Exploring the Use of Augmented Reality to Support Cognitive Modeling in Art Education

by

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ABSTRACT

The present study explored the use of augmented reality (AR) technology to support cognitive modeling in an art-based learning environment. The AR application used in this study made visible the thought processes and observational techniques of art experts for the learning benefit of novices through digital annotations, overlays, and side-by-side comparisons that when viewed on mobile device appear directly on works of art.

Using a 2 x 3 factorial design, this study compared learner outcomes and motivation across technologies (audio-only, video, AR) and groupings (individuals, dyads) with 182 undergraduate and graduate students who were self-identified art novices. Learner outcomes were measured by post-activity spoken responses to a painting reproduction with the pre-activity response as a moderating variable. Motivation was measured by the sum score of a reduced version of the Instructional Materials Motivational Survey (IMMS), accounting for attention, relevance, confidence, and satisfaction, with total time spent in learning activity as the moderating variable. Information on participant demographics, technology usage, and art experience was also collected.

Participants were randomly assigned to one of six conditions that differed by technology and grouping before completing a learning activity where they viewed four high-resolution, printed-to-scale painting reproductions in a gallery-like setting while listening to audio-recorded conversations of two experts discussing the actual paintings. All participants listened to expert conversations but the video and AR conditions received visual supports via mobile device.

Though no main effects were found for technology or groupings, findings did include statistically significant higher learner outcomes in the elements of design subscale (characteristics most represented by the visual supports of the AR application) than the audio-only conditions. When participants saw digital representations of line, shape, and color directly on the paintings, they were more likely to identify those same features in the post-activity painting. Seeing what the experts see, in a situated environment, resulted in evidence that participants began to view paintings in a manner similar to the experts. This is evidence of the value of the temporal and spatial contiguity afforded by AR in cognitive modeling learning environments.

DEDICATION

To my family, Betsy, Slade, Mila, Hera, and Randy, who gave me the inspiration and confidence to pursue this endeavor and without whose love and support I could not have succeeded.

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The ARtVision development team who helped build the AR application for this study also deserve the utmost praise for the work they did and the manner in which they did it. Even after a corporate purchase and subsequent platform shutdown of our first application, the team came back to build the application to the specifications the study required. This was to the direct benefit of the 182 people who participated in the study. The team consisted of Rajeev Mehta, Laurence Welch, Michael Theut, Shane Parton, and Khai Banh. Khai Banh, in particular, spent extra time post-graduation making slight adjustments and improvements to the application during pilot testing. His dedication to

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Chapter 1: Literature Review

Introduction

Imagine a couple of friends or family members walking into an art museum. This could be a repeat trip to their local museum or their first time visiting one on vacation. They might have some works or galleries in mind or they might just see what they see. Let's assume they don't have any formal training in art or art history. What options do they have? Written materials, an audio guide, or perhaps they searched online in the days leading up to their visit. They come across a painting that captures their attention. What do they do first? How long do they look at the painting? Do they talk about the painting with their friends or family members?

As art novices it's difficult for them to know what to do. Even for something as simple as viewing a work of art can become a confusing and frustrating task. There is art historical information (title or work, artist name, year created, etc.) and museums often provide this and other information about selected artists and works but perhaps more can be done to help art novices learn about and appreciate art. Now imagine there is a technology that allowed art novices to see what the expert see when they look at a painting. One where the novices could hear, and more importantly *see*, the thought processes and observational techniques of experts.

The present study uses augmented reality to provide art novices with digital information such as annotations, overlays, and side-by-side comparisons as they listen to at experts observe and discuss works of art. When the art experts (via audio recordings) are discussing the repeated use of shape (squares) found in Johannes Vermeer's *The Wine Glass*, for example, the squares of these objects are highlighted *in that* moment by the

augmented reality technology when viewed through the camera and screen of a mobile device. This pairing of digital information with real world objects provides educators new ways of supporting learning by making the invisible (i.e. expert thought processes and observational techniques) visible.

