey was to differentiate if participants were able, or willing, to participant in the study at all, and to place participants into Group 1 / Group 2, and apply qualifying questions in order separate course groups into iOS and non-iOS user groups. Group 1 attempted in class tasks on their normal course site modules without the

AReducation iOS app. While Group 2 downloaded the AReducation app from iTunes (See Appendix A) and completed the same tasks using an AR overlay trigger interface. AR users also had access to a supplementary AR trigger based LMS with more in-depth Augmented Reality trigger interactions for their assigned online classroom modules (See Appendix E).

### **Data Collection**

The data collected by mixed method inquiry utilized surveys and the unique ability of the Augmented Reality (AR) application-programming interface to collect data via the embedded application programming interface, Google analytics, and time on task based selection for in-depth interviews. Data was also gathered via surveys, LMS course application data and interviews in the two Master's level instructional technology courses. Two intact groups of students from two courses were measured, the ones that download the AReducation application and the ones that do not and completed course content only via the LMS. The group that did not download the application was asked to participate in a survey based on their learning tasks and content transfer without the app. The other group utilize the AReducation app downloaded from the Apple iTunes store. The application graphical user interface displayed AR learning overlays, and embedded software development kit began collection with the AReducation group as soon as the participants downloaded the AReducation app. Both groups answered TLX cognitive load questions after using the app and after completing the LMS course modules. Initial survey data was collected by Qualtrics, and all follow up interview data was collected using audio and visual recording software.



After baseline selection, participants were enrolled in a course hosted on the Learning Management System Piazza. The course LMS collected user information related to user feedback, posts, completion of coursework, and time spent using the custom AR study website and mobile device in combination to unlock Augmented Reality assigned tasks. Embedded analytics data was collected and sent from within the app itself using the SDK from the iOS AReducation app platform. The Augmented Reality communication that was unlocked, and the timing for each interaction, was accessed by the application internally from an enabled database, therefore an Internet connection, or minimal cellphone data, was also required to tether Internet to a working iOS mobile device. All AR interactions were uploaded with the AReducation app and an extensible markup language (XML) compression file via an Apple iTunes Connect developer account. The AR packet contained uniform resource location data, audio, video, flash and three-dimensional object reference content that was tracked and analyzed using the Google analytics software development kit and API embedded within the AReducation app itself (See Appendix A).

### **Data Analysis**

Data quality was assessed based on the attempt to develop a multivariable data set employing mixed-method techniques to attempt to facilitate methodological triangulation (Perlesz & Lindsay, 2003).

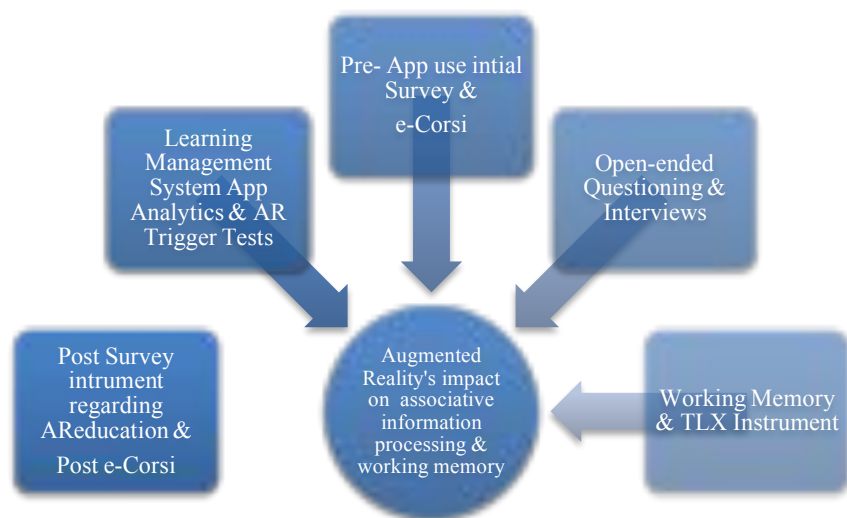


FIGURE 5: DATA TRIANGULATION

The data analysis process integrated multiple rounds of data collection and analysis within participant grouping cycles of group 1 and group 2, those with iOS devices and those without. Each participant set was combined into the results table representing any potential inferential statistical findings. The first round of data analyzed included the initial survey data using descriptive statistics. The data was imported and analyzed using mixed method data analysis software MAXQDA 12. The rationale for utilizing MAXQDA included the importing of statistical data in conjunction with in-vivo, or within the text, lexical coding at the end of the study for in depth interviews and open-ended textual responses and side by side coding. This allowed for the incorporation of statistical data, means, standard deviation, percentages etc., but also included a mechanism for adding quantitative coding, while including themes and lexical search results from qualitative interviews and open-ended survey responses (Creswell, 2015). The qualitative data was coded based on a categorical analysis of the lexical search words from transcripts in Microsoft Word and coded according to captured analytical data and

self-reported instrument responses. Measures were included to gauge frustration levels, how difficult it was using the AReducation application to learn the course concepts and how the participants perceived cognitive load and effective working memory utilization. Working memory measures were documented by comparing the pre-and-post e-Corsi measurements. AR users were selected for interviews based on median time on task using the AReducation app. The textual responses were validated with member checking, by asking the participants whether the summaries of their responses were factually correct: Aiding in creating a qualitative audit trail (Marshall and Rossman 2011).

The inferential quantitative phase of the study served to regulate the point of central tendency and variability, including the mean scores and standard deviation measuring the alignment with participant groups textual and verbal responses (Creswell, 2015). Interviews and open-ended question data aided in further refining and coding using lexical searches, theme identification and memos according to transfer of knowledge while using the application and while not using the application: the data was combined with the numerical data from surveys, Likert scale responses, Google analytics, and the LMS statistics in a descriptive and inferential statistical table to potentially support triangulation with the survey data and cognitive load measuring instruments for AR. A conceptual model following Creswell, and Clark's (2011) triangulated convergent parallel design was developed during several previous pilot studies (appendix A) to represent the quasi-experimental quantitative data collection and the qualitative data collection cycle integrations within the study herein.

### **Validity and Reliability**

The values that qualitative inquiry encompasses acknowledges a triangulated, comprehensive paradigm, and provides a mechanism for detailing and relating personal insight into the thoughts, ideas, and complex expressions that learners have when experiencing and participating with novel tools and learning technology: Namely, the value of qualitatively supplemented mixed methods research can help to capture the multifaceted nature of educational research (Hall & Ryan, 2010). By following up with in-depth interviews and observations, the goal was to analyze whether mixed methods would facilitate integration and interpretation among multiple complex dimensions that coincide with Augmented Reality technology, learning domain applications, and the measurement of participants near and far term transfer; what they remember learning, the application of that learning, their frustration levels, and difficulty learning the concept with and without AR tools. Following Creswell's (2014), convergent mixed method design, qualitative interviewing and direct questioning were employed in order to explore with the participant's, their individual perspective and understandings. Mixed method inquiry that communicates both quantitative survey data and qualitative in-depth interview data may aid in triangulation. A convergent design was selected to complement the quantitative data collected via surveys, e-Corsi working memory assessment, Augmented Reality Experience Language (AREL) application analytics, time on task measurements, TLX assessment data and the and embedded Google application programming interface (See Figure 6):

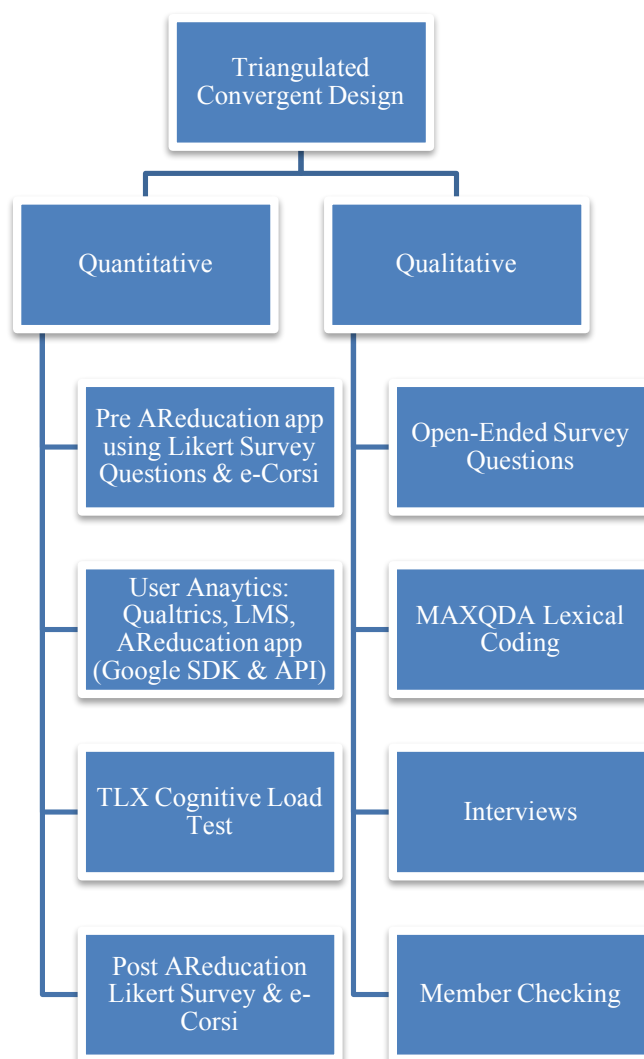


FIGURE 6: TRIANGULATED CONVERGENT DESIGN

### Timeline

TABLE 1: INTRODUCTION TO ANALYSIS PHASES TABLE

<b>Timeline</b>	<b>Instrument</b>	<b>Method</b>	<b>Data Analysis</b>
<b>September 2016</b>	Pre AReduction App Survey & e-Corsi Data Recording Groups 1 & 2	Quantitative	Descriptive Statistics, Averages, Standard Deviation
<b>September –October 2016</b>	Open Ended Response Posts & AReduction Application AREL Data & Google Analytic Data for Time on Task and Student Identification Matching - Group 2	Qual/Quant	Averages, Standard Deviation; Time Of completion
<b>September -November</b>	TLX Cognitive Load Test Groups 1 & 2	Quantitative	Descriptive Statistics, Mean, SD; Time to Complete Task
<b>November</b>	Post e- Corsi & Test Survey	Quantitative	Descriptive Statistics, Mean,

	Application Analytics and LMS data Group 1+2 only (ELC course data, Qualtrics, App AREL, Google SDK)		SD; Perceived Task Workload
<b>December – January 2016-2017</b>	Interviews  Group 2	Qualitative	Interviews imported from Microsoft word into MAXQDA 12: Lexical Search of texts

### **Maintaining Confidentiality**

Consistent with the Internal Review Board standards, all participants were provided with an informed consent choice that was collected at the initiation of the study. Stages of the data collection took place throughout the study in order for the AReduction application to be unlocked, and auxiliary trigger content to be transferred to participant's iOS devices. Only the research team had access to the participant's name and contact information. All interview names and data were later replaced with a unique user identification number (UUID) or qualitative code symbol. All interview data was voluntary, and participants could still complete the survey, download the app, and decline the follow up interview.

The Google analytics application programming interface embedded in the AReduction application identified the approximate amount of time the user uses the app, and the device used (iPhone vs. iPad), and was a personally identifiable item recognized, unless users choose to reveal that information in their surveys. No data was accessed from the AReduction app's social media integration (this included friends list, messages, or anything else related to social media). Participants could choose not to participate at any time if they felt uncomfortable with any of the data collection identifiers (See Appendix B).

There was a limit to the confidentiality that could be guaranteed due to the technology itself. Online data was kept to make sure that the survey data was indeed from legitimate sources (not spam or the same individual repeatedly sending information). This information could theoretically identify an individual using an Internet Protocol log, but to account for virtual private networks and changes to Internet protocol addresses, some type of personal identification was needed for about one year during the data collection cycle to match LMS data, Google SDK, survey logs, website logs and self-identified email addresses. After completion of the online surveys, and once user legitimacy was matched throughout collection sources, any identifying data was de-identified and destroyed. In fact, all user names, emails, or any personally identifying information provided will was completely de-identified with numerical strings to delineate unique users and to maintain participant confidentiality.

### **Data Coding**

The initial Pre AReduction app survey was implemented in order to aid in discriminating between groups of participants in each Master's level course with an iOS



device and those without. Application SDK data further identified the participants that used the AReducation app frequently and those that may have downloaded the application and rarely used it if at all to complete their course modules. TLX Assessment and e-Corsi assessment of spatial and working memory coded with descriptive statistics identified a baseline working memory, further utilizing Pre-and-post testing for each instrument to potentially gauge responses and data over the course of the semester for participants using the AR application and those that did not use the application.

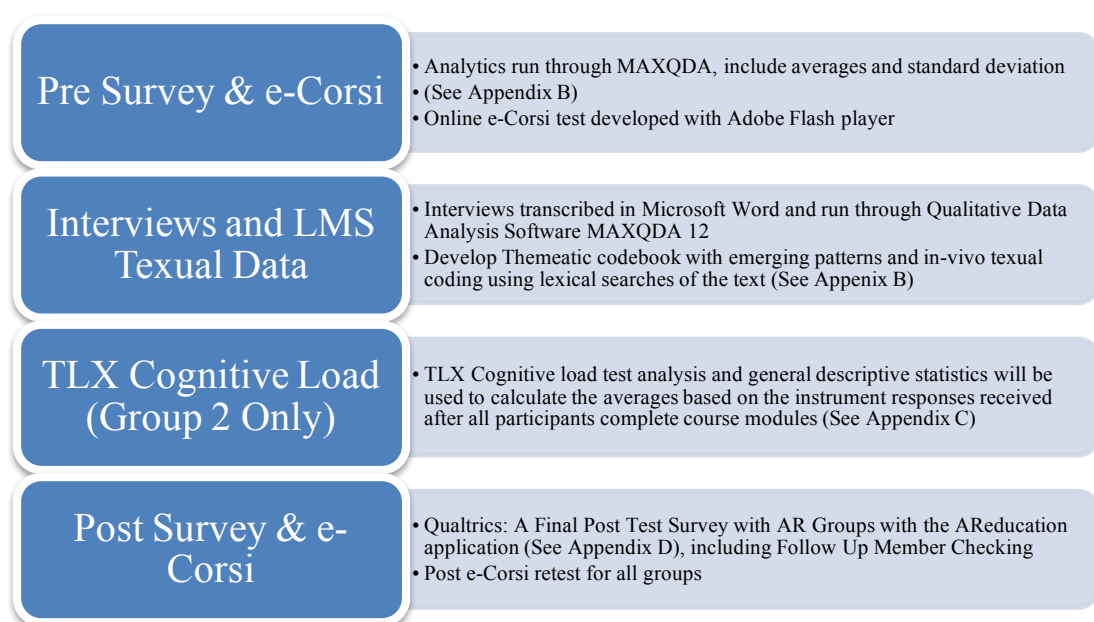


FIGURE 7: DATA ANALYSIS DIAGRAM

- ❖ **Phase 1:** Collected participant information for intact Group 1 and Group 2 (Appendix C)
- ❖ **Phase 2:** Enrolled students in Study, including the course LMS site, participant in Group 2 download the AReducation application based on access to iOS device and begin conducting AR Trigger modules hosted on ELC site unlocking learning content (Appendix E)

- ❖ **Phase 3:** Conducted TLX Cognitive load test after each course module and import data for analysis and general inferential from Google SDK (Appendix F)
- ❖ **Phase 4:** Final Post Test Survey for AR users with the AReduction application and all participants complete another e-Corsi block test (Appendix D).
- ❖ **Phase 5:** Conducted AR user interviews based on averages and selected time on task outliers, then transcribed into Microsoft Word and imported through Qualitative Data Analysis Software MAXQDA 12 to develop thematic codebook with emerging patterns and in-vivo textual coding using lexical searches of the text to identify participant's knowledge transfer, working memory utilization and cognitive load (Appendix F). Combined open-ended surveys, qualitative interviews and descriptive statistic data into averages, SD tables, and develop thematic excerpts for results and follow up member checks for summaries and textual responses (Appendix G, H).

TABLE 2: MIXED METHODS RESEARCH QUESTION ANALYSIS

**Quantitative Data**

Does Augmented Reality have an impact on effective working memory utilization?

Survey instrument, AReduction application analytic data, LMS data

Is there a predictable correlation between Augmented Reality visualizations and working memory?

Survey, TLX Cognitive Load Test

### Qualitative Data

How do participants think or feel about Augmented Reality's use in online learning environments, and if AR an is an effective medium for teaching and learning?

Open-Ended Survey Questions, Participant Interviews, MAXQDA 12 software for textual and lexical response coding

How do participants in the sample explain Augmented Reality's impact on classroom engagement, associative information processing, and working memory?

Open-Ended Survey Questions, Participant Interviews, MAXQDA 12 software for textual and lexical response coding

### Integration of Qualitative and Quantitative

Does the quantitative data and qualitative data converge to support a conclusion that Augmented Reality can positively impact associative information processing and working memory?

Survey instrument, Interviews, AReducation application analytic data, LMS data, Survey, Open-Ended Survey Questions, Participant Interviews TLX Cognitive Load Test Results

### **Researcher Subjectivities and Assumptions**

The research perspective of this study was informed by a constructivist philosophy that looks at post-positivism, interpretivism, symbolic interactionism in the way humans relate, interpret, and access technology, and incorporate that technology within relatively novel help seeking and instructional design based learning environments. Founded on initial pilot studies and data collection and coding, the impetuous was to account for methodologies that might differ from the researcher's own perspective. That is, on one hand there is a degree of concrete measurability in collecting surveys and application analytic data. On the other hand, it is equally important to collect semi-structured interviews and participant observations with new and emerging technology for classroom instruction. For this reason, several strategies were employed to interpret data using mixed method interpretations that were based on examining novel technological integrations that define the essence of a lived experience, in this case deploying an AR application in an online learning environment. The thinking behind exploring alternative methods of inquiry was grounded in the awareness that analytics and application data can only go so far in revealing said lived experience: Qualitative researches are often called to contribute practical solutions to human problems (Wertz, Pg.). Namely, human understanding is interconnected and observations and one-on-one interview analysis of a lived experience of novel technological tools, and impact on our daily lives, can reveal many uncovered nuances that embedded analytics alone cannot. Among others, to address statistical reliability with small sample sizes and to further elucidate the positive and negative influence of new tools, integrations, and research

methodologies can have on institutionalized ways of learning and thinking online. Therefore, a constructivist and post-positivist theoretical perspective significantly influenced the decisions within this study that sought to encompass a wider range of strategic inquiry methodologies that focused on quantitative and qualitative analyses.