Augmented reality. Research in augmented reality (AR) has made great strides in recent years due in no small part to the ubiquity of smartphones and educators' continued interest in leveraging mobile technology. Interest in AR in education can be attributed to a number of factors including the growing power of mobile devices (Feng, Duh, & Billinghurst, 2008, Martin, Diaz, Sancristobal, Gil, Castro, & Peire, 2011; Squire & Klopfer, 2007) and the potential for enhancing learning experiences and increasing learner outcomes. AR is used in medicine, aeronautics, industry, entertainment, social media, marketing and education (Azuma, 1997; Hincapie, Caponio, Rios, & Mendivil, 2011; Shin, Kim, Kang, Jang, Choi, & Woo, 2010; Shuhaiber, 2004). While the integration of AR in educational settings is still in its early phases (Bujak, Radu, Catrambone, MacIntyre, Zheng, & Golubski, 2013; Chen & Tsai, 2012; Martin et al., 2011; Wu, Lee, Chang, & Liang, 2013), examples can be found in such educational disciplines as science (Chen, 2006, Squire & Klopfer, 2007; Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012), mathematics (Mitchell, 2011), and language learning (Liu & Chu, 2010).

In basic terms, augmented reality pairs digital information to real world objects and locations. This is often done by leveraging the camera and other capabilities of a mobile device. Augmented reality software can recognize an object or location and display the digital information on the screen of the device so that it appears relative to the

real world object. An example might be a sign in a natural history museum where an augmented reality application might be designed to recognize the museum graphic on the sign and when that graphic is viewed through the mobile device a (digital) tyrannosaurus rex appears to leap out of the graphic and nearly consume the unsuspecting museum visitor.

More formally, Azuma (1997) defines AR as systems that have three characteristics: a combination of real and virtual worlds, real-time interaction, and accurate 3D integration of real and virtual objects. Milgram and Kinshino's Virtuality Continuum (1994) (Figure 1) helps put AR into context with other virtual, or digital, objects that are integrated into the real world. AR, particularly in this study, strongly emphasizes real world environments with digital information providing additional information.

Figure 1: Virtuality Continuum



Among the multiple technologies that support AR (e.g., head mounted devices, web cams), AR software uses a mobile device's camera and internal sensors to recognize objects, images, and its own location (using GPS). Once an object or place is identified, the software can pair digital information (text, images, animations, video etc.) to said objects. Increasingly, almost anything digital can be tied to any object. For instance, a

digital dinosaur could appear to jump out of a movie poster or a digital arrow could animate over an intersection to point the way to a destination; all by leveraging AR software with the camera and sensors of a mobile device.

Multiple studies have identified AR's potential for teaching and learning (Billinghurst & Duenser, 2012; Dalgarno & Lee, 2010; Dunleavy et al., 2009; Johnson, Adams, & Cummins, 2012; Squire & Jan, 2007), for learning gains (Di Serio, Ibáñez, & Kloos, 2013), helping establish relevance of learning activities (Jerry & Aaron, 2010), overall motivation (Bujak et al., 2013; Chang, Chang, Hou, Sung, Chao, & Lee, 2014; Liu & Chu, 2010), to support collaboration (Li, Chang, Gu, & Duh, 2011) and as evidence of transfer (Dede 2009; Kaufmann & Schmalstieg, 2003). All of the above factors are integral to learning and thus show how much potential this technology could have on learners.

AR has been leveraged in complex learning activities including teacher-created role-playing scenarios (Dunleavy, Dede, & Mitchell, 2009; Squire & Jan, 2007), games (Klopfer & Sheldon, 2010), and spatial/temporal visualizations (Kerawalla, Luckin, Seljeflot, & Woolard, 2006; Shelton & Hedley, 2003). Experts, including teachers or professionals working in their respective fields, have played a pivotal role providing authenticity and value to these learning experiences. In most of these learning activities, AR technology is provided to learners as a tool to receive additional information, to complete a specific task, or engage in a scenario as determined by the teacher or professional (Bacca, 2014).

The present study sought to leverage AR technology to support the delivery of authentic expert narratives (i.e., not scripted, in context as they occur) for novices. The

AR application used in the present study was intended to help novices view art through the eyes of two art experts with the goal of increasing their skills at viewing art. With the support of custom-built AR application delivered on a mobile device, participants in the present study where guided with AR elements to see what the experts observe as they perform the tasks of viewing and interpreting works of art. The AR application displayed digital annotations, overlays, and side-by-side comparisons so they would appear directly on high-resolution, printed-to-scale, painting reproductions (from this point forward referred to simply as "paintings") when viewed through the camera and screen of a mobile device. This digital information appears in a just-in-time manner so that just as participants listened to audio recordings of the experts discussing the real life paintings in person. The relevant information appears at designated times. From this unique and precise contextualization, the present study sought to better understand the effect of these visual supports on learning and motivation.