Client Id	
1. d6d3f556-102b-47b2-aa9a-14a21540283a	<a href="mailto:d6x@uga.edu">d6x@uga.edu</a>
2. af10fec3-96f8-49dd-8fdf-8c5afebd6f00	<a href="mailto:afx@uga.edu">afx@uga.edu</a>
3. bf2b1aa7-94c9-4c15-acf6-1a0a87ecaab5	<a href="mailto:bfx@uga.edu">bfx@uga.edu</a>
4. 28da4db9-fb56-438f-8a2a-308989dbf2ea	<a href="mailto:28x@uga.edu">28x@uga.edu</a>
5. 8a335d31-f1d5-4f25-af78-b06a5c09579f	<a href="mailto:8ax@uga.edu">8ax@uga.edu</a>
6. b904c4e2-e07f-4cd9-8c3b-5350e72f9e5b	<a href="mailto:b9x@uga.edu">b9x@uga.edu</a>
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8. 826ea840-dafc-4a11-86c1-5f22d870ea34	<a href="mailto:82x@uga.edu">82x@uga.edu</a>
9. 2cae7ca2-4d7c-4d0d-974d-5838c0abbda0	<a href="mailto:2cx@uga.edu">2cx@uga.edu</a>
10. 8ada0fdb-95ed-4885-926b-41e416f910d0	<a href="mailto:8ax@uga.edu">8ax@uga.edu</a>
11. 24728a74-548e-4e37-9491-7c76fc77e2b7	<a href="mailto:24x@uga.edu">24x@uga.edu</a>
12. 3d00ec39-2563-4062-a41b-4a3c57aa99e3	<a href="mailto:3dx@uga.edu">3dx@uga.edu</a>
13. c0a02080-6106-40c7-bdd8-4febb311bcb3	<a href="mailto:c0x@uga.edu">c0x@uga.edu</a>
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15. 1d97432b-f665-451a-92ca-7097ec4b05fd	<a href="mailto:1dx@uga.edu">1dx@uga.edu</a>

AREducation mobile device APP  
ID – Linked with LMS UGA ID  
– and Qualtrics Survey ID – De-  
Identified.

FIGURE 8: DE-IDENTIFIED IOS USER DATA

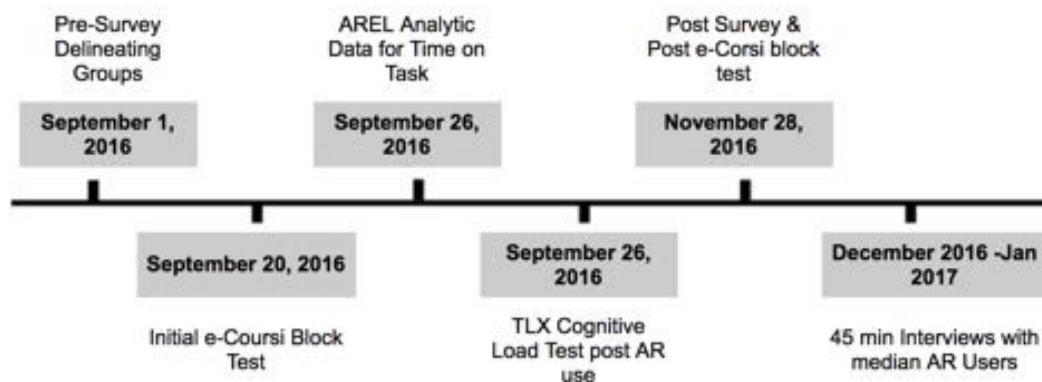


FIGURE 9: TIMELINE

## Chapter IV

### Results

Of the 27 total students in the two Master's level educational technology courses surveyed ( $n=14$ ,  $n=13$ ) all ( $n=27$ ) agreed to participate in the study. In course #1 (female  $n=7$ , male  $n=5$ ) agreed to participate in the study ( $n=13$ ) and in course #2 (female  $n=8$ , male  $n=6$ ) agreed to participate ( $n=14$ ). The Pre-survey served the purpose of enrolling Course 1 and 2 participants and dividing participants between discriminating factor of access to a mobile Apple iOS device (See Appendix C). The Course 1 group contained iOS users, 7 (female  $n=4$ , male  $n=3$ ) and non-iOS users, 5 (female  $n=3$ , male  $n=2$ ). Course 2 was divided between iOS users, 8 (female  $n=4$ , male  $n=4$ ) and non-iOS users, 6 (female  $n=4$ , male  $n=2$ ). The total group of iOS users for each combined course was 15 and 12 non-iOS users. After the Pre-survey, each of the two course groups were combined and divided into groups 1 — iOS users and groups 2 — non-iOS users. All participants completed an initial online e-Corsi block test in mid/late September. Statistics are reported as descriptive statistics and inferential statistics were conducted but due to limited sample size lack statistical significance. Qualitative data is broken into two segments detailing open-ended survey responses, and narrative inquiry excerpts from combined interview data.

### e-Corsi Block Test

TABLE 3: E-CORSI BLOCK TEST AR IOS USERS

Corsi Blocks	Pre Test AR-Users	%		
1-2	4	26.67%		
3	1	6.67%		
4	2	13.33%		
5	4	26.67%		
6	3	20.00%		
7+	1	6.67%		
Total:	15	100%		
Pre-Test	Mean	Std. Deviation	Variance	Count
e-Corsi Block Test AR- Users	3.27	1.65	2.73	15

On average AR users score about 3.27 blocks per users. With lows ranging in the 1-2 block range (26.67%) and only one user scoring 7 blocks or above (6.67%).

TABLE 4: E-CORSI BLOCK TEST NON-AR USERS

Corsi Blocks	Pre Test Non – AR		%	
2	5		41.67%	
3	1		8.33%	
4	1		8.33%	
5	2		16.67%	
6	1		8.33%	
7+	2		16.67%	
Total:	12		100%	
Pre-Test	Mean	Std. Deviation	Variance	Count
e-Corsi Block Test Non-AR users	2.92	1.93	3.74	12

Non-AR users on average score about 2.92 blocks per user. With lows ranging in the 1-2 block range (41.67%) and two users scoring 7 blocks or above (16.67%). Results on the e-Corsi pretests show that there is a marginal difference between AR (mean= 3.27) and non-AR groups (mean= 2.92). With subscales showing a difference between standard deviation with the AR groups (1.65) and non-AR groups (1.93) and overall variance between AR groups (2.73) and non-AR groups (3.74).



### AReduction SDK Results

After completion of the e-Corsi Crouse Group#1 iOS users, 7 (female  $n=4$ , male  $n=3$ ) and Course Group#2 iOS users, 8 (female  $n=4$ , male  $n=4$ ) downloaded the AReduction application and completed a course module on their course page in the Electronic Learning Commons LMS using Augmented Reality from September through October, with only one outlier completing the modules in November. AR iOS user's application data was recorded with the Google analytics SDK and Non-AR; all user's grades are recorded on the course ELC LMS site.

AR users identified using the app embedded Google Analytics SDK and users identified with a unique device Client ID to track time on task, usage, and a link between user emails and ELC LMS identification.

TABLE 5: GOOGLE ANALYTICS SDK AREDUCTION OUTPUT

Mobile Device Info	Sessions	Screen Views	Screens/Session	Avg. Session
Total	52	255	4.90	00:06:40
iPhones	44 (84.62%)	222	5.05	00:07:27
iPads	8 (15.38%)	33	4.12	00:02:22

Results from the Google SDK analytic data show AR groups opened the AReduction application on 52 separate total instances. AR users opened the app 44 times on an iPhone (84.62%) and 8 times (15.38%) on an iPad tablet. iPhone users view

an average of 5.05 screens with an average session time of 7.27 minutes per use. iPad users view an average of 4.12 screens with an average session time of 2.22 minutes.

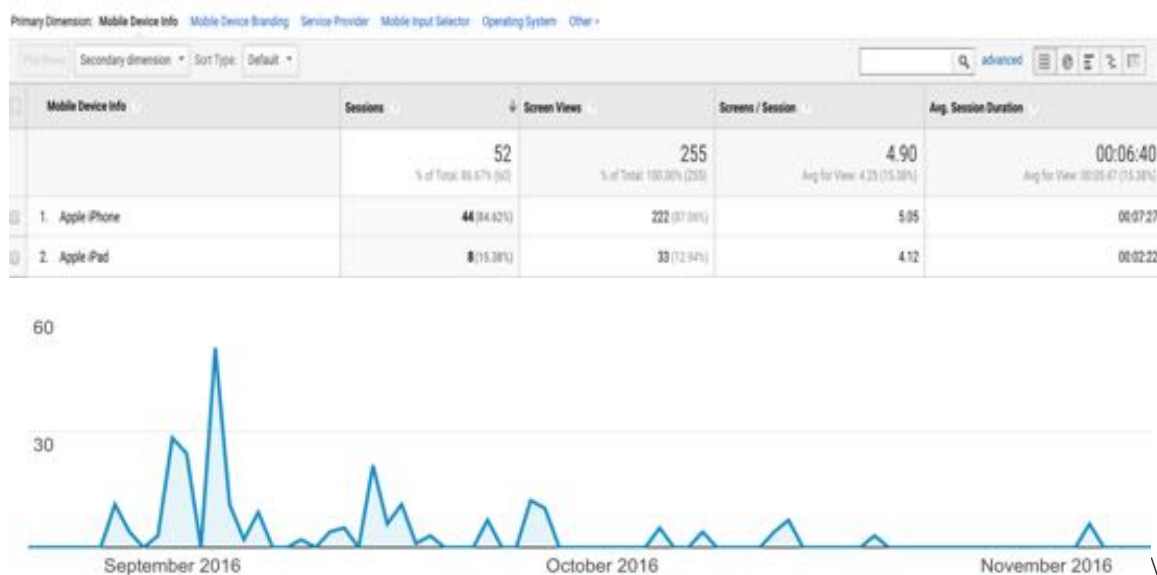


FIGURE 10: RETURNING VS. NON RETURNING IOS USERS

AR users view AReduction the most during their assignment module training in September; however, the SDK data shows that users return to view the AR content throughout the semester dwindling completely after November.



FIGURE 11: AVERAGE SESSION DURATION / TIME-ON-TASK FOR IOS USERS

The SDK analytic data shows that the most screen views in early September at the start of the module. AR users that returned to the AReduction application and viewed the AR content had higher average session durations, peaking in late September and October.

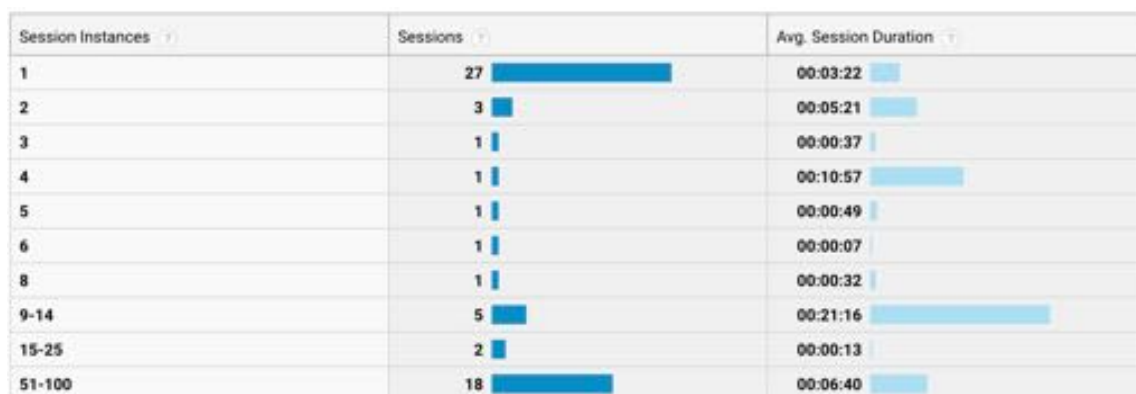


FIGURE 12: AREDUCTION GOOGLE ANALYTICS SDK SESSIONS AND AVG. DURATION

SDK data shows that particular AR users, identified through their unique device UUID, used the AReduction app significantly more than others. Particular users have more sessions and opened the app multiple times, while other users have longer than average session durations (5 AR users had 21.16 minutes of user on average). This data identified ( $n=3$ ) users based on median usage (High, Low, Middle) for in-depth interviews later in the convergent qualitative portion of the study.

The AReduction content path reveals that the iOS users (n=15) open the AReduction application on their devices 52 times. Users ID's store and link with email accounts and allow collection of each unique users AR viewing path, the time they spent on the trigger, and what course learning content they view, including surveys.

After completion of the AR embedded modules iOS participants received embedded prompts to complete a TLX cognitive load assessment survey of the AR tasks on their mobile devices (See Appendix F).

TABLE 6: DO YOU REMEMBER WHAT YOU JUST LEARNED

Do you remember what you just learned with the AR Trigger image?				%	Count
1- Definitely yes				33.33%	5
2 - Probably yes				46.67%	7
3 - Might or might not				20.00%	3
4 - Probably not				0.00%	0
5 - Definitely not				0.00%	0
Total:				100%	15
Field	Mean	Std. Deviation	Variance	Count	
Do you remember what you just learned with the AR Trigger image?	1.87	0.72	0.52	15	

On average AR user's report definitely (33.33%), or probably remembering (46.67%) they could remember what they just learned with the AR triggers (mean=1.87). A minority of AR users ( $n=3$ ) report they might or might not remember (20%).

TABLE 7: IOS CAN YOU APPLY WHAT YOU LEARNED

Can you apply what you just learned?		%	Count
1- Strongly agree		33.33%	5
2 - Agree		46.67%	7
3 - Somewhat agree		6.67%	1
4 - Neither agree nor disagree		13.33%	2
5 - Somewhat disagree		0.00%	0
6 - Disagree		0.00%	0
7 - Strongly disagree		0.00%	0
Total		100%	15

Field	Mean	Std. Deviation	Variance	Count
Can you apply what you just learned?	2.00	0.97	0.93	15

The majority of AR user group report they strongly agreed (33.333%) or agreed (46.67%) that they could remember what they just learned with the AR content (mean=2). Some users ( $n=2$ ; 1 being they strongly agree, 7 being they strongly disagree) reported they neither agreed or disagreed (13.33%) that they could remember with only one user (6.67%) reported that they only somewhat agreed that they could remember what they learned.

TABLE 8: IOS HOW HARD WAS THE TASK TO LEARN?

AR Users	Mean	Std. Deviation	Variance	Count
Extremely Easy	3.42	1.32	1.74	12
0-10 Scale (0 = very easy 10 = extremely hard)				

AR users report that the task of aiming at AR triggers with their mobile devices and completing course content was generally easy (mean=3.42).

TABLE 9: HOW INSECURE, DISCOURAGED, IRRITATED, STRESSED, AND ANNOYED WERE YOU?

AR Users	Mean	Std. Deviation	Variance	Count
Very Low	1.73	0.96	0.93	11
0-10 Scale (0 = very easy 10 = extremely hard)				

AR users report a low instance of insecurity, discouragement, irritation, stress or annoyance (mean=1.73) while completing the AR only tasks.

TABLE 10: DO YOU REMEMBER WHAT YOU JUST LEARNED ON THE ELC COURSE SITE?

Do you remember what you just learned on the ELC course site module?				%	Count
1- Definitely yes				41.67%	5
2 - Probably yes				33.33%	4
3 - Might or might not				16.67%	2
4 - Probably not				8.33%	1
5 - Definitely not				0.00%	0
Total:				100%	12
Field	Mean	Std. Deviation	Variance	Count	
Do you remember what you just learned on the ELC course site?	1.92	0.95	0.91	12	

On average non-AR users report definitely (41.67%) or probably remembering (33.33%) that they could remember what they just learned with only the ELC course content (mean=1.92). With a minority of non-AR users (n=2) reporting they might or might not remember (16.67%) and 1 user reporting they probably could not remember (8.33%).



TABLE 11: CAN YOU APPLY WHAT YOU JUST LEARNED FROM THE ELC COURSE SITE?

Can you apply what you just learned from the ELC course site?		%	Count
1- Strongly agree		58.33%	7
2 - Agree		8.33%	1
3 - Somewhat agree		8.33%	1
4 - Neither agree nor disagree		16.67%	2
5 - Somewhat disagree		8.33%	1
6 - Disagree		0.00%	0
7 - Strongly disagree		0.00%	0
Total:		100%	12

Field	Mean	Std. Deviation	Variance	Count
Can you apply what you just learned?	2.08	1.44	2.08	12

The bulk of non-AR user group reported they strongly agreed (58.33%) or agree (8.33%) that they could remember what they just learned with the AR content (mean=2.08; 1 being they strongly agree, 7 being they strongly disagree). Some users ( $n=2$ ) reported they neither agreed nor disagreed (16.67%) that they could remember with only one user (6.67%) reported that they only somewhat agreed that they could remember

what they learned and one user somewhat disagreed (8.33%) that they could remember the ELC content.

TABLE 12: ELC - HOW HARD WAS THE TASK TO LEARN?

Non-AR; ELC	Mean	Std. Deviation	Variance	Count
Extremely Easy	3.50	2.12	4.50	8
0-10 Scale (0 = very easy 10 = extremely hard)				

Non-AR users report that the task of logging into the course LMS and completing course content was generally easy (mean=3.5).

TABLE 13: ELC - HOW INSECURE, DISCOURAGED, IRRITATED, STRESSED, AND ANNOYED WERE YOU?

Non-AR; ELC	Mean	Std. Deviation	Variance	Count
Very Low	3.00	1.50	2.25	8
0-10 Scale (0 = very easy 10 = extremely hard)				

Non-AR users report a generally low instance of insecurity, discouragement, irritation, stress or annoyance (mean=1.73) while completing the non-AR ELC only tasks. There was a difference between AR (mean=1.73) and non-AR groups (mean=3) with subscales showing differences between standard deviation in AR groups (0.93) and non-AR groups (1.50).

Non-AR and AR groups were compared based on their grades and average completions rates with the ELC course site LMS.

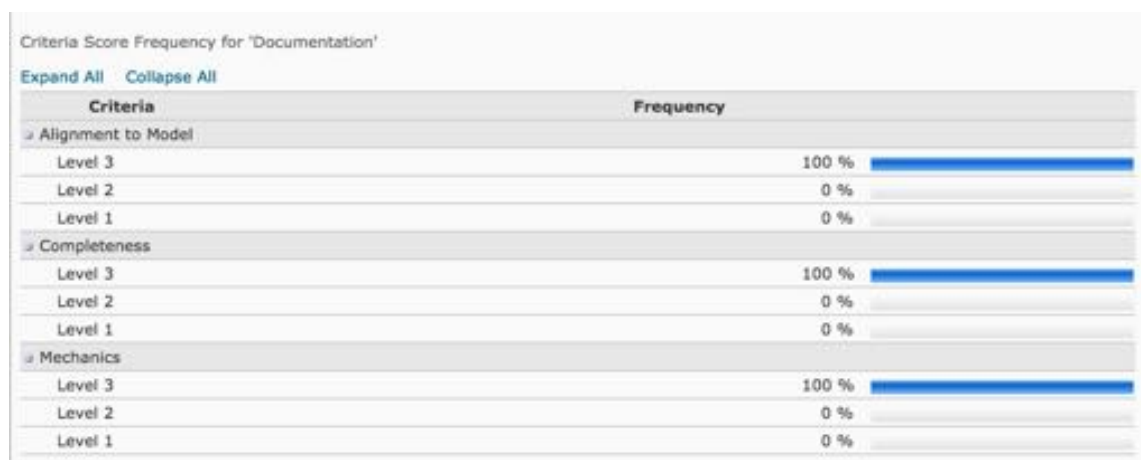


FIGURE 14: COURSE 1 ELC GRADES AR & NON-AR USERS

All participant groups, both AR & Non-AR users recorded, achieved 100% in both respective course modules for their graded content.