The present study builds upon multiple research efforts, which are outlined below. The discussion begins with a review of a recent meta-analyses that provides insight into the current state of AR in educational settings. Topics discussed include: (a) the effectiveness of AR, (b) AR versus other technologies, (c) AR in its use in location and manipulatives, and (d) the importance of instructional approach in AR learning experiences.

Effectiveness of AR in Educational Settings

Bacca, Fabregat, Baldiris, Graf, and Kinshuk (2014) conducted a meta-analysis of 32 studies published from 2003-2013 in order to investigate advantages, limitations, and

effectiveness of using AR in educational settings. The authors found learning gains (44%), motivation (32%), and collaboration (19%) among the highest reported advantages, which substantiated findings of other researchers working in the same area (Chang et al., 2014; Di Serio et al., 2013; Liu & Chu, 2010; Shelton & Hedley, 2004). Noticeably low on the list of advantages were just in time information and authenticity (4%), both of which were a major focus in the design of the learning activity of this study.

Bacca et al. (2014) also tabulated the types of AR used across the 32 studies. They found that 12.5% of the studies using markerless AR (where the software recognizes images or objects by their features), another 22% used location-based AR (utilizing GPS coordinated), while 59% of the studies used marker-based AR (using a pre-loaded library of possible images of objects to later be recognized). This imbalance in favor of the latter type of AR is presumed to be due to technological constraints and the superiority of tracking with QR codes and other markers. The image recognition used in the present study represents a recent version of marker-based AR (thus consistent with the main type of AR used in the meta-analysis described above).

The meta-analysis also examined the rationale for using AR to support instruction across the studies and found that the authors of the clear majority of studies (83%) stated that they leveraged AR to either explain a given topic or to supplement information related to a topic, while no studies (i.e., 0%) used AR in order to evaluate or better understand a topic. While the present study also included the former two approaches, there was added value in the attempt to use the AR application in a learning activity that

included evaluation by the experts' cognitive modeling and by the participants themselves as they learned how to approach viewing paintings.

AR versus Other Technologies to Support Learning

Radu (2014) conducted a review of 26 publications to explore how AR compared to other forms of instructional media in learning environments. The review found evidence of increased content understanding, long-term memory retention, and increased student motivation. Additionally, the author found that AR experiences often resulted in increased collaboration which is relevant to the present study and the decision to incorporate a variable designed to explore whether pairs of learners (dyads) might collaborate more and how that might affect learning and motivation.

Spatial skills, in particular, were compared between AR and video and text (Valimont, Vincenzi, Gangadharan, & Majoros, 2002), text alone (Sin & Zaman, 2010), physical and AR models (Chen, 2006), and even to virtual reality (Quarles, Lampotang, Fischler, Fishwick, & Lok, 2008). These results complement other physical task performances. However, the present study moves towards exploring cognitive-based skills in a given physical environment. Leveraging temporal and spatial contiguity principles for media (Chandler & Sweller, 1992; Mayer & Moreno, 2003), AR has the potential for bringing the learner relevant, contextualized information both in time and space.

In this study, the information was intended to represent the thought processes and observational techniques of art experts as they observe and interpret works of art. The effect of these expert performances on learning outcomes is compared across three

technologies: AR, video, and audio-only. Both AR and video provide participants with visual supports of digital annotations, overlays, and side-by-side comparisons on a tablet screen. However, the main difference is that AR technology, when viewed via the device's camera, displays the visual supports to appear as though *directly onto* the real world paintings whereas the video simply displays them as a static image on the tablet screen. The audio-only conditions experience no visual supports, instead providing only the audio recordings of the expert conversations heard in all conditions. The present study will contribute to the comparative research of AR and other forms of media.

There have been some studies conducted in art and other museum-related contexts, in particular, comparing the effects of AR with other technologies. Yoon and Wang (2014) studied the use of an AR tool (comparing it with physical manipulatives) to help visualize the invisible phenomenon of magnetism in a science museum. In a similar discipline, electromagnetism in a physics classroom, Ibáñez, Di Serio, Villarán, and Kloos (2014) compared AR to a web application for effects on knowledge acquisition and levels of enjoyment. While using fiducial markers (as opposed to full image recognition), the study provides insight into forms of visualization, particularly with abstract concepts like electromagnetic fields, as well as a concentration on tasks and sense of control found in using mobile devices.

Chang et al. (2014) once again looked at art from a museum visitor perspective across AR guided, audio-guided, and non-guided conditions. The researchers looked at several variables including learning effectiveness, flow experience, time spent focusing at paintings, behavior patterns, and attitude towards guided systems in general. The study included a mobile AR application that used image recognition technology to help novice

art viewers better understand and appreciate art (paintings). The application (and audio for the audio guide condition) allowed the user to listen to commentary that corresponded with each of sixteen designated works. Functionality within the AR application included a zooming in and out of small areas as well. The authors used a 4-step methodology of art appreciation that included description, analysis, interpretation, and judgement. In the present study, these kinds of details are found within the expert's conversations, however, the content was delivered in a more natural, conversational manner akin to the skills exercised in real world settings, as opposed to a more linear, label text delivery. Additionally, the learning focus of the present study was strategically narrowed down to *viewing* the works: identifying subject matter, elements of design, and features of the artist's life and culture. This both serves the discipline but also accounts for the inherent limitations of single, one-time learning activity; that is, one that is unlikely to result in novices performing expert-like interpretations of paintings.

Di Serio et al. (2013) examined student motivation in an art course comparing information on Renaissance masterpieces delivered via AR and traditional slides. The authors reported higher ratings of attention and satisfaction among students for the AR-based learning experience. In addition to the learning outcome goals of this study, effects on motivation of participants of the present study (i.e., art novices) are also of interest. Motivation can have a strong impact on learning and the present study aims to build on these findings of higher motivation to discover how confidence within the discipline (art) is impacted by specifically designed AR-based learning experiences. The present study sought to understand how the potential development of observation skills might impact levels of relevance and confidence in viewing art.

Though the Di Serio et al. (2013) study appears to be very similar to the present study, there are important differences. First, all of Di Serio et al.'s content appeared as images including paintings, frescos, and architecture, in order to compare slideshows to AR. In contrast, the present study used AR to augment artworks in an appropriate setting and with the appropriate information, by overlaying digital information over the view of the physical paintings. The painting reproductions were presented on easels in a galley-like setting and were of very high resolution and printed to the exact dimensions of the real works. Second, while the method section for the Di Serio et al. doesn't disclose what specific instructional strategies were used beyond the free exploration of the student, it may be assumed that the data superimposed onto the images via webcam did not have specific learning goals beyond access to additional information, fitting as an exploratory study into motivational factors of AR and art education. In the present study, the instructional model was much more structured. The paintings were arranged in a prescribed sequence with specific steps articulated in the instructions and reinforced directly within the audio recordings in the form of the narrator prompts.

Location and Manipulatives in AR

Reviews by Bujak et al. (2013) and Dunleavy and Dede (2013) also provide insight for this study. Dunleavy and Dede's review discusses location-based AR while Bujak et al. explore mathematical manipulatives, both providing key context into AR affordances. Dunleavy and Dede discuss AR's ability to embed multiple perspectives on a problem situated within a physical space (Facer, Joiner, Stanton, Reid, Hull, & Kirk, 2004; Perry, Klopfer, Norton, Sutch, Sandford, & Facer, 2008; Squire, 2010) and

contextualizing them into a problem-based narrative. Additionally, the ability to integrate outside resources (e.g., the Internet) via mobile devices containing AR software, and the high reports of student engagement are distinctive affordances of AR. These align with the present study where the cognitive modeling of experts was supported by AR.

The virtual manipulatives in mathematics used by Bujak et al. (2013) reinforce these views, listing physical, cognitive, and conceptual affordances for AR. Physical affordances, such as embodied cognition, are somewhat removed from the present study but cognitive and contextual affordances are both relevant. Cognitive aspects include the relationship between physical and abstract concepts (potentially helpful in understanding works of art) as well as contextual affordances related to expert performances and the spatial and temporal contiguity (Mayer, 2009; Mayer & Moreno, 2002) considerations of AR. These manifest within the present study as information appeared when and where the participants' attention was to be focused, that is, directly on works of art themselves. Contextual parallels between Bujak et al. and the present study include the aforementioned real-world setting of the learning (i.e., situated cognition, Brown, Collins, & Duguid, 1989), the value in collaboration and dialogue in such a learning experience (Chi, 2009), and the personal relevance and knowledge-building scaffolds for the learner (Yoon et al., 2012) which is especially important to novice art viewers.