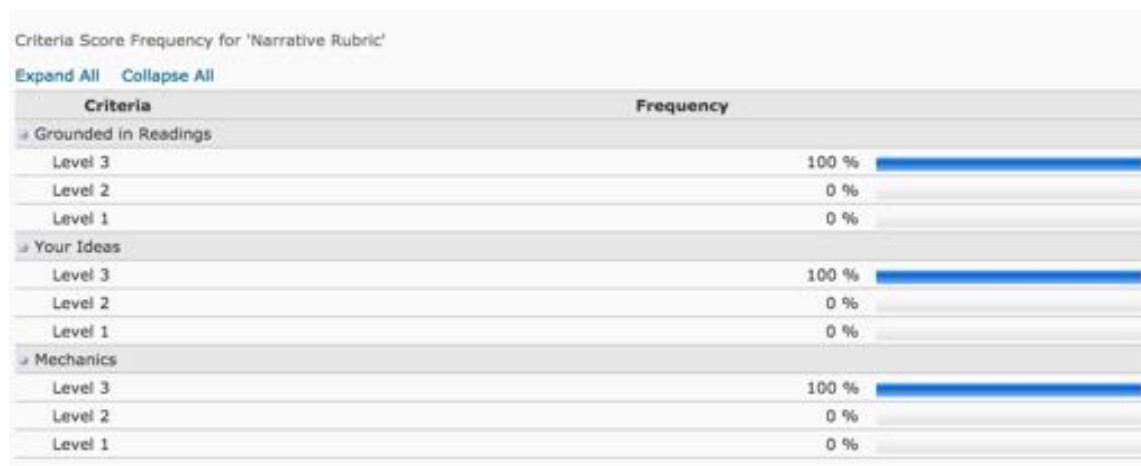


FIGURE 15: COURSE 2 ELC GRADES AR & NON-AR USERS

All participant groups, both AR & Non-AR users recorded, achieved 100% in both respective course modules for their graded content. There was no differences.

### Post e-Corsi Block Test

After completion of their course content participants conduct a final e-Corsi block test assessment.

TABLE 14: E-CORSI BLOCK TEST AR-USERS

Corsi Blocks		Post Test AR-Users		%	
1-2		1		6.67%	
3		1		6.67%	
4		2		13.33%	
5		4		26.67%	
6		2		13.33%	
7+		5		33.33%	
Total:		15		100%	
Post - Test		Mean	Std. Deviation	Variance	Count
e-Corsi Block Test AR-Users		4.33	1.53	2.36	15

On average AR users scored about 4.33 blocks per users in the post use test. This was a 1.06 block increase from the pre-test. Users in the low range shifted from 26.67%

in the Pre-test to only 6.67% in the post AR use test (increased by 20%). Further, users in the 7 blocks plus range increased (26.66%) from users in the post-test. This was a shift from the pre-test, with only one user (6.67%) scoring in the 7+ block range to 5 users (33.33%) in the Post-test.

TABLE 15: E-CORSI BLOCK TEST NON-AR USERS

Corsi Blocks		Post Test Non – AR		%	
2		1		8.33%	
3		1		8.33%	
4		0		0.00%	
5		2		16.67%	
6		4		33.33%	
7+		4		33.33%	
Total:		12		100%	
Post-Test		Mean	Std. Deviation	Variance	Count
e-Corsi Block Test Non-AR Users		4.58	1.55	2.41	12

On average Non-AR users scored about 4.58 blocks per users in the post use test. This was a 1.66 block increase from the Pre-test. Users in the low range shifted in the Pre-test (41.67%) and Post-test (8.33%) showing an increase in block remembered (increased by 33.34%). Users in the 7 blocks plus range increased (16.66%) in the Post-test. This was a shift from the Pre-test, with only two user (16.67%) scoring in the 7+ block range, to 4 users (33.33%) in the Post-test. This was a shift from the Pre-test, with only one user (6.67%) scoring in the 7+ block range, to 4 users (33.33%) in the Post-test.

Results on the e-Corsi post-tests show a marginal difference between AR (mean= 4.33) and non-AR groups (mean= 4.58). With subscales showing a difference between standard deviation with the AR groups (1.53) and non-AR groups (2.41) and overall variance between AR groups (2.36) and non-AR groups (2.41) slightly favoring the AR only groups.

### **Open-ended Augmented Reality Survey Questions**

After completion AR participants concluded with open ended survey questions (See Appendix G). The open-ended responses ( $n=15$ ) show that the majority of AR users would recommend AR application in a classroom and in general they found the modules and learning experience with AR to be beneficial: *“Useful to help create interactive course material.”* The participant feedback shows that users found that AR enabled video content in online classes would be more engaging than standard YouTube videos: Users reported that they found AR *“More engaging than a YouTube video when you can see video floating on an AR image.”* Participants indicated that AR content would be more hands-on, would be more interactive, or would work the same as standard YouTube videos while aping an overall novel level of engagement with the hands-on nature of AR

overlaying content onto the learning environment: *“AR keeps users more engaged.”* After using AR applications participants responded that they recommend using them in the future in online environments: *“It would help in making it more interactive or the instructors could use it to make it more understandable.”*

Participants reported that they would use AR outside the classroom and that AR’s multiple uses could be adapted to numerous iterations of implementation and use cases: *“Outside of the classroom provides alternative experience to what could be found in a face to face environment.”* Participants found that after using the AReducation application, AR might be beneficial for novice learners and might help in training environments offering engaging content and learning strategies: *“...it seems pretty engaging and has the potential to enhance instruction.”* Participants reported that AR overlay content did help them to learn and in general did not distract them, but had the opposite effect helping them to engage with and recall content: *“AR in learning helps to organize relevant information.”* Participants indicated that after using AR for their course modules Augmented Reality could likely be adapted to allow users to learn in a hands-on way: *“It definitely would be a great alternative if using hands on the real thing isn't an option.”*

In general, participants reported primarily affirmative quantitative feedback in regards to Augmented Reality and expressing a strong relationship to learning (See Appendix G and Tables 26 - 32).

## **Discussion**

The purpose of this study was to measure what impact, if any, Augmented Reality has in relation to associative information processing, working memory and cognitive load in

Master's level online learning environments. The AReduction overlay framework adapted from previous frameworks posits that effective cognitive load reduction frees up more processing power to focus on learning tasks (Tang, Owen, Biocca, and Mou, 2004). As a theoretical process for applying AR in online learning environments the AReduction learning application framework was developed to measure convergence between the associated information in working memory, and AR's potential impact on reducing cognitive load and the long-term impacts on user cognition and learning engagement. The model for the AReduction framework is the human brain, just as a computer with too many programs running in the background, or too many tasks being compiled, is analogous to how cognitive load reduces effective working memory utilization creating overload. AR cognitive systems provide a tangible interface to analyze and think about new learning material in tactile cognitive systems acting in an adaptive way. This is related to the undeveloped cognitive framework adopted from Proctor and Van Zandt's mental model when applied to AR systems may facilitate building up an enduring cognitive map that supports a human's ability to comprehend and grow spatial relationships potentially reducing cognitive load and increasing overall working memory (Proctor and Van Zandt, 2008).

### **Is there a predictable correlation between AR visualizations and working memory?**

The study explored potentials of AR in learning environments and for students to become more engaged and active with online learning environments utilizing novel Augmented Reality-based learning. The user feedback of the study showed that all AR participants ( $n=15$ ) agreed that AReduction systems featured significant potentials for learning. The data indicated that during working memory pre and posttest measurements



e-Corsi working memory blocks remembered increased by 1.06 blocks on average in the Augmented Reality application group posttest.

TABLE 16: ANALYSIS WORKING MEMORY PRE AND POSTTEST MEASUREMENTS

Corsi Blocks	Pre AR Users	Pre AR Users	Post – AR Use	Post – AR Use
1-2	4	26.67%	1	6.67%
3	1	6.67%	1	6.67%
4	2	13.33%	2	13.33%
5	4	26.67%	4	26.67%
6	3	20.00%	2	13.33%
7+	1	6.67%	5	33.33%
	Mean		Mean	
	3.27		4.33	

AR users had a mean average of 1.06 blocks per participant increase. With comparative baseline testing showing that participants remembering 7 blocks or more increased by 26.66% after using the AReduction content overlay framework.

TABLE 17: ANALYSIS WORKING MEMORY PRE AND POSTTEST MEASUREMENTS

Corsi Blocks	Pre AR Users	Pre AR Users	Post – AR use	Post – AR use
1-2	5	41.67%	1	8.33%
3	1	8.33%	1	8.33%
4	1	8.33%	0	0.00%
5	2	16.67%	2	16.67%
6	1	8.33%	4	33.33%
7+	2	16.67%	4	33.33%
	Mean		Mean	
	2.92		4.58	

The ELC non-AR framework users e-Corsi blocks increased by 1.66 blocks per participant. With comparative baseline testing showing that participants remembering 7 blocks or more blocks increased by 16.66%. This may support previous AR studies claim that AR can be a poignant catalyst to assist learners with elaborative rehearsal strategies and may aid in increasing working memory (Lin, Duh, Li, Wang, and Tsai, 2013). However, the participant group and statistical data was not large enough to be statistically significant to show correlation, or to infer onto a larger population. Due to the limited sample size and limited response data running a more in-depth statistical will have to be undertaken in future studies.

TABLE 18 PRE VS. POST AR HYPOTHESIS TEST

		What was your eCorsi score? Pre AR only	What was your eCorsi score? Pre Non-AR
What was your eCorsi score? Post AR- Only	Chi Square	32.44*	26.70*
	Degrees of Freedom	25	25
	p-value	0.15	0.37

The posttest e-Corsi data shows that it is highly unlikely to determine the probability of a relationship between the Post AR only groups based on the p-values. The data is not statistically significant for the Pre AR only and Pre Non-AR participants scores.

TABLE 19 PRE VS. POST NON-AR HYPOTHESIS TEST

		What was your eCorsi score? Pre AR only	What was your eCorsi score? Pre Non-AR
What was your eCorsi score? Post Non-AR	Chi Square	19.50*	16.20*
	Degrees of Freedom	25	25
	p-value	0.77	0.91

The posttest e-Corsi data shows that it is highly unlikely to determine the probability of a relationship between the Post Non-AR only groups based on the p-values. There were no differences. The data is not statistically significant for the Pre AR only and Pre Non-AR participants scores.

The posttest descriptive statistics data suggests an increase in working memory from both AR and non-AR groups ( $n=27$ ) after utilizing mobile and online learning content during the course of the study. While the non-AR group increased 0.6 blocks on average higher than the AR only group, the AR only group increased users in 7+ or more range at

about 10% more overall. While several factors might explain why the AR group increased to higher levels of overall memory practicing with the AR visual overlays lead to higher block level memory increases. This may support previous findings that AR systems can be shaped to minimize cognitive load by developing different working memory encodings and maximizing the efficiency of attention allocation (Dunston and Wang, 2006). The AR only group was also asked to aim a device viewfinder at AR triggers in a succession and report on the tagged content that is overlaid on the optional Piazza.com site. Symbols in working memory procedures are often presented as self-paced, and once a response is recorded the next symbol appears (Lawlor-Savage, and Goghari, 2016). The data may suggest that the AR system where participants aim at the tagged content and then move on the next image in a succession, mirrors the e-Corsi working memory model where participants remember blocks and placement.

### **Does AR have an impact on effective utilization of working memory?**

The TLX cognitive load assessment survey was implemented after each participant group finished the online learning content. The concept being, the TLX assessment would reveal the AReducation framework's relation to associative information processing, working memory and cognitive load, versus traditional online learning content.

The data indicates that AR only group, experienced a very marginal .05% average increase of self-reported remembered content versus the ELC only group. When asked if participants could apply what they learned from the AR only group versus the ELC only group participants had a 0.08% difference favoring the AR only group strongly agreeing that they could apply what they had learned. This may support research documented by Bujak, Radu, Catrambone, MacIntyre, Zheng, and Golubski (2013), that indicates

interacting with AR-based learning experiences, leverage situated cognition, by allowing the student to connect to the virtual educational content by simply pointing a camera at their environment, whether inside or outside the classroom (See Table 26).

When asked how hard the task was to learn AR only users report on average the AR only task was not that hard to learn compared to the ELC users. This may support Willis, Levine, & Haywood, (2011) theory that AR ease of access is highly beneficial to students because it overlays contextually relevant information that can be procured to satisfy the student's interest. Johnson, Smith, Willis, Levine, & Haywood, (2011) specified that Augmented Reality implementations have a strong potential to provide both powerful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world.

Furthermore, the AR only group reported that they were less insecure, discourage, irritated, stressed and annoyed when using the AReduction framework compared to the ELC non AR groups average responses (See Table 27 and 28). The data suggests that AR users were less frustrated. Participant feedback suggests that due to increased novelty effect and potential increase in motivation from interacting with tangible digital objects, users were more inclined to open the AReduction app multiple times based on the embedded Google SDK analytics (See figure 20). As the literature suggests AR may have the unique quality of being more novel, and therefore engaging learners in a variety of interactive ways, but also AR potentially provides each individual user with one's unique discovery path with rich content from computer-generated overlays onto the digital environment, combining haptic, sensory and tactile content with learning (Lee, 2012).

## Time on Task and Usability Reporting

The embedded Google SDK revealed users time on task and corresponded with unique users device identifiers and email. These data were matched with users that opened and accessed the AReducation app a lot, a little and a medium amount through the Internet.

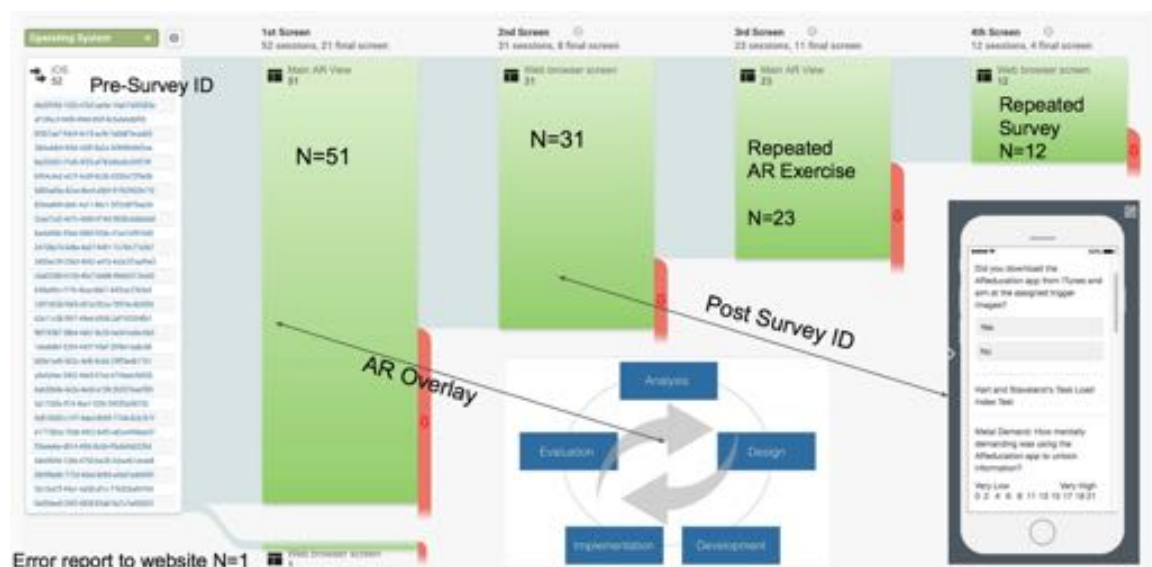


FIGURE 16: TIME-ON-TASK, SESSIONS, AND AREDUCTION TRACKING

Users matched with Unique User Identification (UUID) numbers showed that the AR users ( $n=15$ ) viewed multiple AR overlays and interacted with the content by engaging with the overlaid matter and pressing on their mobile devices to link exercises that were normally only accessible in the ELC LMS. The participant path also shows that the same UUID accessed triggers and surveys over 51 times. The AR users were asked to complete qualitative open ended question to help elucidate and elaborate on the SDK data that tracked their behavior while using the AReducation application framework. The

UUID shows that users primarily opened the AReducation app during the beginning of the semester, and did open the application to complete their learning modules. There were no discernable quantitative impacts on AR user's overall course grades versus non-AR user's grades based on the ELC data from all participant groups. Both AR & Non-AR users ( $n=13$  and  $n=14$ ) recorded achieved 100% in both respective course modules for graded content

Based on the graded content alone it would appear that Augmented Reality did not have an impact on users grades in the course, and their completion of the course content, because both groups scored very high in the final submission. However, AR users did report less frustration and more interactive engagement. This may have been due to the novelty of using a new method to interact with the course content and may not directly relate to working memory gains, or cognitive load, but rather the self-report stimulation from using a novel learning tool.

### **How do participants think or feel about Augmented?**

The qualitative open ended surveys suggest that users found the AR content to be "Useful to help create interactive course material." A major of AR users found the AR overlay interactions that contained videos more valuable than clicking a YouTube video or link for accessing course content within the ELC. They also reported that in general having content overlaid on real world images & objects helped them learn and did not overly distract them:

*Ex. AR can bring still images to life and for many applications offer the possibility of simulating real-life situations without the need to fear consequences of a mistake. I especially see the benefits in medicine, technology and vocational education.*

*Ex. It would be useful to have glasses that respond to AR, that way you can walk into a place and automatically learn its history, or other information needed. Then in the classroom you can have an interactive get out of your seat test and have students walk around and use the AR glasses to fulfill respond to overlays in the classroom.*

*Ex. I think that having detailed and accurate AR overlays can enable people to be more successful at some job tasks.*

*Ex. interactivity, endless possibilities*

**How do participants explain Augmented Reality's influence on classroom engagement, associative information processing, and working memory?**

AR users reported that in general the AReducation framework helped them to learn and engaged them perhaps helping them remember more content, or in so far as they self-reported that they remembered more content overall:

*Ex.1 It definitely would be useful for real time use.*

*Ex. 2 Repetition with low risk and low cost.*

*Ex.3 It definitely would be a great alternative if using hands on the real thing isn't an option.*

*Ex.4 A student could see the inner workings of a car engine or whatever they are working on.*

*Ex.5 Absolutely-- or even studying the brain, cells, etc. I think this is extremely beneficial to science classes.*

*Ex.6 This would be great in learning environments that have layers to look at (i.e.*

*Biology, Fashion Studies, Medical fields, Visual Art, Music, etc.)! WOW!*



Following Marshall and Rossman's in-depth qualitative design based on interviewing and direct questioning three participants were selected out of the total AR users ( $n=15$ ) for in-depth interviews. In order to help elucidate open ended questions more fully. Participants expressed their individual perspective and understanding of Augmented Reality and potential for cognitive training (Marshall & Rossman, 2011). Codes were refined, and symbols with acronyms were used instead of icons and colors.

Total participants interviewed (N=3):

EJ = Interviewee 1 (UIID Used Average of 27x for 3 minutes each)

HT = Interviewee 2 (UIID Used Average of 1X for 10 minutes total)

BP = Interviewee 3 (UIID Used Average of 5X for 27 minutes total)

TABLE 20: QUALITATIVE THEMES THAT EMERGED FROM INTERVIEW CODING

➤ ARHIDI = "Augmented Reality Helps Instructors Deliver Information" (N=3)
❖ MLWHI = "Mobile Learning Would Help Instruction" (N=3)
❖ ARFSL = "Augmented Reality Facilitates Students Learning" (N=3)
○ RUARA = "Recommended Using Augmented Reality Applications (N=3)

Saldaña's model to illustrate the user evaluation content based on the participants' overall interaction with the iOS application (Saldaña, 2013).

This approach was particularly helpful because of its versatility in handling different types of data; all of the data goes through the same data analysis procedure on the way to generating a theory (Charmaz, 2006). The selection of codes was based on first reading though the interview transcripts, writing memos, conducting descriptive

analysis, checking for frequency trends between the three interviews, and developing a thematic codebook based on the ‘coding’ function and assigning these symbols and emoticons to excerpts of text thereby denoting key terms and concepts with images, themes, and colors (Saldaña, 2013). Symbols were used to identify key themes and text segments.

Analysis Process with examples:

❖ MLWHI = “Mobile Learning Would Help Instruction” (N=3)

Participants indicated that AR and Mobile applications in relation to instruction:

EJ: *This is something that would be really, really helpful no matter what. And, I feel like for me, and maybe people like me, that are more tactile learners, it would be so helpful because it would give you a tool and a resource outside of the classroom to be able to study.*

HT: *OK. It'd probably be really helpful, probably because it would allow a lot of people to be able to access that kind of information quickly, and in a different way. It could be more in depth, and maybe less boring. I couldn't see myself being bored with something like that online.*

BP: *Yes. There's a specific way to use something like this; in the classroom setting, traditionally or online, if you were to use it as a tool for those kinds of courses, then yes. For example, in an o chem. class, using something like AR to see how certain processes happen. Having something like that, without having to access a certain link, just opening that information by pointing your phone at a trigger, that would be invaluable. That would be such an invaluable tool, because a lot of the time, it's difficult to imagine those kinds of things when they're just being taught to you in a*

*lecture setting. Being able to have a video or a diagram or a 3D image of something, and being able to do what you imagine it doing in text, would just be so important to understanding concepts. That way, you can see what's going on, you can see it in real time. I would appreciate that next semester going into the second semester of o chem., it can be really difficult to imagine what's going on. And I think something like this to help with understanding those ideas – I know I would use it consistently. It would be so much easier.*

❖ ARFSL = “Augmented Reality Facilitates Students Learning” (N=3)

Participants indicated that AR could facilitate student learning:

*EJ: I think it would, ultimately, help them. I think for tactile and visual learners, something like this would really help them in many ways. [Pause] I think that sometimes things can seem abstract, if you're just being lectured about something in a traditional classroom. But I feel like if you have something like this that can connect the teacher and the students, it will make it seems more interesting.*

*HT: I think that augmented reality, from what I've seen so far, it just seems like it takes that information, and allow the user to be able to play – if that makes any sense- with the information you set up for them. For example, with the skin cell [from the trigger images] it looked like what you could do with augmented reality is have a more playful environment where there wouldn't be regurgitating information on cue. “The skin cell contains three layers, and these layers are...” etcetera and so on. I think that augmented reality makes it more of a 3D game, and would make learning more fun.*

*BP: I think it would in a classroom setting; I think in that way it would be most beneficial. And, I think it's important not to shy away from new tools. It's something that*

*happens when each year a new device comes out, like Apple watch, and now it's something that we grow accustomed to – making life easier and more convenient. I feel like these kinds of tools we can love them or hate them But I feel like I would want something that would make my life easier. I know in school, we go through really difficult classes, and it's always more beneficial to have something help you in class. I know that I would use it, not even being a visual learner. I know that you can never help too many things to help students.*

- RUARA = “Recommended Using Augmented Reality Applications (N=3)

Responses: Would you recommend using Augmented Reality applications outside of classrooms?

*EJ: It might actually be better for that, because that way – you're not in the classroom- so it actually might be even better for it to be used in online settings because you're away from the classroom, and if you're a visual learner, or a tactile learner, it may be difficult 'cus a lot of online classes are through the computer. I think it would really help to bring those learners who have a difficult time, to able to make that material more [pause] understandable.*

*HT: A lot of my friends would be very interested in this kind of technology, especially since they talk about it pretty frequently; the next kind of technology, and where it will go from here. This is definitely it. I think that this is what we'll end up using soon to develop apps. I think it'll just become more popular. There will be more interest in it.*

BP: *I would recommend it to a colleague. Someone like a classmate, who would see this as a really great tool to help them with school – especially in the field I'm in. I know it would be really helpful.*

➤ ARHIDI = “Augmented Reality Helps Instructors Deliver Knowledge” (N=3)

Participants indicated that in their opinion AR would help instructors deliver learning content:

EJ: *I think it would, ultimately, help them. I think for tactile and visual learners, something like this would really help them in many ways. [Pause] I think that sometimes things can seem abstract, if you're just being lectured about something in a traditional classroom. But I feel like if you have something like this that can connect the teacher and the students, it will make it seem more interesting.*

HT: *Oh. Yeah. I think that it's just so easy to use, that you just have to point your phone at something tagged. Unless they had difficulty downloading the app to begin with, or they were just a luddite – no offense, but they were just not keen on technology - then I can't see how you couldn't use it easily. I think it could almost be impossible to fail with this kind of technology. It kind of does the work for itself. You don't have to do a whole lot, and the possibilities are endless with this kind of programming. You can tag so many different things, like the inside of a house or office, and do whatever you want with those images – add links, add video. You could unlock something in a gamification kind of way, like adding points or badges. Pretty much anything you wanted, as long as you understand this program.*

BP: *I think this is a great stepping-stone for maybe other things in the future of learning. I hope that my kids can grow up and have tools like this, so that learning for*

*them, isn't necessarily easier because nothing worth doing is ever easy, but maybe something that they'll find more interesting. STEM degrees could be more interesting to more people. This would be a great tool for that.*

Themes emerged through the interview process and helped to identify that the participants experience with AR enabled learning environments was very positive. Further the potential impact AR could have on their learning environment was seen as beneficial. The selected users indicated that they found AR would help instructors to deliver information. Mobile learning tools, such as AR, would help with instruction. AR in general helps to facilitate students learning and they would recommend using augmented reality applications when appropriate.

The quantitative data was limited due to a small sample size and ultimately found no relationship. However, the qualitative results indicated that AR users were highly engaged and remembered content more readily due to the novel nature of AR devices in their online classroom. Both non-AR and AR only groups showed increased working memory gains from e-Corsi pre and post testing. While there are several data points to suggest something positive happened with the AR only group, perhaps greater engagement, the general combination of qualitative and quantitative data to triangulate a discernable conclusion to AR's ability to increase working memory remained inconclusive statistically.

## **Chapter V**

### **Conclusions**

The qualitative data suggested that the AR only users were more engaged and remembered content more positively due to the novel nature of AR devices in their online classroom. Based on user's verbal feedback, and the simple human information processing model implemented, some type of positive effect was documented with AR. The effects on the AR only group versus the ELC group was documented and these differences were statistically minor. Ultimately, the participant sample size was too small to provide any practical significance between groups. However, both non-AR and AR groups did experience working memory gains from doing the e-Corsi test based on descriptive statistics of the sample groups. While there are multiple data points to suggest something affirmative happened with the AR only group: perhaps greater engagement. The general combination of qualitative and quantitative data to triangulate a discernable conclusion to AR's ability to increase working memory remained inconclusive. Further, due to limitations in the research design the ELC group was not interviewed in order to compare qualitative findings between AR and non-AR groups.

In general, the descriptive data from the e-Corsi and TLX instrument may indicate that AR users were slightly less frustrated when completing assignments only with the mobile AReducation framework. AR may have been more novel and engaged learners in a variety of interactive ways. While the AR only group reported that they were less insecure, discourage, irritated, stressed and annoyed when using the AReducation

framework compared to the ELC non-AR groups average responses. The data suggests that the AR only group, experienced a very marginal .05% average increase of self-reported remembered content versus the ELC only group. When asked if participants could apply what they learned from the AR only group versus the ELC only group participants had a 0.08% difference favoring the AR only group, strongly agreeing that the AR only group could apply what they had learned to a higher degree. While the non-AR group increased 0.6 blocks on average higher than the AR only group, the AR only group increased users in 7+ or more range at about 10% more overall gains. While several factors might explain why the averages of the AR group increased to higher levels on both the TLX and the e-Corsi the narrow sample indicates that the overall statistical data reliability is not significant, and it may be more likely that users increased their working memory through repeating the e-Corsi tests rather than aiming at AR trigger images and completing course content.

### **Limitations**

A major limitation of this study was the small number of participants and limited overall sample size. Participants were selected for convenience and their enrollment in Master's level Instructional Design and Development courses, where most participants already had some level of familiarity with mobile learning devices and Augmented Reality. Another limitation noted was in regards to AR users versus non-AR users in the study already having higher baseline working memory. While inferences may be made based on the AR and iOS user data, it may be just as likely that each user group performed better at the e-Corsi test as the users became initiated with the testing model and took the test more. Therefore, the data does not appear to offer a predictable



correlation between Augmented Reality visualizations and working memory based on the e-Corsi groups and may not be directly related to users training with Augmented Reality hand held devices, but rather user's mastery of the e-Corsi working memory test. Another major limitation was due to data collection around the non-AR users and limited amounts of qualitative data as well as a lack of time on task related analytics when using the ELC learning management system. While, these limitations will be addressed in future studies, having only the AR groups time on task, qualitative feedback, compared to only the e-Corsi and TLX data from non-AR users creates an incomplete picture and indeed requires more investigation when comparing the mobile AR experience of tactile aiming of a mobile device and engaging with a device with small screen size, versus the ELC users clicking and interacting from personal computers. There are also weaknesses in the data analysis and statistical significance related to the limited sample size. This also necessitates that future studies compel a larger sample size to demonstrate concrete significance. Further, qualitative measures should also encompass both non-AR and AR groups. Future studies planned will address the limitations in the survey instrumentation and questioning by complementing qualitative questioning for non-AR users also. Many of the initial questions and follow-up interview survey questions were limited in developed, and almost provided an obvious yes or no-context without fully exploring in depth nuances as much as the research would have liked to have seen. The survey issues and open-endedness that is necessary to elicit richer participant responses will be addressed in future studies and iterations of the AR survey instrumentation in the future.

### **Educational Implications**

This study might help to increase the body of knowledge on effective working memory utilization in technology-enhanced classrooms, and the viability of Augmented Reality assistive devices in online learning domains in the future. The influence of information overlays, outside industry specific domains, is still relatively under examined in the literature. Using AR-technology is evolving and developing; yet, there are indications that AR tools may help learners to acquire, and to convey knowledge more readily. Inchoate evidence may indicate a connection between mobile and AR pedagogical implementations increasing working memory and moreover enabling next generation learners with a more stimulating and adaptive feedback structure compared to more traditional training methods.

Novel AR technology and the rapid proliferation of powerful computing tools for the next 10 to 15 years, encompassed by power mobile computing devices with access to a world-wide network of stored and shared human knowledge, illustrates a significant shift in learning technology and supporting instructional design theories. While some benefits and drawbacks have been documented, Augmented Reality is only as suitable as the instructional design and didactic constructs used to sustain its implementation and instructional viability. Further, the relatively limited body of AR research indeed compels further inquiry, it is possible that the overall potential for ease and deliverability of Augmented Reality technology, and customized learning content, may also help to free up more time for class discussion, student engagement and other forms of innovative learning over time. Therefore, the permutations of this comparatively new teaching and learning tool are indeed thought provoking, in so far as what the future of mobile

computing portents, and the nascent effects on enriching teaching and learning. While many free Augmented Reality tools exist, and are rapidly advancing, a single “Internet Explorer” of AR, or unifying content database does not exist. AR is still currently in a closed garden with the same standardization process propelling other learning mediums into more conventional learning domains. While the spectrum of the AR-browser is evolving, it may be difficult for streamlined, or even effective implementation for the uninitiated without resorting to custom programming, and instructors creating their own custom content. Future studies will ideally set the groundwork for multiple designs of AR being used in a larger framework, instead of isolated sandboxes or closed gardens.

Currently, the nature of AR experiences, AR course creation, and AR knowledge recall is only as good as the planning and construction behind its creation. Without major contributions from open source and uniform frameworks AR will likely remain isolated in a vacuum. Although, many major organization are working on Virtual Reality and Augmented Reality standardization, much in the same way SCORM standardized eLearning, AR development for instructional design is largely depended on educator’s independent development and the creative utilization of open source and commercial AR platforms. Therefore, future studies that take into account the creation of a sizable open source code base, one that can be shared and standardized, will hypothetically set the stage for large scale AR integrations trials. Due to the emerging open source and standardization of AR content that can be adapted and fully integrated into instructional settings, future research and AR trials would then include large scale, statistically relevant participant samples sizes.

### **Future Research**

More research is needed to elucidate AR's potential role within intentional online learning spaces. Arguably, effective Augmented Reality technology adoption for classroom instruction shares the common theme that it is learner centered, systematic, sustainable, accounts for instructor preparation, and considers the environment of adoption along with the practicality of implementing the technology (Knowles, 1997). There is no one size fits all solution for new technology, and an effective technology implementation is contingent on learners' pre-existing knowledge, along with the instructional goals of the appropriate stakeholders. While the results of this study may reflect an affirmative relationship with Augmented Reality and online learning this does 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. Mobile devices are connecting humans around the world that might not be able to afford traditional computers to access a compendium of world knowledge. AR technology is not a new technology in various iterations, and yet the affordances AR can produce within an instructional setting are continuously evolving. As Kesim & Ozarslan (2012) have noted 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. Future research sites that are already being considered such as factory floors, medical and cognitive rehabilitation centers, and historical museums each offer unique and unexpected challenges and rewards for future implementation and conveying content to a new generation of learners. Future studies planned will ideally take into account theoretical frameworks that seek to measure AR's impact on increase quality, working

memory as it is related more directly to the content being superimposed in a 3-D based dimensional reality, and the potential memory advantages that can be achieved while reducing time and errors with assistive overlays and heads up AR displays.

Future studies will necessitate larger sample sizes to demonstrate concrete statistical significance; gather qualitative and quantitative data from both AR and non- AR groups equally; develop more robust survey instrumentation; and take into consideration domain specific research sites. While the results of this study reflect an affirmative relationship with Augmented Reality and online learning, this does not broadly represent a population that is unfamiliar with the tool itself and requires another step in the design process to bridge the content and knowledge gaps for uninitiated learners.

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## **Appendix A: Research Design**

In this unit, you have the option to interact with the learning material using an Augmented Reality device to convey and overlay information. Or you have the option to not use this device.

Intact Groups:

### *Lesson Group 1*

- Follows the selected modules within the existing online course structure and participants are asked to complete Surveys and potential follow up interviews.

### *Lesson Group 2*

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 on the AR training.

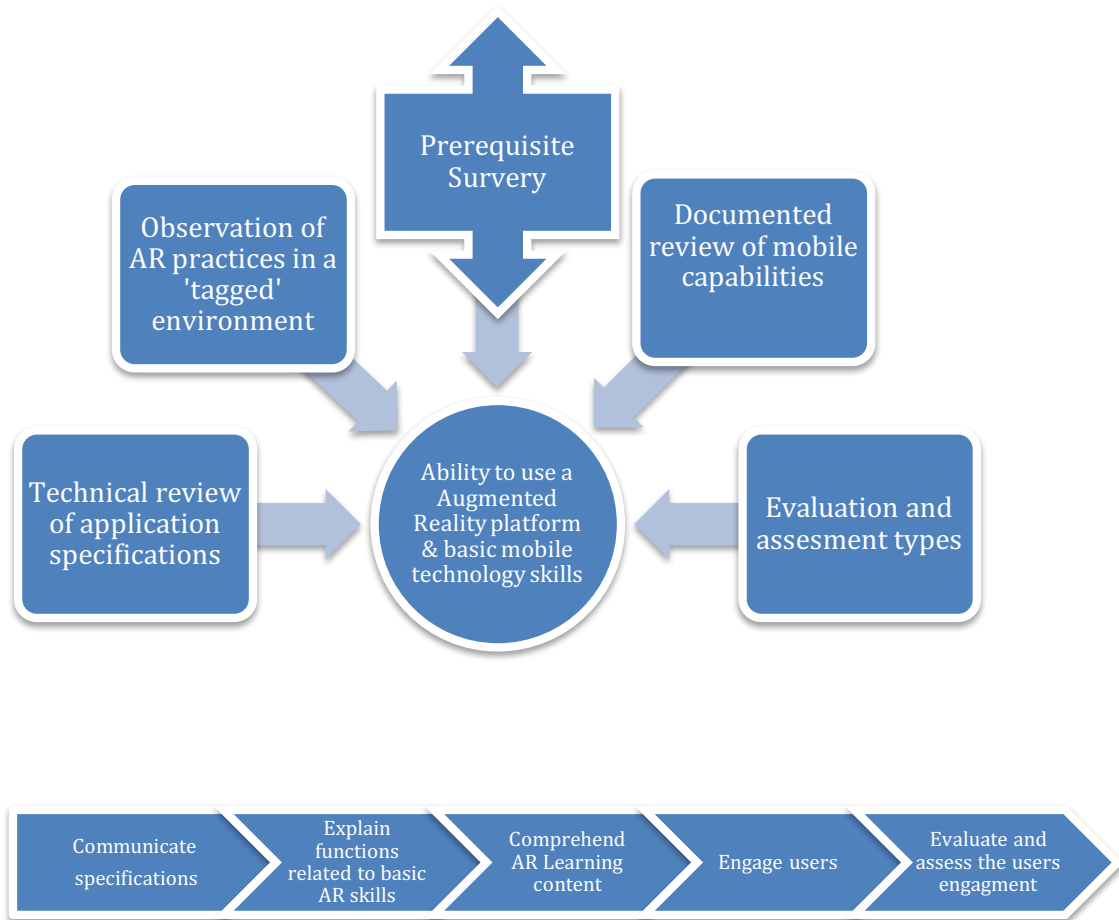


FIGURE 17: RESEARCH DESIGN PATH

1. Participants download an Augmented Reality application. This app is published in the iTunes store as ARed:

<https://itunes.apple.com/us/app/ared/id841114342?mt=8>

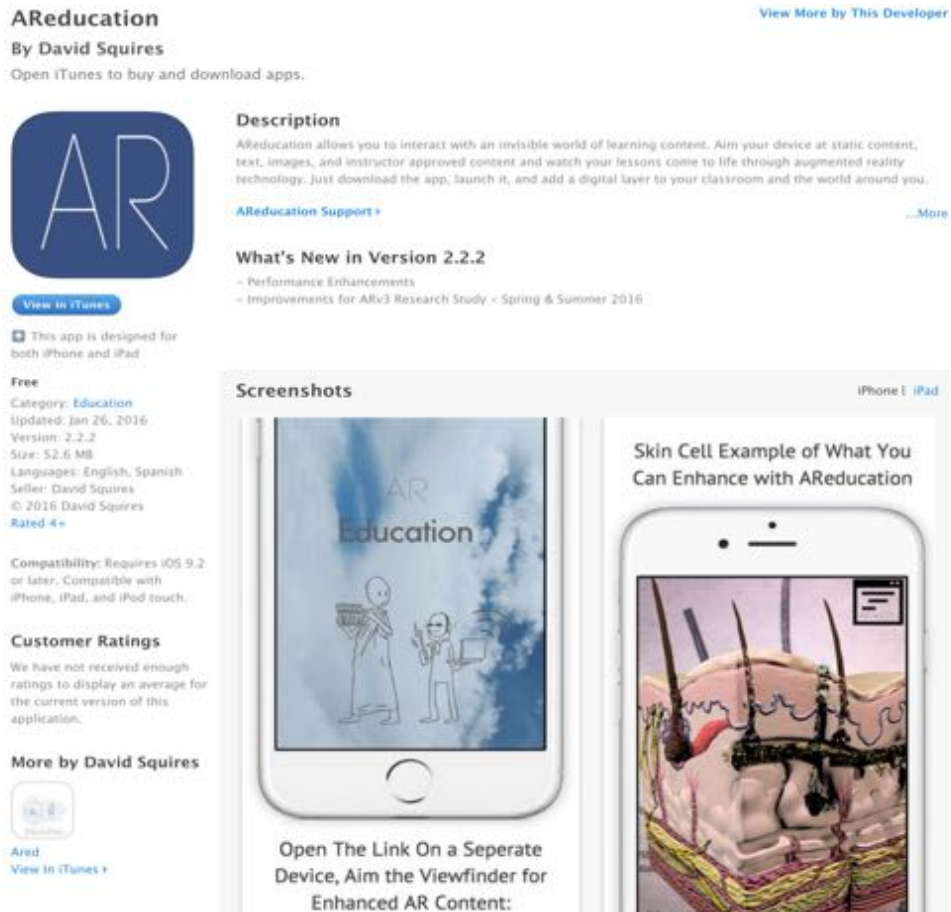


FIGURE 18: AREDUCTION APPLICATION

2. The AReduction app synchronizes with the research & design plan to measure mobile tools influence on learning, and these tool's potential influence on working memory when used as Electronic Performance Support System.