Importance of Instructional Approach

Wu et al.'s review of AR (2013), while also addressing the affordances of AR relative to other applications, provides context to the present study in the importance of

the instruction itself. The authors' prioritization of the instructional approach and design of the learning experiences echoes Dede (1996) and Dunleavy et al. (2009).

The present study gave much consideration to the design of the learning activity and how it would leverage the expert performances. Much thought also went into the design and development of the AR application and how it would function within the learning activity with the study participants (i.e., adult, self-identified art novices). Synthesizing the discussion above, and leveraging the meta-analysis of design aspects from Santos, Chen, Taketomi, Yamamoto, Miyazaki, and Kato (2014), the present study focused on how AR technology utilizes real-world annotation and contextual visualization in a learning experience. While the present study was interested in leveraging the spatial and temporal contiguity afforded by AR, the goal of this research is to better understand the use of AR to model the cognitive processes of experts for the learning benefits of novices. Therefore, the application and instructional model will provide context and guidance to the novices as they progress through the learning activity and interact with their peers.

Wu et al. (2013) also discussed AR affordances of collaborative and situated learning, a learner's sense of presence, and visualizing the invisible. Collaboration and a sense of presence reinforce the reviews above while visualizing the invisible has additional implications. AR technology and the cognitive apprentice instructional model in the present study were designed with that common goal; making the invisible visible. AR has been used to make the invisible visible for processes like photosynthesis (Liu, Cheok, Mei-Ling, & Theng, 2007) as well as for issues of scale such as Sin and Zaman's

solar system (2010) but it hasn't been used to make visible the thought processes of experts in the environment in which it occurs.

While novices may be able to learn simply by listening to experts explain how they see and understand works of art, the present study was interested in a deeper understanding of cognitive modeling where the novice is able to listen to experts discuss works of art while simultaneously seeing the visual representations of those thought processes and observational techniques directly on the work of art via the mobile device. Thus seeing what the expert sees, as they see it.

Theoretical Underpinnings.

Situated and constructivist learning. Research in AR is often underpinned by situated and constructivist learning theories (Dunleavy & Dede, 2013; Dunleavy et al., 2009; Kamarainen et al., 2013; Santos et al., 2014; Wojciechowski & Cellary, 2013). Situated learning theory argues that meaningful learning only takes place within the social and physical context in which it will be used (Brown, Collins, Duguid, 1989). Learning environments should provide authentic activities, access to expert performances, and provide ample opportunities for articulation and reflection (Herrington & Oliver, 1995). From a constructivist perspective, learners need to interact with their environment while having access to alternate views such as those of their peers and experts within the domain. Constructivist approaches to learning activities include aligning tasks to a larger problem the learner might experience in the real world and would reflect the complexity inherent in said tasks (Kirkley & Kirkley, 2004).

Additionally, constructivism often includes a focus on expert performances within domains that apply directly to this study.

AR is capable of providing learners with access to information in authentic, real-world contexts, allowing them to actively observe, inquire, and participate in complex learning activities (Dede, 2014). These complex learning activities more closely resemble the actual environments in which learners should perform the learned tasks because often times they are those exact environments. The device mobility of AR, in particular, allow users to access information (via internet connect of via device software) within these contextualized situations which can aid in both learning outcomes and motivation (Radu, 2014). Both situated learning and constructivist theories reinforce the need for authentic learning experiences that tie the learning to a social and physical context (Bransford et al., 1999). The authenticity of this context allows learners to act more meaningfully and purposefully when interacting within that space (Martin & Ertzberger, 2013) which is well supported by AR both in the geo-location sense but also in the ability of software (such as that used in this study) to recognize elements of the environment and augment them with digital enhancements. Using AR, learners can interact with objects and access information that allows them to see the world in different ways (Klopfer & Sheldon, 2010) which can support a situated learning approach of helping learners see their environment from multiple perspectives such as how an expert might see. If one takes a situated view of an experience, say, viewing artwork, then a primary goal is to help learners to see the experience as an art expert might (Squire & Klopfer, 2007). AR is able to leverage a physical space as an additional source of information for learners to observe, manipulate, and analyze (Dunleavy & Dede, 2013).

Device use. The present study aimed to draw a specific distinction between viewing a painting (physically mounted on an easel) through a mobile device versus viewing a digital version on a tablet screen in one's hand. As with any technology used in an educational setting, it is important that a mobile device not become a barrier to experiencing and interacting within an environment (Dunleavy, 2014). The focus should remain on the task and the device should simply act as a tool for completed said task.

In this study, participants held up a mobile device to see digital annotations, overlays, and side-by-side comparative works appear directly on the paintings themselves. The device, in other words, became the lens through which participants saw digital information on the actual, physical painting on the easel (Dunleavy, 2014). Participants in the AR conditions, when prompted by the haptic response of the device (short vibrations often used as a form of notification in smartphones), lifted the device into their gaze to view the digital annotations, overlays, and side-by-side comparisons in support of the comments being made on the audio recordings of the experts. The AR technology combined the real world paintings with the digital information so that the digital information appeared directly on the painting just at the moment when the experts made the related comment the information was intended to support. In essence, annotating and highlighting the painting itself, albeit digitally, as the expert conversations progressed. The seamless viewing of one's surroundings, and interacting with objects (just as an expert might do in an actual gallery or museum-like setting) is how context is created and learning can occur (Dewey 1938, as cited by Sharples & Pea, 2014).

Spatial and temporal contiguity. An often cited challenge of AR is extraneous cognitive load (Dunleavy et al., 2009). The Cognitive Load Theory of Multimedia

Learning is built on the foundation that people learn more deeply from text and pictures than text alone (Mayer, 2014). This is based on three assumptions: 1) people have separate channels for processing visual and auditory information, 2) people are limited in the amount of information that can be processed at a given time, and 3) that incoming information is attended to and organized with other knowledge (Mayer, 2014). These assumptions directly relate to the present study (and many others in AR) due to the multimedia nature of the learning experience and to the unique experience of integrating digital information with real world objects and spaces. Participants of the present study engaged visual and auditory channels actively processing information provided by the audio recordings of expert conversations as well as the visual supports afforded by the videos and the AR application. Therefore, the present study took deliberate focus of spatial and temporal contiguity.

Ginns (2006) conducted meta-analysis of spatial and temporal contiguity across multiple domains and levels. His research reinforces previous efforts that demonstrate that learners often learn more when educational materials are designed to minimize the space and time between disparate but related elements. When the learner has to use cognitive energy to integrate multiple elements of a learning experience, either in time or space, there is a risk of extraneous cognitive overload and learning can be negatively impacted.

In this study, the learning activity represents the temporal integration of the audio recordings of expert conversations with the visual supports offered by the video and the AR conditions. Ayres and Sweller (2014) discuss how Baggett's (1984) study of animation in computer-based environment influenced work like Mayer's multimedia

learning theory by demonstrating the value in aligning auditory information with visual supports and those principles are reflected in the instructional design of this study. There are also considerations of modality principles, namely the pairing of narration, as opposed to text, with visual information, however, the rationale for comparing the use of a tablet as a "lens through which to view the world" (Dunleavy, 2014) rather than simply as a mobile source of information (within the same space) is more relevant.

Ginns (2006) also discussed spatial and temporal contiguity in regards to domain novices. He explained how studies have found that novices are at higher risk for extraneous cognitive load due to factors like a lack of context and available schemas and often are unsure where to focus attention when using complex learning materials.

This relates to the study's focus on novices and may be particularly applicable when using AR and other technologies as these technologies may pull attention and energy away from the learning itself. There were learning and motivational risks to participants in the video conditions who were required to listen to audio recordings, while viewing physical paintings, while also repeatedly having to adjust their gaze down to the video to see the digital information on the tablet. That additional source of information, even if only slightly removed from the other visual source could have shed light on the advantages of AR's ability to effectively integrate the digital and the real world and thus have a stronger impact on learning outcomes and motivation. (Also of note from Ginns' analysis is that of the fifty independent studies examining spatial and temporal contiguity, many focused on learning outcomes but none were within the domain of visual arts.)

Peer Learning

Learning together. The present study explored differences in learning outcomes and motivation between individual participants and dyads because learners often have more success learning with others (Lou, 2004; Lou, Abrami, & d'Apollonia, 2001; Weinberger, Stegmann, & Fischer, 2010). Peers can support each other's learning by asking each other questions, giving and receiving feedback, and by sharing different perspectives. Dyads, like those used in this study, have demonstrated success in abstract visualization (Nokes-Malach, Meade, & Morrow, 2012; Schwartz, 1995) and solving ill-defined problems, even when compared to the most competent individuals (Uribe, Klein & Sullivan, 2003). Small groups, like dyads, working together have shown that they use more learning strategies and attempt greater number of tasks in computer-mediated environments (Lou, 2004). Many studies report additional time required for dyads and small groups (Lou, 2004; Uribe et al., 2003), but this can be attributed to many factors such as technology calibration, training, and usability to the additional discussions to the identification of incorrect solutions like those found by Uribe et al. (2003).