- A Learning Management System (LMS) is available where participants can take assessments and engage with the supplementary materials. It can be accessed by Group 1 & 2 at:

<https://piazza.com/uga/summer2016/areductionv3/home>

## AREducation V3: Mobile Learning & Augmented Reality

Number of posts: 5

Course Information

Staff

Resources

### Description

This course will be conducted entirely online and the use of a smart phone capable of downloading applications is required. The course is designed to help illustrate how Augmented Reality and Trigger-images can work in both a synchronous and asynchronous classroom environment. This course will take into account that the uninitiated learner may not have experience with AR systems and help to shed light on their use, functionality, and integration within virtual learning environments.

- 1) Please click enroll in course in the upper right corner on your screen to receive more content, assignments, and instructor updates.
- 2) Enrollment Code (case sensitive): ARed
- 3) To access the full class content please email: [squiresd@uga.edu](mailto:squiresd@uga.edu). Include your name and mobile phone number; After registration you will receive an SMS from the instructor including Trigger tags for class assignments.
- 4) Scroll down -- your first assignment begins at the bottom of the page.

General Information  
Augmented Reality  
Need access to smart phone and iTunes store:  
<https://itunes.apple.com/us/app/ared/id941114342?is=1&mt=8>

Student's will use a unique Augmented Reality application to discover and display learning content for this course site. Student work will also be submitted to the AR-ed application database using a File Transfer Protocol system (discussed in more depth during the course).

Readings will consists of PDFs, Googlesites, and Accesses to Youtube instructional audio/video.

### Announcements

No announcements, yet. Stay tuned!

### General Information

#### Course Goals

The goal of this course is to instruct learners on how to interact, implement, and design Augmented Reality interactions to be utilized in a variety of learning environments.

#### Discussion Board

Please post your first assignment on the unlocked discussion board once you enroll in the course.

#### Assignments & Homework

Assignments will consist of accessing Trigger overlays, designing your own 'story cache', and writing brief discussion board comments on implementation and Augmented Reality tool specificity.

Assessments will be conducted online.

FIGURE 19: PIAZZA STUDENT LMS

3. Data is collected within the application itself using mixed methods, with Likert-survey, open-ended survey. Also, live 'analytic observations' of device IDs, Internet Protocol addresses, and interview follow-ups are requested. Once user consent is granted via an online consent form, that includes a "live button," participants can click to demonstrate their consent.





FIGURE 20: ONLINE RESEARCH SURVEY ACCESS SITE

4. Using Piazza, Qualtrics, and the Google Analytics engines and data export tool, data analysis is converted into tables and converted using descriptive statistics and added to the Mixed-Method tool MAXQDA. Data for each segment of the near and far transfer question testing and other “trigger” events can be logged as each learning category using both survey & Google Analytics in order to confirm user completion of transfer questions.

➤ Do you remember what you just learned?

Can you apply what you just learned? This successful completion triggers the Likert

TLX instrument measuring:

➤ How frustrated were you?

➤ How hard was the concept to learn?

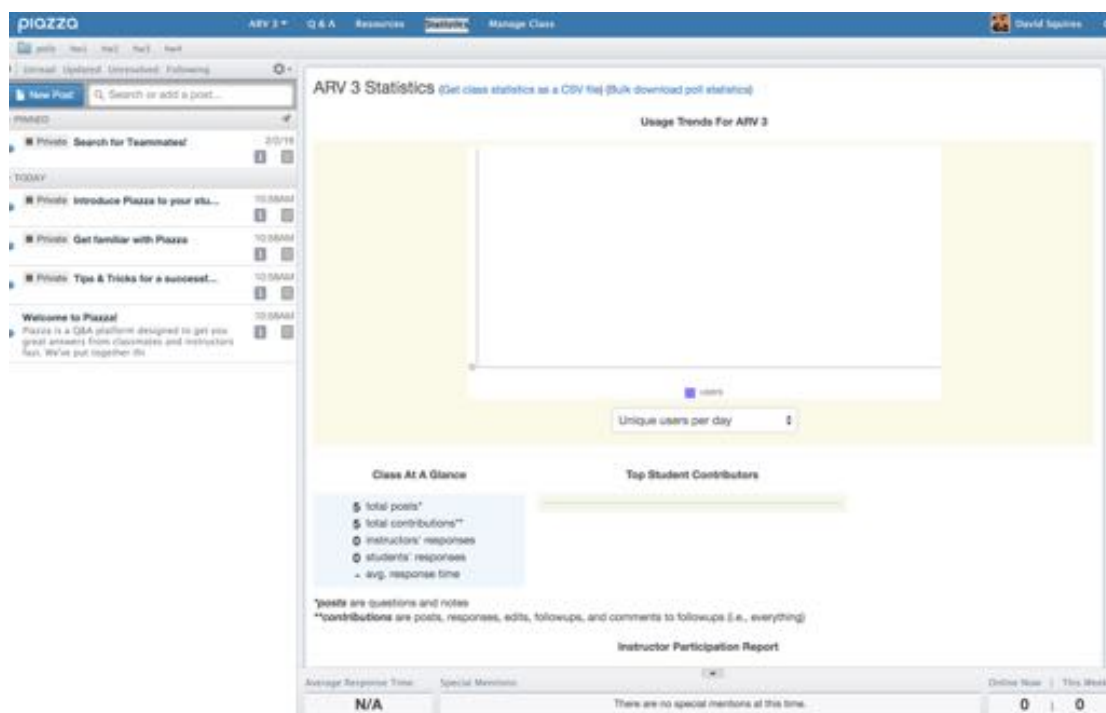


FIGURE 21: LMS ANALYTICS COLLECTION SITE

5. Assess the Group learning participant engagement and usability and pre and posttest feedback surveys.

6. A companion website is both available natively with the app, the research survey and online by following the is link: <http://www.davidsquires.info/trigger>

### AR –Learning Module

By simply pointing the device’s camera viewfinder at a designated media artifact, (digital and tangible - such as a ‘card deck’ of printed artifacts) and “triggering” a database recall interaction; the triggered interaction initiates the first step in an AR training course designed to collect and measure user outputs.

- Step 1: Download the ARed (AR-Education) app on iOS.



iOS Augmented Reality Experience Language (AREL) view screen:

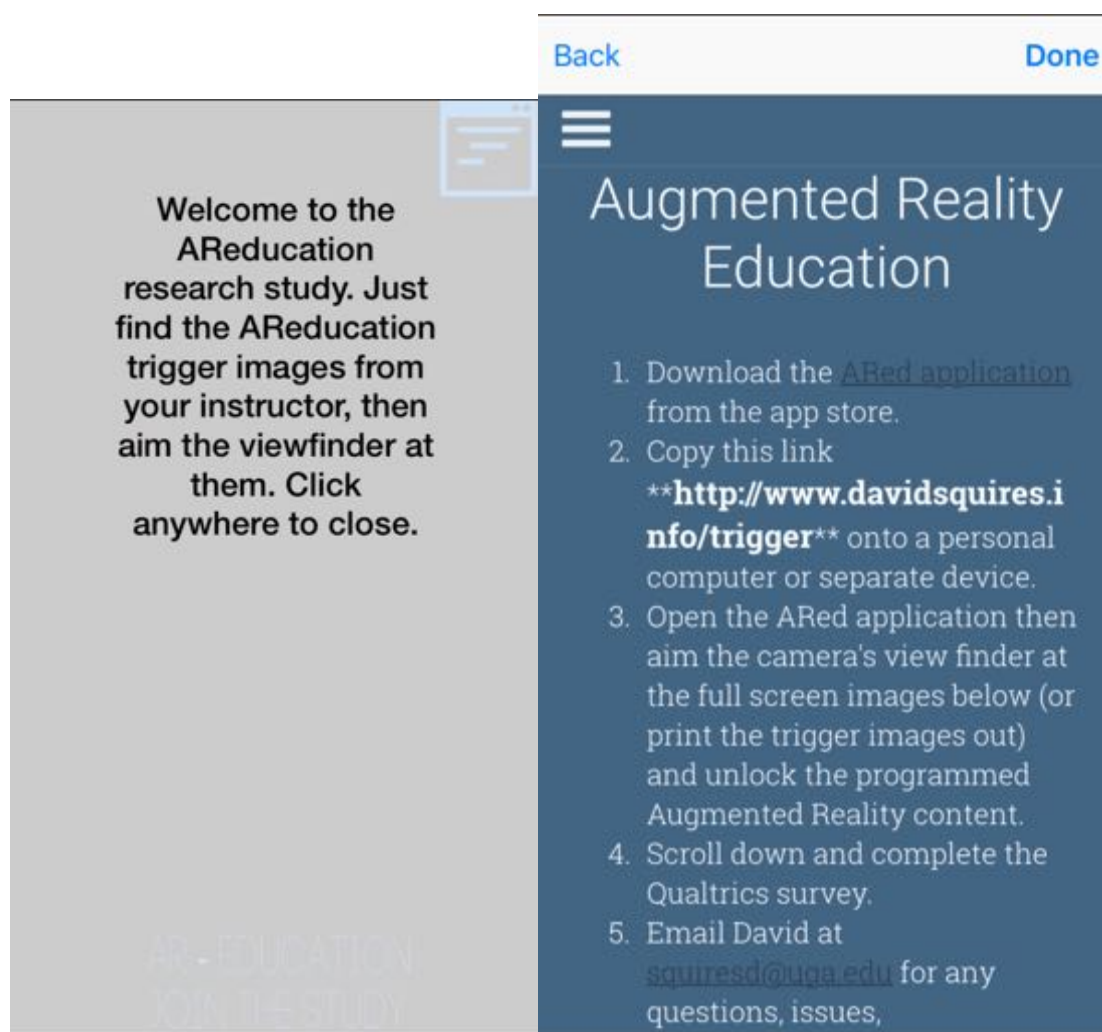


FIGURE 22: AREDUCTION IN APP JOIN STUDY VIEW

Examples of Augmented Reality to be applied within Learning Module

### Lesson Example

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

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

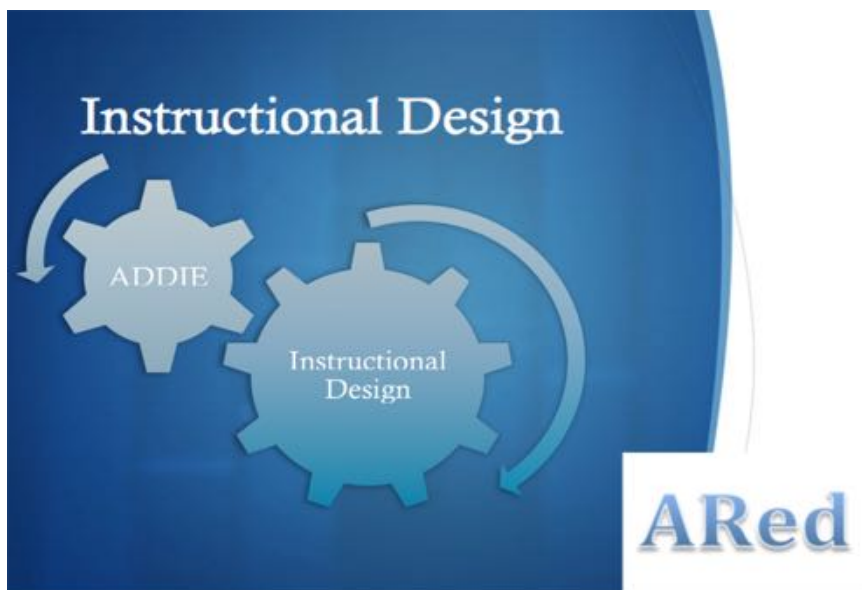


FIGURE 23: AR DEMO “TRIGGER”

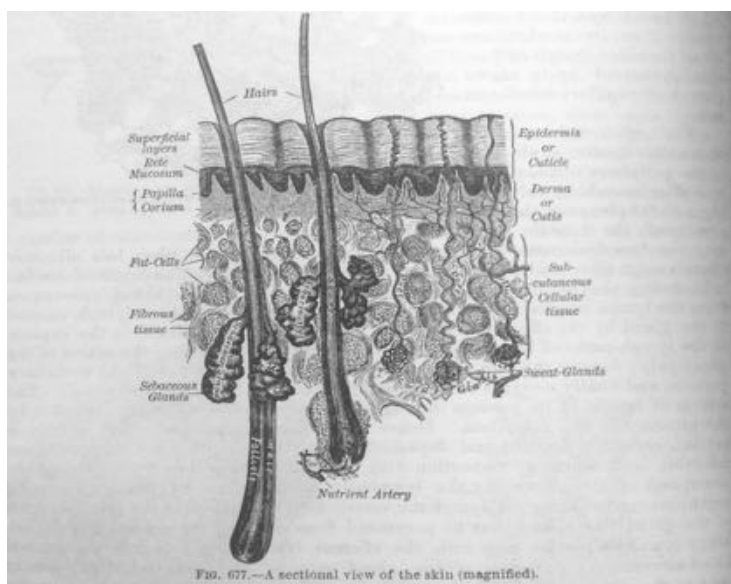


FIGURE 24: HUMAN ANATOMY AND PHYSIOLOGY— IN CLASS AR STUDY AID

- From the end user's perspective, creating an AR working memory utilization regime would be as user friendly as possible, including downloading the app onto an iPad for a larger screen resolution, but also initiating the action by simply pointing the device's camera at a designated object, and "triggering" a database recall interaction that would begin an AR module designed to target key concepts within the course structure.

### **Delivery System: 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 complain website for the survey analysis. Participants have the option not use the application, or use a blended strategy to measure if it 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 will include: 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 can be downloaded through a combined application programming 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.

### **Ethical Considerations**

- Consent is required during all stages of the data collection in order for the AReducation application to be unlocked, and auxiliary trigger content transferred to an iOS device, or a Glass Development Kit (GDK) wearable Augmented Reality device. Only the research team will have access to the participant's name and contact information. All interview names and data will later be replaced with an identification number or symbol. All interview data is voluntary and participants may still complete the survey, download the app, and decline the follow up interview.
- There is a limit to the confidentiality that can be guaranteed due to the technology itself. Online data will be kept to make sure that the survey data was indeed from legitimate sources (not spam or the same individual repeatedly sending info). This info could theoretically identify an individual using an Internet Protocol log, but to account for virtual private networks and changes to Internet protocol addresses, some type of personal I.D. is needed for a short amount of time during the data collection. After completion of the survey, and once user legitimacy is guaranteed, any identifying data will be destroyed or de-identified. Only the research team will have access to data, and Internet protocol addresses that may be personally indefinable, and all identifiers will be replaced with numerical codes or symbols. The results of the research study may be published, but user names or any personally identifying information provided will not be used. In fact, the published results will be presented in summary form only.

- Google analytics will identify the approximate amount of time the user uses the app, and the device used will be the only personally identifiable items identified, unless users choose to reveal that information in the survey. Nothing else will be accessed (this includes friends list, messages, or anything else related to social media). Users can choose not to participate at any time if they feel uncomfortable with any of these data collection identifiers.
- The benefits of this study include the chance to test a novel form of technology using an Augmented Reality screen reader, and providing feedback on its use in learning environments. Augmented Reality is a novel technology that can bring learning content to life. Therefore, the risks are minimal in so far as personally identifiable data could first be captured and then somehow decrypted. Furthermore, it is unlikely, but even if data were captured the participant's submitted data would be a small price for the added benefit of their personal feedback and use of the technology, and how it can be applied to learning environments. The findings from this project may provide information on mobile learning, learning engagement, and 'brain training' games that could potentially increase memory and recall. There are no known risks or discomforts associated with this research.

## **Appendix B: Pilot Study**

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 through the Summer of 2016. 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.

### **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 through the interview transcripts, writing memos, conducting descriptive analysis, checking for trends, and developing a qualitative codebook (Creswell, 2015).

### **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 AReduction course that included AR enhancement. Participants downloaded the ARed Augmented Reality program, 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 engine embedded in the AReducation app to match participant responses to the reporting device used to unlock the AR overlay content.

### **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. Most 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 increasing the interaction and engagement to increase the transfer of knowledge).

TABLE 21: PARTICIPANT'S REACTIONS TO AUGMENTED REALITY ENABLED ONLINE COURSE CONTENT

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 influences my memory of the content	<b>4.58</b>	<b>0.57</b>

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

## **Appendix C: Survey Instruments**

### **Initial Survey and Follow Up Surveys to Triggers**

The rationale for the survey is to measure if participants are able to participant in the survey, and to apply qualifying questions in order for participants to move onto the next survey questions, download the AReduction app from iTunes, enroll in the online course, and test their response to cognitive load from triggered content.

#### **Initial Grouping**

Q1 You must be 18 years of age or older to participate in this survey.

Q2 Gender

- ☐ Male (1)
- ☐ Female (2)

Q3 Affiliation with the University of Georgia

- ☐ Undergraduate Student (1)
- ☐ Graduate Student (2)

Do you have an iOS device, and did you download the AReduction app from the iTunes store? Right click the link and select open in a new tab: AReduction app download.