Situated and constructivist considerations. The underpinning of situated and constructivist learning in AR learning environments was a factor in examining the role of group size in this study. Many studies in AR have leveraged collaborative or group-based environments (Kamarainen et al, 2013; Squire & Klopfer, 2007; Rosenbaum et al, 2007). Some AR studies such as Lin, Duh, Li, Wang and Tsai (2013) investigate collaboration with AR in a physics learning environment where participants used AR manipulatives (QR codes on cards) and given open-ended questions that required solving and discussion

within the dyad. Studies like Squire and Jan's *Mad City Mystery* (2007) seek deeper forms of scientific inquiry using role-playing activities.

Within the authentic contexts mentioned above, participants in the present study were prompted to articulate and share ideas and points of view as they move through the learning activity. They were also prompted to reflect on the performances of the experts and on their own experiences. This pairing of the social context with the physical may impact both learning outcomes and motivation. In this study, dyads were well-positioned for various components of the cognitive apprenticeship instructional model such as coaching, articulation, and reflection. While AR applications and games have been used by teams before (Mitchell, 2011; Squire & Jan, 2007), it is unclear how cognitive modeling with AR might differ between dyads and individuals.

The comparison between dyad and individual learning in the present study is valuable because it mirrors the experience of viewing art, namely, talking with peers in an introductory class or with friends and family in a museum. The present study focused on novices and therefore included scripted scaffolds in the form of structured and targeted prompts integrated into the learning activity (Weinberger, Kollar, Dimitriadis, Kati, & Fischer, 2009). Participants were guided to discuss specific topics at specific times during the learning activity. There were no designated roles, and participants were free to answer how they wish, but it was the intent of the researcher that script-like discussion prompts provide support to participants during the articulation and reflections exercises that come after each painting. This added structure was meant to encourage participants to feel more secure in sharing their observations with one another.

Art as Domain Choice for Instructional Activity

The present study was aligned to a college-level introduction to art course but also has parallels to elements of art museum learning beyond the gallery-like environment where the study was run. Viewing art often takes place in a museum and includes conversations among groups and other participatory activities (Falk, 2009; Falk & Dierking, 2000; Leinhardt & Knutson, 2004). However, understanding and appreciating art still proves difficult for novices. Studies such as Smith and Smith (2001), where museums goers were spending an average of only 27 seconds (median 17 seconds) in front of paintings, illustrate what can occur when novices visit an art museum but lack the basic skills and understanding to appreciate and learn from works of art. This applies to formal, classroom-based art education and for independent art learning like the couple of friends or family members in the introduction above.

Researcher motivation. One motivation of the researcher selecting art as a domain choice for the present study was to address the issues above by providing art novices the opportunity to develop skills to successfully view and appreciate art. The lack of context and skills found in the general public outside of the art community (Villeneuve & Erickson, 2008; Worts, 2003) was a strong motivation for the researcher, also a self-identified art novice. Art represents human stories and everyone deserves the chance to enjoy and learn from the arts.

Beyond understanding the human condition, learning in the arts also includes "habits of mind" such as observing, envisioning, expressing, and reflecting (Halverson & Sheridan, 2014; Hetland, Winner, Veenema, & Sheridan, 2013). These skills, whether exercised in concert or separately, can be part of many effective learning environments.

Halverson and Sheridan (2014) outline three main topics of interest in the arts by learning scientists: richness of representation, integration of form and meaning, and the examination and exploration of identity and culture. These topics have cognitive and sociocultural components, however the present study focused on foundational skills of observation within the context of the expert performances.

Another motivation of the researcher was more strategic. Observing art experts' performance in a natural environment (in a museum, for example) is quite difficult. Even if they are coherently articulating everything they, see, think, and feel to another person, much of those processes and techniques goes unseen. They may gesture towards a work of art while making a point but how they go about the seemingly simply task of just *viewing a painting* is not apparent. What better technology than AR to not only make visible those thought processes and observational techniques, but also for the learning benefit of novices? Perhaps AR technology could close this perceived gap between formally trained art-savvy people and the typical novice with limited skills and understanding from which to begin viewing and appreciating art.