- ☐ Yes (1)
- ☐ No (2)

Q1 I know how to download an app for iTunes

☐ Yes (1)

☐ No (2)

Q2 I have access to an iPhone or iPad capable of downloading apps from the internet

☐ Yes (1)

☐ No (2)

Q3 I have the technical skills I need to download and use an app from iTunes

☐ Yes (1)

☐ No (2)

Scan the Quick Response code below using any iOS or Android approved QR reader application



FIGURE 25: QR CODE AR STUDY

## Appendix D: e-Corsi Block Tests

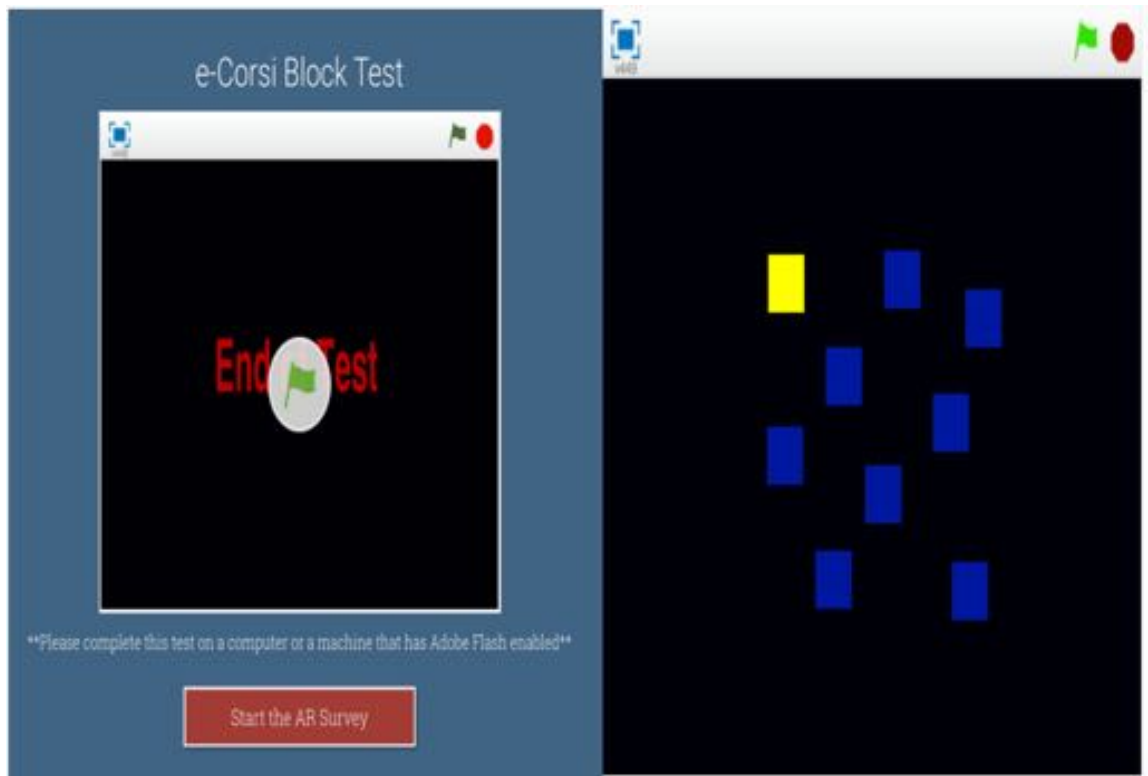


FIGURE 26: ONLINE E-CORSI BLOCK TEST

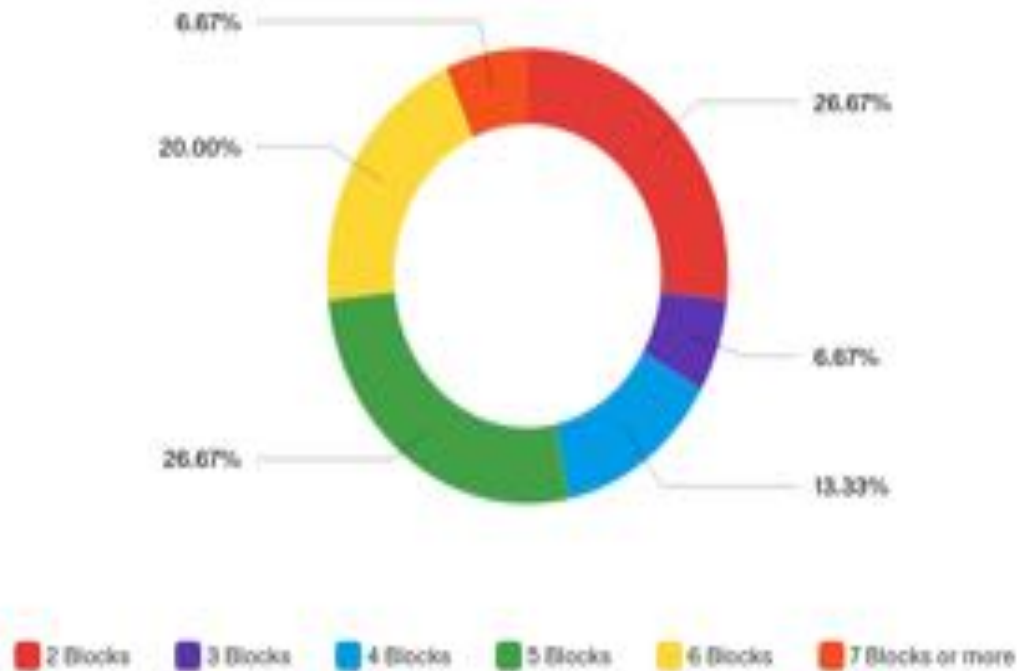


FIGURE 27: PRE-TEST AR USERS REPORT

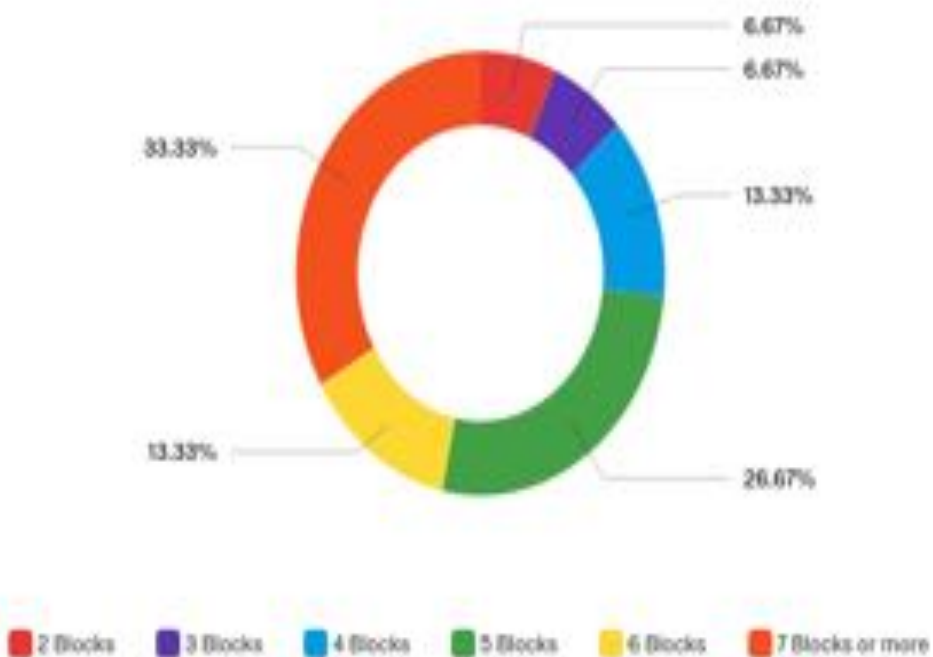


FIGURE 28: POST-TEST AR USERS REPORT

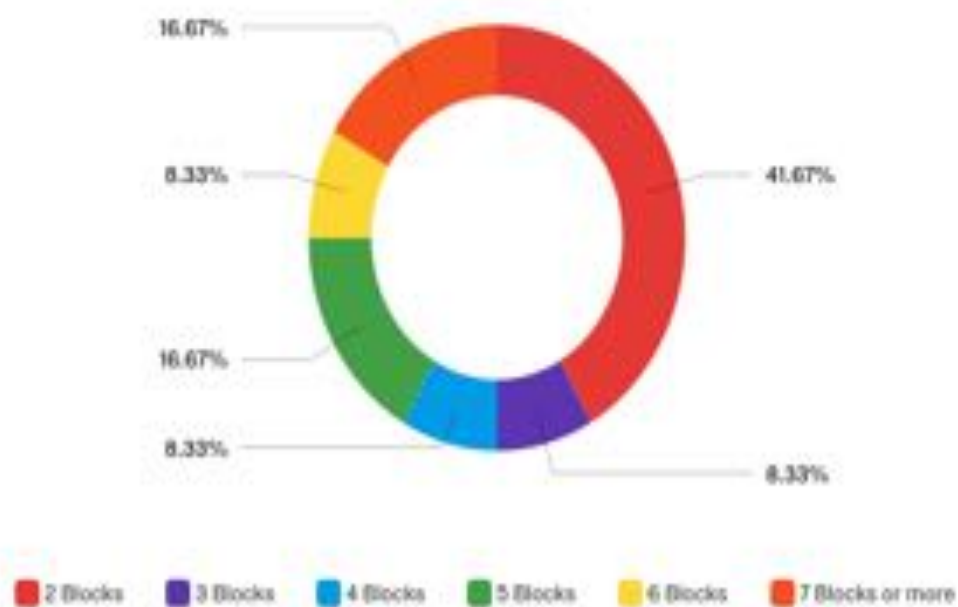


FIGURE 29: PRE-TEST NON USERS REPORT

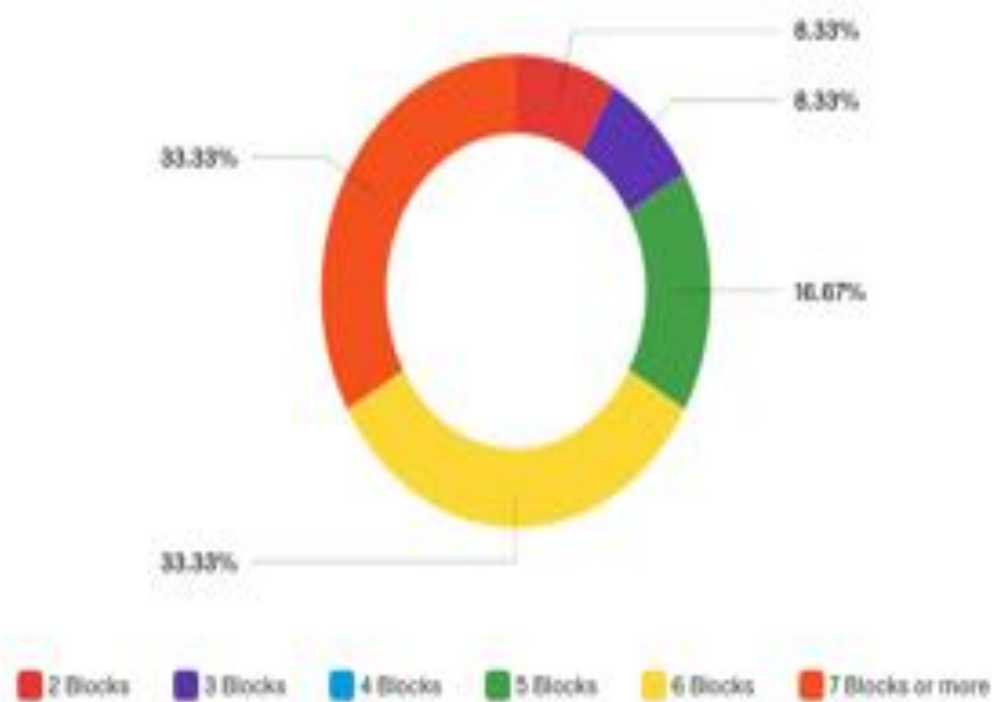


FIGURE 30: POST -TEST NON USERS REPORT



## Appendix E: AR Content & Non-Augmented Course Content

### Non-AR Content

#### Course Group 1

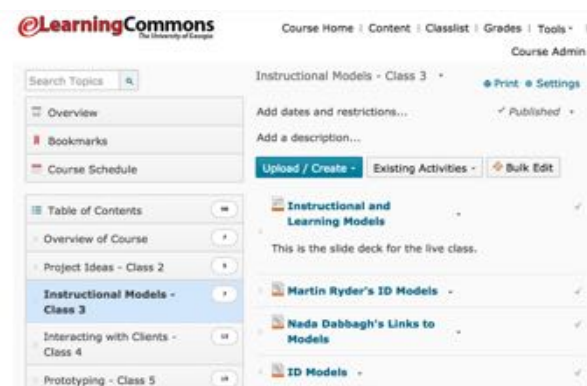


FIGURE 31: NON-AR GROUP USES THE ELC LMS SITE TO ACCESS COURSE CONTENT

For this assignment, you need to specify your client, instructional strategy or instructional model, and project title with an indication of scope for the project. While this can be changed later, it would be in your best interest to use the initial weeks in the class to make sure that you have a solid project, and a cooperative Subject Matter Expert (SME)/ Client.

The most important component of this experience is choosing an instructional model to guide the design of your instructional product.

FIGURE 32: COMPLETE ASSIGNMENTS



FIGURE 33: VIEW READINGS

**Instructional Design Knowledge Base**  
*Select Instructional Models / Theories to Develop Instructional Prototypes*

Embedded Theories / Principles/Theories | Goals of Instruction | Instructional Models | Implications for Instructional Design

Behavioral/Behaviorism	Cognitive/Processivism	Constructivism/Interpersonalism
<p>Learning happens when a correct response is demonstrated following the presentation of a specific environmental stimulus.</p> <p>Learning can be detected by observing an organism over a period of time.</p> <p>Emphasis is on observable and measurable behaviors.</p> <p>Uses a "black box" metaphor - the learner is a black box, what happens inside is unknown.</p> <p>Emphasis is on relationships between environmental variables and behavior.</p> <p>Instruction utilizes consequences and reinforcement of learned behaviors.</p> <p>Believes behavior is guided by purpose.</p> <p>Care are antecedents to behavior and set the conditions for its occurrence.</p>	<p>Learning is a change of knowledge state.</p> <p>Knowledge acquisition is described as a mental activity that entails internal coding and structuring by the learner.</p> <p>Learner is viewed as an active participant in the learning process.</p> <p>Emphasis is on the building blocks of knowledge (e.g. identifying prerequisite relationships of content).</p> <p>Emphasis on structuring, organizing and sequencing information to facilitate optimal processing.</p> <p>Focus is on how learners remember, retrieve, and store information in memory.</p> <p>Examines the mental structure and processes related to learning.</p> <p>Learning is viewed as an active process that occurs within the learner and which can be influenced by the learner.</p> <p>The outcome of learning is not only dependent on what the teacher presents but also on what the learner does to process the information.</p>	<p>Learners build personal interpretation of the world based on experiences and interactions.</p> <p>Knowledge is embedded in the context in which it is used (authentic tasks in meaningful, realistic settings).</p> <p>Create novel and situation-specific understandings by "assembling" knowledge from diverse sources appropriate to the problem at hand (flexible use of knowledge).</p> <p>Believes that there are many ways (multiple perspectives) of structuring the world and its access.</p> <p>Believes that meaning is imposed by the individual rather than existing in the world independently.</p>

FIGURE 34: VIEW READINGS 2

## Course Group 2

**eLearningCommons**  
The knowledge of tomorrow

Course Home | Content | Classlist | Grades | Tools | Course Admin

Mobile Learning Level 1

Print Settings

Add dates and restrictions... Published

Add a description...

Upload / Create Existing Activities Bulk Edit

Expand All Collapse All

**AReduction\_EDIT6150**

**Horizon Report on Mobile Learning k12 (read if k12)**

**Horizon Report on Mobile Learning HigherEd (read if HigherEd)**

**Tempest - Augmented Reality TED talk (watch)**

**Educause - Are you ready for mobile learning? (read)**

Optional

Upload / Create Existing Activities

**What is mobile learning? (read)**

**Tempest - Truth and lies (and iPods) (watch; it's amazing, take 4min to watch!)**

FIGURE 35: NON-AR GROUP USES THE ELC LMS SITE TO ACCESS COURSE CONTENT



FIGURE 36: WATCH COURSE VIDEOS

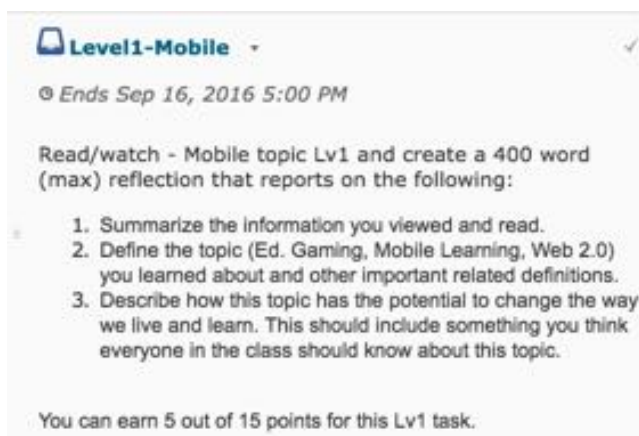


FIGURE 37: COMPLETE ASSIGNMENTS

### AR CONTENT COURSE GROUP 1

Learners aim at single static image linking the entire course module content from the LMS within the mobile application AReducation.

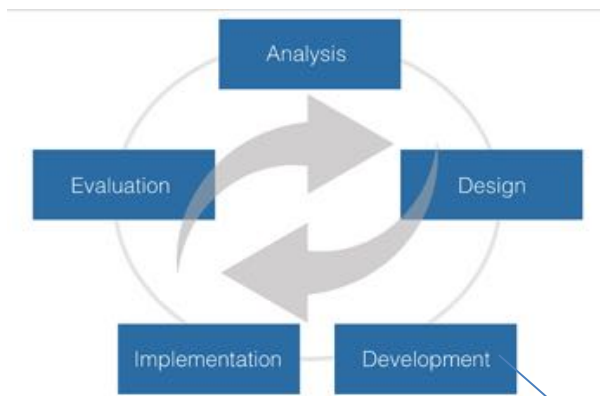


FIGURE 38: OVERLAYS AR GROUP 1



FIGURE 39: LINKED OVERLAYS AND TRIGGERED CONTENT

## AR Content Course Group 2



FIGURE 40: AR OVERLAY EXAMPLE WITH TRIGGER BASED LINKED ASSIGNMENTS

AR Content: Examples of Augmented Reality overlay trigger based content linked to Piazza LMS. Participants are asked to post in the discussion if they remember the AR content that is randomized from 7 images. The model is based on the e-Corsi block test model attempting to measure if participants remember content more fully by aiming their mobile device at the images in a succession and recalling the overlays in the discussion posts:





FIGURE 41: AREDUCATION DIAGRAM OF OVERLAY PROCESSED CONTENT



FIGURE 42: GOOGLE ANALYTICS SDK EMBEDDED IN AREDUCATION APP

University of Georgia - Fall 2018  
**AREDUCTION V4: Mobile Learning & Augmented Reality**  
 Number of posts: 5 |

Course Information Staff Resources

### Description

This course will be conducted entirely online and the use of a smart phone capable of downloading applications is required. The course is designed to help illustrate how Augmented Reality and Trigger-images can work in both a synchronous and asynchronous classroom environment. This course will take into account that the uninited learner may not have experience with AR systems and help to shed light on their use, functionality, and integration within virtual learning environments.

- 1) Please click enroll in course in the upper right corner on your screen to receive more content, assignments, and instructor updates.
- 2) Enrollment Code (case sensitive): ARed
- 3) To access the full class content please email: [squiresd@uga.edu](mailto:squiresd@uga.edu) include your name and mobile phone number; After registration you will receive an SMS from the instructor including Trigger tags for class assignments.
- 4) Scroll down -- your first assignment begins at the bottom of the page.

General Information  
 Augmented Reality  
 Need access to smart phone and iTunes store:  
<https://itunes.apple.com/us/app/ared/id641114342?ls=1&mt=8>

### Announcements

After completion of the e-Corsi block test download the AReduction app and aim at the trigger images. When completed post in the discussion which overlays appeared and can you remember which trigger image is associated with each AR trigger overlay.

Trigger Test: <https://www.davidsquires.info/trigger>

FIGURE 43: AREDUCATION PIAZZA LMS SITE

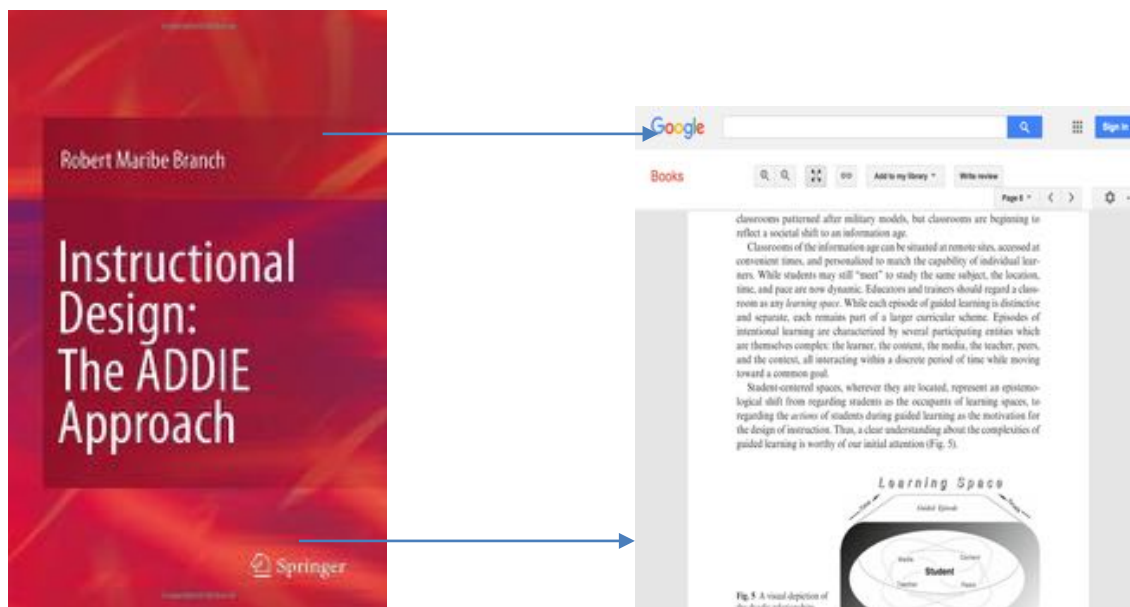


FIGURE 44: PIAZZA AREDUCATION TRIGGERS #8

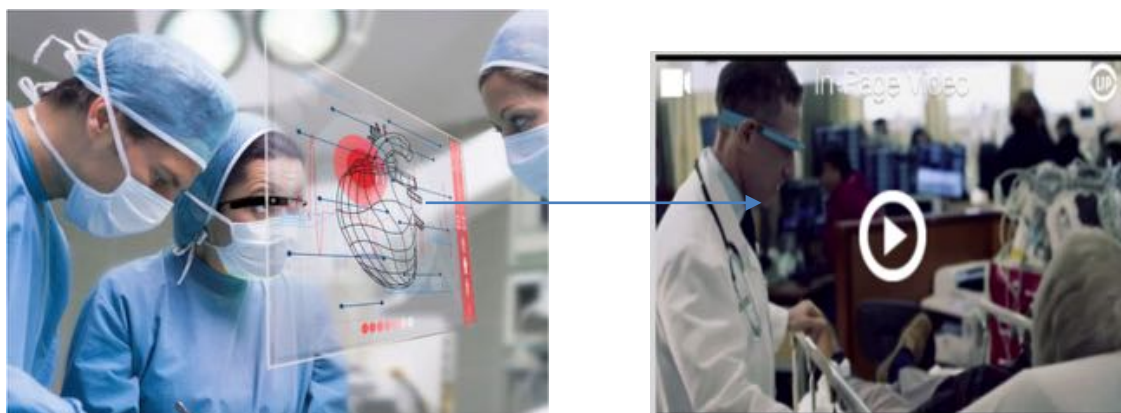


FIGURE 45: PIAZZA AREDUCATION TRIGGER #4

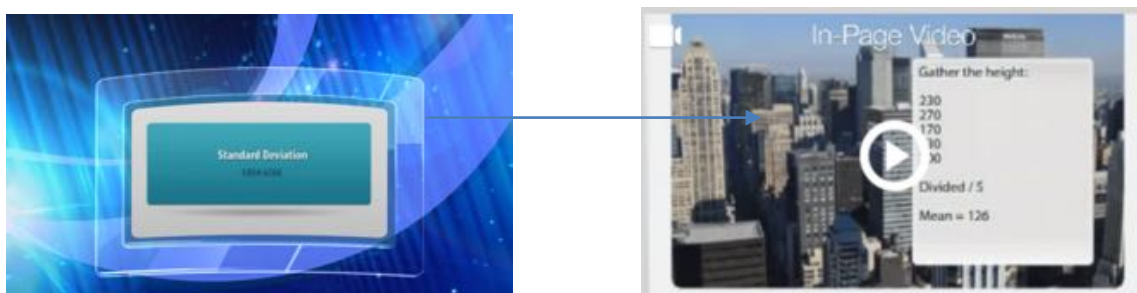


FIGURE 46: PIAZZA AREDUCATION TRIGGER #1



FIGURE 47: PIAZZA AREDUCATION TRIGGER #2



FIGURE 48: PIAZZA AREDUCATION TRIGGER #7

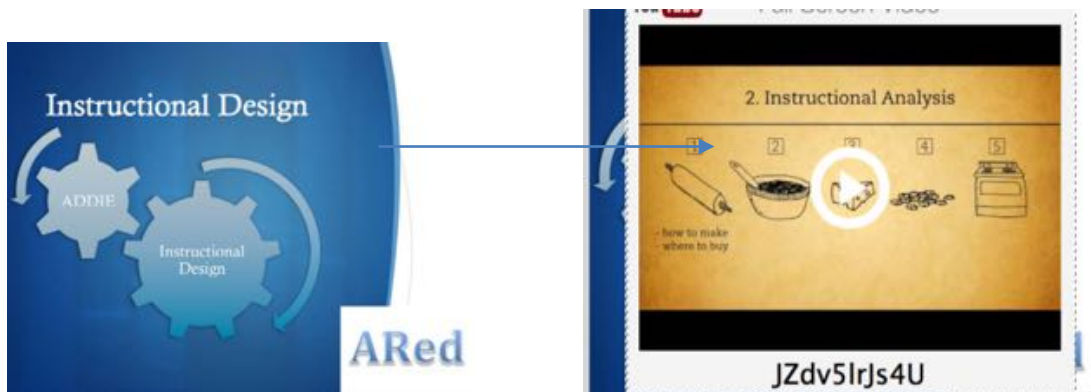


FIGURE 49: EXAMPLES OF OVERLAY IMAGES WITH AR OVERLAID CONTENT IN PIAZZA LMS



## **Appendix F: TLX Instrument and Survey**

Follow-Up Survey After Each AR-Trigger: Did the participants ascertain the learning material and can they recognize what they learned?

### **AR - Users**

- Do you remember what you just learned with the AR Trigger image?
- Can you apply what you just learned?
- How hard was the task to learn?
- Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

### **Non –AR users**

- Do you remember what you just learned on the ELC course site module?
- Can you apply what you just learned from the ELC course site?
- How hard was the task to learn?
- Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

Key Concepts of Augmented Reality followed by Triggered Based AR Events (Adapted from TLX).

Mental: How hard was the task to learn?

Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

### **NASA Task Load Index**

*Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.*

Name	Task	Date
------	------	------

**Mental Demand**                      How mentally demanding was the task?

Very Low                      Very High

**Physical Demand**                      How physically demanding was the task?

Very Low                      Very High

**Temporal Demand**                      How hurried or rushed was the pace of the task?

Very Low                      Very High

**Performance**                      How successful were you in accomplishing what you were asked to do?

Perfect                      Failure


**Effort**                      How hard did you have to work to accomplish your level of performance?

Very Low                      Very High

**Frustration**                      How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low                      Very High

FIGURE 50: ORIGINAL TLX INSTRUMENT

 THE UNIVERSITY OF GEORGIA


How Hard was the task to learn?

Extremely easy	Moderately easy	Slightly easy	Neither easy nor difficult	Slightly difficult	Moderately difficult	Extremely difficult				
0	1	2	3	4	5	6	7	8	9	10

Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Very Low






FIGURE 51: TLX ADAPTED FOR AREducation APPLICATION

Mental: How hard was the task to learn?

Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

THE UNIVERSITY OF GEORGIA

How Hard was the task to learn?

Extremely easy      Moderately easy      Slightly easy      Neither easy nor difficult

0 1 2 3 4 5 6 7 8 9 10

Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

0 1 2 3 4 5 6 7 8 9 10

Very Low

FIGURE 52: MOBILE EXAMPLE OF TLX FOR AUGMENTED TRIGGER INFORMATION TEST

### AR Only Participants

		Pre Test						Post Test							
		2 Blocks	3 Blocks	4 Blocks	5 Blocks	6 Blocks	7 Blocks or more	Total	2 Blocks	3 Blocks	4 Blocks	5 Blocks	6 Blocks	7 Blocks or more	Total
e-Corsi Pre Test	2 Blocks	4	0	0	0	0	0	4	1	1	2	0	0	0	4
	3 Blocks	0	1	0	0	0	0	1	0	0	0	1	0	0	1
	4 Blocks	0	0	2	0	0	0	2	0	0	0	2	0	0	2
	5 Blocks	0	0	0	4	0	0	4	0	0	0	1	2	1	4
	6 Blocks	0	0	0	0	3	0	3	0	0	0	0	0	3	3
	7 Blocks or more	0	0	0	0	0	1	1	0	0	0	0	0	1	1
Total		4	1	2	4	3	1	15	1	1	2	4	2	5	15
e-Corsi Post Test	2 Blocks	1	0	0	0	0	0	1	1	0	0	0	0	0	1
	3 Blocks	1	0	0	0	0	0	1	0	1	0	0	0	0	1
	4 Blocks	2	0	0	0	0	0	2	0	0	2	0	0	0	2
	5 Blocks	0	1	2	1	0	0	4	0	0	0	4	0	0	4
	6 Blocks	0	0	0	2	0	0	2	0	0	0	0	2	0	2
	7 Blocks or more	0	0	0	1	3	1	5	0	0	0	0	0	5	5
Total		4	1	2	4	3	1	15	1	1	2	4	2	5	15

FIGURE 53: E-CORSI PRETEST VERSUS POST-TEST RESULTS AR ONLY GROUPS

### Non-AR Participants

		Pre Test						Total	Post Test						Total
		2 Blocks	3 Blocks	4 Blocks	5 Blocks	6 Blocks	7 Blocks or more		2 Blocks	3 Blocks	4 Blocks	5 Blocks	6 Blocks	7 Blocks or more	
e-Corsi Pre Test	2 Blocks	5	0	0	0	0	0	5	1	1	0	2	1	0	5
	3 Blocks	0	1	0	0	0	0	1	0	0	0	0	1	0	1
	4 Blocks	0	0	1	0	0	0	1	0	0	0	0	1	0	1
	5 Blocks	0	0	0	2	0	0	2	0	0	0	0	1	1	2
	6 Blocks	0	0	0	0	1	0	1	0	0	0	0	0	1	1
	7 Blocks or more	0	0	0	0	0	2	2	0	0	0	0	0	2	2
Total		5	1	1	2	1	2	12	1	1	0	2	4	4	12
e-Corsi Post Test	2 Blocks	1	0	0	0	0	0	1	1	0	0	0	0	0	1
	3 Blocks	1	0	0	0	0	0	1	0	1	0	0	0	0	1
	4 Blocks	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 Blocks	2	0	0	0	0	0	2	0	0	0	2	0	0	2
	6 Blocks	1	1	1	1	0	0	4	0	0	0	0	4	0	4
	7 Blocks or more	0	0	0	1	1	2	4	0	0	0	0	0	4	4
Total		5	1	1	2	1	2	12	1	1	0	2	4	4	12

FIGURE 54: E-CORSI PRETEST VERSUS POST-TEST RESULTS ELC ONLY GROUPS

TABLE 22: DO YOU REMEMBER WHAT YOU JUST LEARNED WITH THE AR TRIGGER IMAGE?



TABLE 23: CAN YOU APPLY WHAT YOU JUST LEARNED?

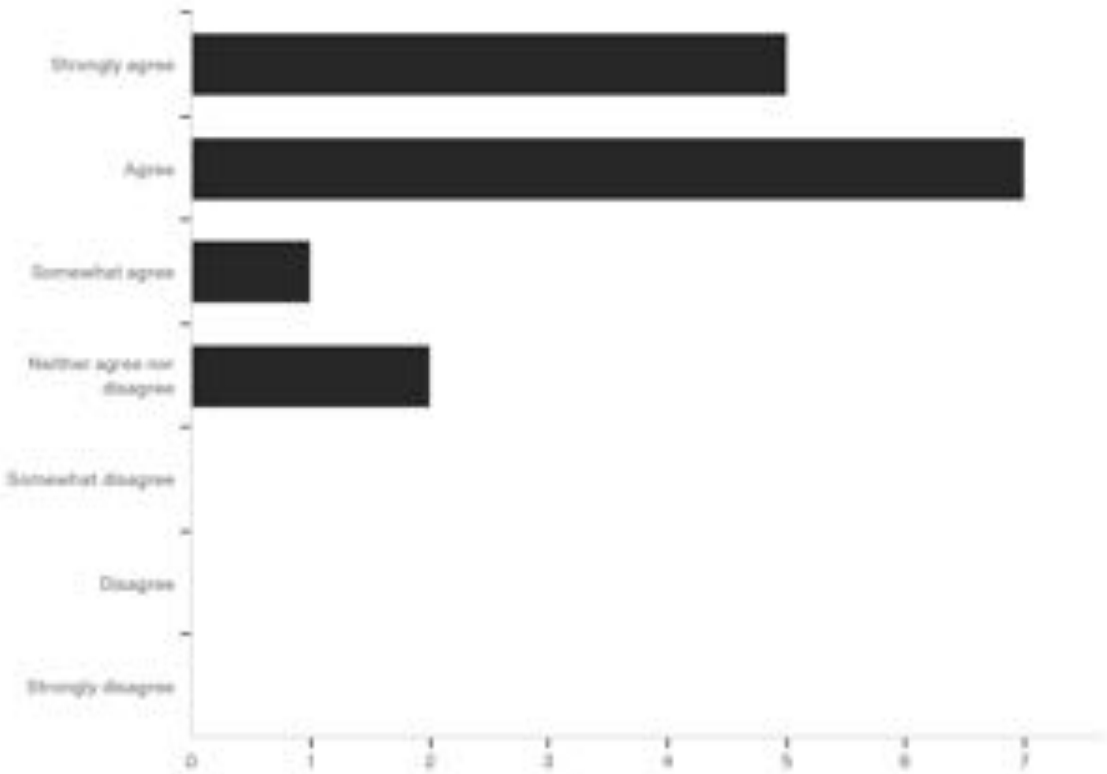


TABLE 24: DO YOU REMEMBER WHAT YOU JUST LEARNED ON THE ELC COURSE SITE MODULE?

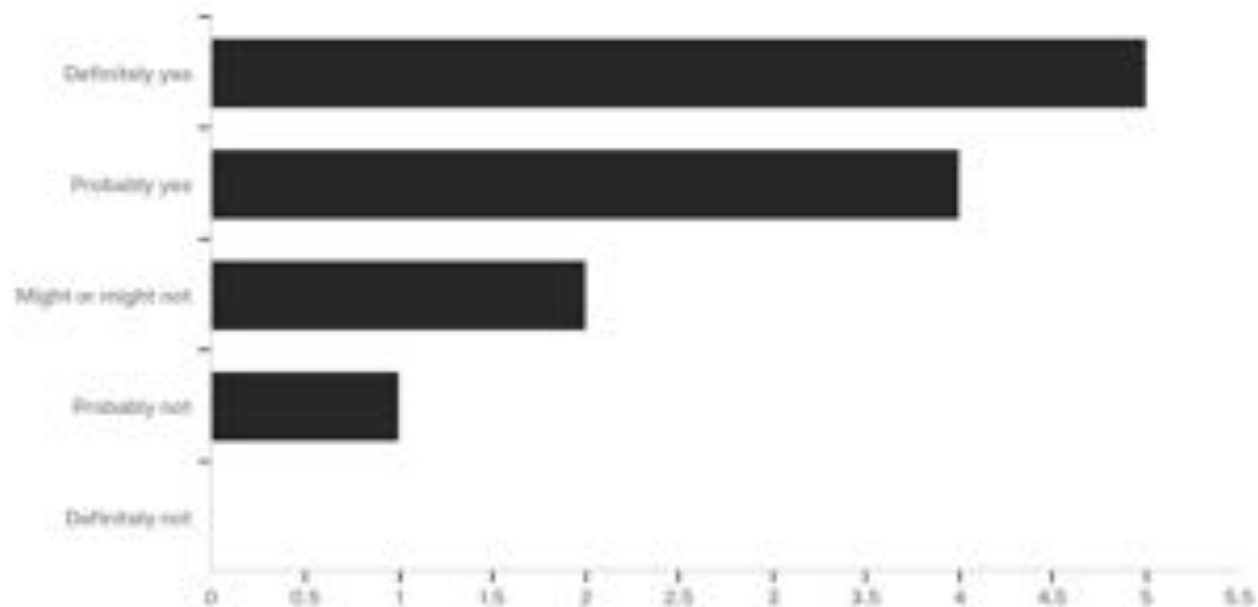
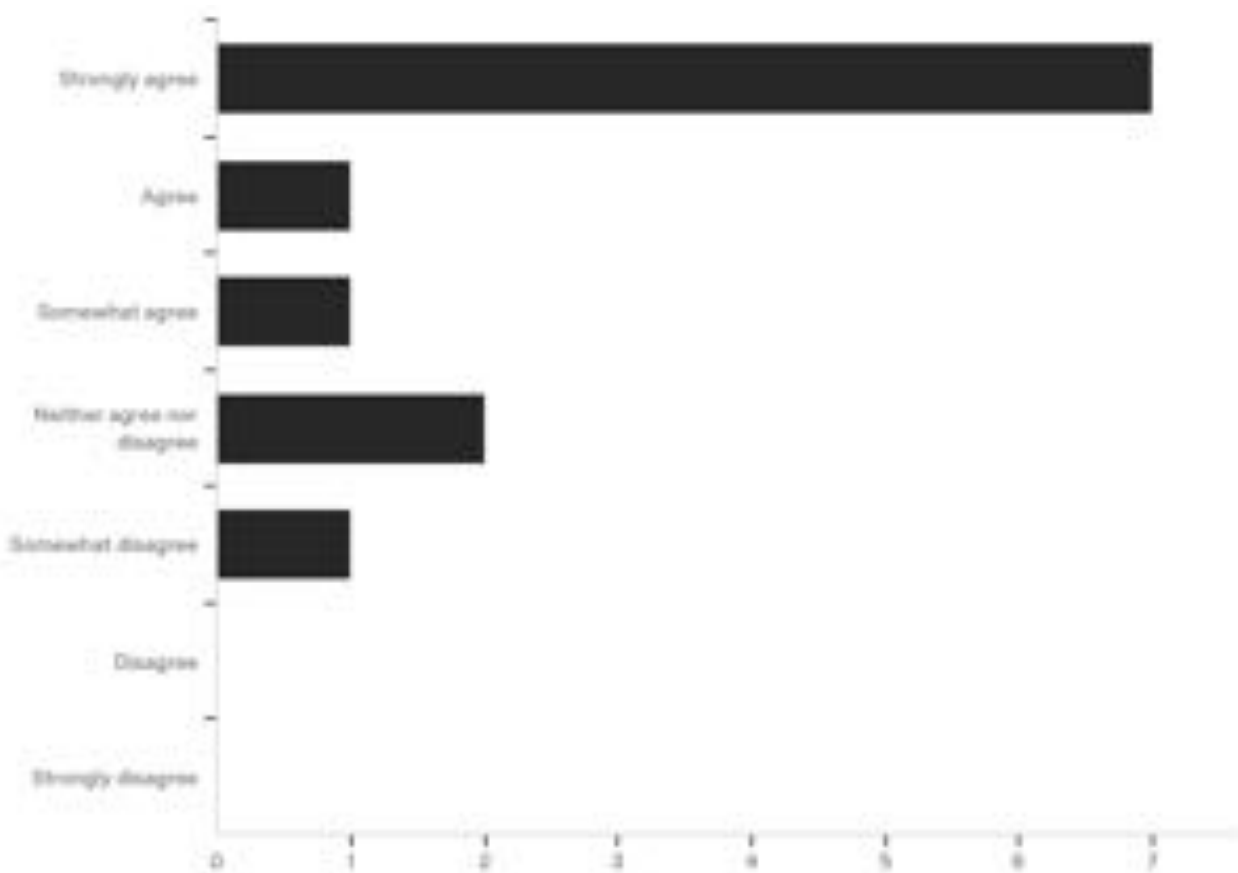


TABLE 25: CAN YOU APPLY WHAT YOU JUST LEARNED FROM THE ELC COURSE SITE?



### Appendix G: Open-ended AR Survey Questions

TABLE 26: WOULD YOU RECOMMEND USING AR TRAINING APPS IN A FACE-TO-FACE CLASSROOM ENVIRONMENT?

Useful to help create interactive course material.
It looked really neat to use - not sure how hard to create the aura.
Anything that brings an image to life and makes it more than just a 2D image can help stimulate learning.
For mathematics teachers, being able to display a more accurate 3-D environment. For example, when studying the 3-D plane and trying to visualize Octants.
It would provide a different approach to learning. It would facilitate concept understanding and can be incorporated to animations and simulations.
It makes the lesson more interactive. Instead of using drawing you can use this application for a more realistic depiction.
Useful: Promoting creativity with students helping them to literally use their imagination to change the world around themselves. (Thinking about creative writing.)
This would have many useful pieces in class-from review, assessment, small groups, tutoring, etc.



This would be great in learning environments that have layers to look at (i.e. Biology, Fashion Studies, Medical fields, Visual Art, Music, etc.)! WOW!
Interactive lessons-- As a government teacher, I would like it to show the interworkings of Congress
This will be great for the Sciences. Being able to see what carbons look like in 3D.
Better live interactions with objects that may be too expensive or inaccessible by a program.
I can see this device used during research projects where the teacher provides several different resources and additional information organized by trigger images.
AR can be very useful in teaching concepts that by their nature are difficult to visualize.
For many novice learners, the clearer information is presented the better the learner is able to understand. AR seems like a great way to build a more solid understanding.

The open-ended responses ( $n=15$ ) show that the majority of AR users would recommend AR application in a classroom and in general they found the modules and learning experience with AR to be beneficial.

TABLE 27: ARE AR OVERLAY INTERACTIONS THAT CONTAINED VIDEOS MORE OR LESS VALUABLE THAN CLICKING A YOUTUBE VIDEO OR LINK FOR ACCESSING COURSE CONTENT?

More this is where I see the strengths of AR, especially with a tool like Microsoft HoloLens that can offer overlays while looking at objects.
Yes - just like YouTube - people could use AR to learn things they have interest in.
I think so. Especially if what they are learning is a hands on process.
Helps to provide interaction to static images.
More, if even to challenge student's brains to form new connections when experimenting with a new type of tech.
Our society has more kinesthetic individuals. Because of this, we learn in a more hands on approach. This will give individuals more of a hands on version of the content and allow for a deeper understanding even if it is just a video.
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).
It helps individuals who are more kinesthetic to see and understand a task
Nothing beats tangible objects
I think it definitely provides hands on experience

More engaging than a YouTube video when you can see video floating on an AR image
Could be more useful especially when you need the information immediately can just point your device at it instead of searching a link or google for a website
I like how interactive it is. Anything that allows for more engagement between the student and the computer screen is a benefit.
I think it would work the same way as a regular
AR keeps users more engaged.

The participant feedback ( $n=15$ ) shows that users found that AR enabled video content in online classes would be more engaged than standard YouTube videos. The rationales varied but many posit that the AR content would be more hands-on, would be more interactive, or would work the same as standard YouTube videos while aping an overall novel level of engagement with the hands-on nature of AR overlaying content onto the learning environment.

TABLE 28: WOULD YOU RECOMMEND INSTRUCTORS USE AR TRAINING, OR AR TOOLS IN AN ONLINE CLASSROOM ENVIRONMENT?

It would help in making it more interactive or the instructors could use it to make it more understandable.
---

I believe that the same benefits are possible in the online environment as in the face-to-face classroom.
Instructors need to be on the cutting edge
It can help engage students.
Could boost interest in students
It would allow students to gain a different perspective
Interactivity
AR is safer and more cost efficient for many applications.
With online classes, I believe it is important to ensure that it is still as interactive and engaging as possible. AR technology is both of those things. It also provides instructors to provide additional information that may answer a question regarding a specific detail of a broader picture or topic.
AR would be perfect to demonstrate the different levels, abilities and mindsets of students. I envision being able to wear a device like google glass and being able to see student information as I look at them.
I think AR Training in an online class environment would be ideal alternative to what could be found in a face to face environment.
Repetition and practice at low cost.

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.
Definitely. Dissection of a brain/heart, etc. I believe that AR should definitely be used during AR training.
Useful for any instruction and or training

The participant responses ( $n=15$ ) show that after using AR applications participants would recommend using them in the future in online environments.

TABLE 29: WOULD YOU USE AR OUTSIDE OF THE CLASSROOM?

I would love to use AR outside of the classroom. I am very excited about the possibilities that Microsoft HoloLens offers and would love to see where the technology leads us.
I think AR would be useful in everyday life, might even have a market for creating instructional manuals for different consumer items.
I play Pokémon GO, and would be interested in finding other apps which use AR.
Yes, I would use this type of AR for sightseeing on vacation.
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 I use it in other applications outside of the classroom

I can see this possibly being used effectively for advertisements.
AR would be a great tool to help organize the vast amounts of information that our brains process in a given day. At would be great with reading. You could point your device at the page you are reading to discover more information on a topic.
I can see me using it for my own child in helping him learn technology. Or even in teaching something to myself.
Outside of the classroom provides alternative experience to what could be found in a face to face environment
Nature-related field trips would be spectacular!
Outside of my classroom, I try to keep my device use to a minimum
Sure, it seems like it is interesting.
Yes, on field trips
Applications are limitless....

Participants ( $n=15$ ) indicated that they would use AR outside the classroom and that AR's multiple uses lend itself to numerous iterations of implementation and use cases.

TABLE 30: USING THE AR EDUCATION APP FOR A WEEK OR MORE, AND TRAINING WITH UPDATED TRIGGER IMAGE OVERLAYS, DO YOU THINK THAT THIS PROCESS WOULD BE BENEFICIAL TO NOVICE LEARNERS?

If someone is interested enough, they could definitely have an idea of what to do/expect.
Yes, but I think it would need to be carefully constructed so that the novelty of the program fades quickly and the learners can see the benefits of using the app for their studies.
Novice learners (especially those who have grown up in the technology age) would find it easy to use the AR education app.
It can make learning more fun.
would speed learning
Novice learners will pick up quicker with the use of AR
Certainly, it would be helpful, assuming the learner is committed to the learning process, wants to learn, etc. A student who is distracted or does not want to learn will still not learn even with an AR display.
I think continued use would result in improved results
I believe that it is a fairly simple task to open an application and aim the camera at a trigger image.

It provides the basic technological literacy for a novice user to be more confident with their skills.
Yes. I see it very useful for children because it is so interactive.
Repetition with low risk and low cost.
Most novice learners may learn best initially to see a physical representation.
Yes, it is easy to setup and to use. This will even be great in Early Childhood education. Being able to teach kids how objects look in 3D when learning the alphabets etc.
it seems pretty engaging and has the potential to enhance instruction.

Participants ( $n=15$ ) found that after using the AReducation application, AR might be beneficial for novice learners and might help in training environments offering engaging content and learning strategies.

TABLE 31: DOES HAVING CONTENT OVERLAID ON REAL WORLD IMAGES & OBJECTS HELP YOU LEARN, OR DISTRACT YOU?

People are becoming self-learners, they are exploring different realms, AR could be a great option for them. As a teacher, Field trips are too expensive, but I could use AR to help my students experience moments not possible in real life for them.
---



AR is exciting since it is relatively new technology, but eventually it could get annoying. It's all about finding that sweet spot where it is useful and functional, but does not get in the way and is not used as a gimmick.
Could be used for technical training. Could also be used for therapy.
AR can bring still images to life and for many applications offer the possibility of simulating real-life situations without the need to fear consequences of a mistake. I especially see the benefits in medicine, technology and vocational education.
It would be useful to have glasses that respond to AR, that way you can walk into a place and automatically learn its history, or other information needed. Then in the classroom you can have an interactive get out of your seat test and have students walk around and use the AR glasses to fulfill respond to overlays in the classroom.
I think that having detailed and accurate AR overlays can enable people to be more successful at some job tasks.
interactivity, endless possibilities
AR brings interaction to otherwise static displays and images. Imagine an art gallery tour where the artist appears next to the painting and explains it, or watching a football game and getting instant stats about the players on the field. Even a simple trip to the grocery store could be more efficient with arrows on the floor pointing to the correct aisle!
AR in learning helps to organize relevant information.

I think this could have many uses and applications in simulated practice of tasks
I think is the Web "3" of QR codes
Trigger images could be words on a word wall or in a book where it would reveal the definition to students. It could also be used in a scavenger hunt with a specific theme in which the images revealed clues. It could also be used to provide additional resources that might be helpful in completing a task.
I am looking to be an administrator and this could help children learning.
students could get direct feedback and instruction on a piece of equipment or tool while using it. For example, during an oil changing exercise the student could receive instruction on when the cap is while looking under the hood, the AR could show on the dip stick what the proper oil level is, and even show the proper direction to turn the filter in order to remove it.
This is a portable application that could eventually be used in real life. I could see so many uses for this in the classroom and out of the classroom.
As mentioned above, I have seen studies where cardiologists are learning to work with 3d hearts by using AR. Would be a safe way to train Dr's

Participants indicated ( $n=15$ ) that AR overlay content did help them to learn and in general did not distract them, but had the opposite effect helping them to engage with and recall content.

TABLE 32: DO YOU THINK AR COULD HELP STUDENTS ATTEMPTING TO LEARN USING A HANDS-ON PROCESS?

In some parts of the world, interns and students do not have access to real life tools/specimen - this could be great for them. Also, it would help them figure out if they really want to do it or not before diving head first.
Yes, especially if you can adapt the program to a Microsoft HoloLens type device. I believe that having a reference projected over or nearby the item you are working on would be a huge benefit for learning the process.
Yes, most learners now are used to 3D imaging and such.
Could be the new version of an exploded view diagram-aids in process learning
Yes, if you could point to an area of the car and have things labeled and explained it would help the repair process.
If a trigger image could be generalized somehow to any picture of a particular make and model of an engine, I think that it would make a powerful tool for hands on processes.
I can see it being beneficial in healthcare, engineering, or other fields where viewing an item in 3 dimensions would help increase understanding.
AR provides real-time feedback and on demand background information that help the student.
It definitely would be useful for real time use.

Repetition with low risk and low cost.
It definitely would be a great alternative if using hands on the real thing isn't an option.
A student could see the inner workings of a car engine or whatever they are working on.
Absolutely-- or even studying the brain, cells, etc. I think this is extremely beneficial to science classes.
Google Cardboard and Oculus Rift are doing this now. I could see AR doing the same.
Keeps injuries to a minimum and allows for more effective use of time, money, and space

Participants ( $n=15$ ) indicated that after using AR for their course modules  
 Augmented Reality could likely be adapted to allow users to learn in a hands-on way.

## Appendix H: Qualitative Interview General Guideline Questions

Based on the AReducation embedded SDK time on task data and session duration time ( $n=3$ ) participants were selected for in-depth interviews. Exploratory examples were used to later define qualitative themes.

EJ = Interviewee 1 (UUID Used Average of 27x for 3 minutes each)

HT = Interviewee 2 (UUID Used Average of 1X for 10 minutes total)

BP = Interviewee 3 (UUID Used Average of 5X for 27 minutes total)

David Squires [DS]: It appears that [EJ] you used the AReducation very often over the course of the semester at least 27 times based on your analytics data, can you tell me more about why and what happened?

EJ: *“Aside from doing the course models...I wanted to show some the interactions to my kids. They love Pokémon go and I opened it when I did the surveys.”*

DS: It appears that [HT] you used the AReducation very little over the course of the semester, only 1 time based on your analytics data, can you tell me more about why and what happened?

HT: *“I just used to complete the assignment. It was straightforward downloading and pointing and clicking on the stuff that popped up.”*

DS: It appears that [BP] you used the AReducation medium amount compare to other participants during the semester, 5 times time based on your analytics data, can you tell me more about why and what happened?

BP: *“Oh [laughing] well that is good to know I guess just used it to aim at the images and click on things but I did come back and use it for the surveys to make sure I remembered what I was doing.”*

DS: After using and completing modules with AR apps in your online course do you think AR could help you learn using a hands-on process?

EJ: *“Yes! Definitely. It has so many applications; car engine, dissecting frogs, stuff like that. There are a lot of things you could use it for. There are so many ways you could potentially use it, like learning how to build a building in engineering, learning the inside of a computer, microchips, data transfers, microscopes, all sorts of things. There’s so many possibilities for this sort of thing, you would just need time, and the person – maybe an expert in his/her field to consult. Say you wanted to create an app for biology students in middle school. You could have an expert in the field of biology come in, and talk to the programmer, and they can create the programming to create that information in an app, then you have these kids that have a use for their phones other than just texting each other – they can use them for learning about biology. I think if you were to incorporate some kind of game system, the possibilities to learn would increase because you have a learning tool, but a learning tool that’s fun. You have these apps like Duolingo and Lumosity where they make it into a game – and people want to learn. And I think that’s the greatest thing: when people want to learn because it’s fun.”*

I found that participants were highly receptive to wanting to use a mobile application in class and as a more hands-on approach to learning:

DS: Do you think AR could help students to learn using a hands-on process?

HT: *“Maybe using that for a lot of things that require a hands-on approach would be really helpful to getting a better insight into the job you are doing, the work you are doing. Different kinds of professions, and different classroom settings would absolutely benefit from this: the skin cell diagram [from trigger images], and seeing the Google glass on the surgeon [from trigger images] really opens up all sorts of potential for the medical field. Yeah, I could see a lot of Pre-med students and students who are in their residency could find a lot of use from something like that. Maybe not only just the medical field, but also seeing the potential for things like a car engine, or geologically speaking, the different layers of the Earth and things like that. It just opens up so much potential for students to be able to – pardon the pun but – dig into the meat of their field, and be able to see it in a cool way.”*

DS: Imagine you’re in a face-to-face classroom environment, in one of your classes, and your professor says, “Today you’re going to download an augmented reality app, and learn about information technology”. Do you think that something like that would be an impediment to your learning, or an enhancement to your learning if you could see visually some of the key concepts of the class?

BP: *“I think that would absolutely be an enhancement to the learning process. I think that I am interested in, and I think it’s great to be able to use it while I’m in school. To learn about it, and work with it on my phone is just the best of both worlds. To have it in a curriculum for a course I am enrolled it would make it the cherry on the cake.”*

DS: Do you think AR can help with online instruction:

EJ: *I think it would, ultimately, help them. I think for tactile and visual learners, something like this would really help them in many ways. [Pause] I think that sometimes*

*things can seem abstract, if you're just being lectured about something in a traditional classroom. But I feel like if you have something like this that can connect the teacher and the students, it will make it seems more interesting.*

*HT: OK. It'd probably be really helpful, probably because it would allow a lot of people to be able to access that kind of information quickly, and in a different way. It could be more in depth, and maybe less boring. I couldn't see myself being bored with something like that online.*

*BP: Yes. There's a specific way to use something like this; in the classroom setting, traditionally or online, if you were to use it as a tool for those kinds of courses, then yes. For example, in an o chem. class, using something like AR to see how certain processes happen. Having something like that, without having to access a certain link, just opening that information by pointing your phone at a trigger, that would invaluable. That would be such an invaluable tool, because a lot of the time, it's difficult to imagine those kinds of things when they're just being taught to you in a lecture setting. Being able to have a video or a diagram or a 3D image of something, and being able to do what you imagine it doing in text, would just be so important to understanding concepts. That way, you can see what's going on, you can see it in real time. I would appreciate that next semester going into the second semester of o chem., it can be really difficult to imagine what's going on. And I think something like this to help with understanding those ideas – I know I would use it consistently. It would be so much easier.*

*DS: Can AR facilitate student learning?*

*EJ: This is something that would be really, really helpful no matter what. And, I feel like for me, and maybe people like me, that are more tactile learners, it would be so*



*helpful because it would give you a tool and a resource outside of the classroom to be able to study.*

*HT: I think that augmented reality, from what I've seen so far, it just seems like it takes that information, and allow the user to be able to play – if that makes any sense- with the information you set up for them. For example, with the skin cell [from the trigger images] it looked like what you could do with augmented reality is have a more playful environment where there wouldn't be regurgitating information on cue. "The skin cell contains three layers, and these layers are..." etcetera and so on. I think that augmented reality makes it more of a 3D game, and would make learning more fun.*

*BP: I think it would in a classroom setting; I think in that way it would be most beneficial. And, I think it's important not to shy away from new tools. It's something that happens when each year a new device comes out, like Apple watch, and now it's something that we grow accustomed to – making life easier and more convenient. I feel like these kinds of tools we can love them or hate them But I feel like I would want something that would make my life easier. I know in school, we go through really difficult classes, and it's always more beneficial to have something help you in class. I know that I would use it, not even being a visual learner. I know that you can never help too many things to help students.*

*DS: Would you recommend using Augmented Reality applications outside of classrooms?*

*EJ: It might actually be better for that, because that way – you're not in the classroom- so it actually might be even better for it to be used in online settings because you're away from the classroom, and if you're a visual learner, or a tactile learner, it*

*may be difficult 'cus a lot of online classes are through the computer. I think it would really help to bring those learners who have a difficult time, to able to make that material more [pause] understandable.*

*HT: A lot of my friends would be very interested in this kind of technology, especially since they talk about it pretty frequently; the next kind of technology, and where it will go from here. This is definitely it. I think that this is what we'll end up using soon to develop apps. I think it'll just become more popular. There will be more interest in it.*

*BP: I would recommend it to a colleague. Someone like a classmate, who would see this as a really great tool to help them with school – especially in the field I'm in. I know it would be really helpful.*

Participants responses: Does AR help instructors deliver learning content?

*EJ: I think it would, ultimately, help them. I think for tactile and visual learners, something like this would really help them in many ways. [Pause] I think that sometimes things can seem abstract, if you're just being lectured about something in a traditional classroom. But I feel like if you have something like this that can connect the teacher and the students, it will make it seems more interesting.*

*HT: Oh. Yeah. I think that it's just so easy to use, that you just have to point your phone at something tagged. Unless they had difficulty downloading the app to begin with, or they were just a luddite – no offense, but they were just not keen on technology - then I can't see how you couldn't use it easily. I think it could almost be impossible to fail with this kind of technology. It kind of does the work for itself. You don't have to do a whole lot, and the possibilities are endless with this kind of programming. You can tag so many*

*different things, like the inside of a house or office, and do whatever you want with those images – add links, add video. You could unlock something in a gamification kind of way, like adding points or badges. Pretty much anything you wanted, as long as you understand this program.*

*BP: I think this is a great stepping-stone for maybe other things in the future of learning. I hope that my kids can grow up and have tools like this, so that learning for them, isn't necessarily easier because nothing worth doing is ever easy, but maybe something that they'll find more interesting. STEM degrees could be more interesting to more people. This would be a great tool for that.*

Magnitude coding aided the refinement process of the interview data by outlining learners verbal responses based on frequency and lexical word searches conducted with the mixed methods software for qualitative data analysis tool MAXQDA 12.



FIGURE 55:EXAMPLE OF CODING USING MAXQDA 12

Themes emerged during the interview process that potentially informed the descriptive statistics, and open-ended survey data and helped to identify how participants experience AR enabled learning environments and the potential impact AR could have on their learning environment.