Art education and technology. Technology has long been part of the art viewing experience. Photography of the late 19th and early 20th centuries is an example of how long technology has played a role in access to art (Bolter, Engberg, & McIntyre, 2013). Art museums have provided label text for decades. Dates, art historical information, and comparative works are all examples of the types of information technology has afforded museum-goers in our lifetime.

A look back over the digital age of the last twenty years shows an increasing interest in the role of (computer) technology in art education. From the early risk of

adding “more stuff” at the expense of pedagogy or connecting experts and learners (Gregory, 1996) to leveraging technology as a tool for research, curriculum, and creativity (Dunn, 1996), discussions at the outset of the digital age don’t seem too different from those of today. Delacruz (2004) reported limits in implementation and training required for teachers to effectively utilize technologies in their classrooms around the same time Stokrocki (2007) reviewed a long list of precedents for the use of avatars in art education, including digital portfolios and virtual museums. These questions of technology, its affordances and risks, and varying implementation models and pedagogical approaches will likely continue, and should continue, as technology becomes increasingly more sophisticated and integrated into our everyday lives.

At the turn of the twenty-first century, there was growing evidence of educators experimenting with technology and using it to enhance their pedagogies and curriculum. Rogers and Erickson (1998) described two websites aimed at supporting art educators in developing their curriculum. They discuss design considerations such as near-linear, guided, and self-directed exploration means of navigation elements as well as particular affordances of providing students access into complex domains in hypermedia environments. Erickson’s *Images of Me* (2001) explored self-identity in artwork in an inquiry-based learning environment with similar categories of interest with this study: theme, mass and space, and technical features. Focusing on sculpture, the online unit provides art education resources like lesson plans and objectives as well as galleries of images and “moveable” virtual reproductions that afford learners the ability to view a sculpture from multiple angles. The twenty-first century also brought advances in student interaction in distance learning such as Lai’s chatrooms (2002) and increased use

of multimedia such as Halsey-Dutton's (2002) artifacts in cyberspace for the teaching of art history. The National Art Education Association (2009) even includes the use of technology in their twenty-first century research agenda (later adopting a full set of media skills in 2014).

Slideshows have long been the mechanism for introductory art students to learn about works of the old masters to contemporary artists but the physical slides have been replaced with PowerPoints, SlideShare, and Google slides which can now be shared and distributed worldwide, at scale, at little to no cost. Museums continue to offer images of their collections online making for near universal access to some of the great art and artifacts of the world whether on a laptop or one's smartphone.

Google Art Project (2016) is a prime example of a resource that provides new and innovative ways to include technology in learning about art (Proctor, 2011). Known for its high resolution gigapixel images (gigapixel = one billion pixels) the site includes galleries from hundreds of art museums around the world and offers viewers opportunities for exploration, comparison, curation, and the ability to take virtual tours of museums via Google's "Street View" functionality. Educators can also utilize features like *Look Like an Expert* where subject matter and art historical periods are examined more closely in simple exercises as well as several other open source sources such as Smarthistory, which was leveraged in the present study (with permission, see Appendix E) for examples of expert performances. This study, however, moves beyond the online access to artworks and the virtual galleries to focus on making visible the thought processes and observational techniques of art experts for the learning benefit of novices.

Cognitive modeling and art education. Building on the strategic motivation of the researcher to make visible the thought processes and observational techniques of experts, cognitive modeling was a natural choice for the learning activity in this study. AR technology can pair the visual support of digital information with the audio recordings of the expert performances in a way that adheres to modeling aspect of cognitive apprenticeship instructional model.

Liu and Pedersen (2002) demonstrate advantages of expert cognitive modeling in their study of problem-based learning (PBL) and *Alien Rescue*, a hypermedia based environment. The authors compared the effects of modeling to didactic and Help feature learning for measures of directed learning and attitudes toward the learning environment. Learners exposed to expert cognitive modeling demonstrated expert-like skills such as organizing their notes into sections, accessing the notebook far more frequently, and consulted other resources more frequently when creating their own artifacts. Though designed for a PBL environment, the authors do note challenges specific to novices including difficulty applying domain knowledge and strategy. (The present study explored the effects of AR and expert cognitive modeling in an arguably more contextualized manner.) The authors go on to discuss the potential for technology to move beyond the *coaching* of intelligent tutoring systems and explore deeper levels of learning via cognitive apprenticeship instructional models.

Recent research on cognitive apprenticeship often focuses on teacher education including the integration of web tools (Liu, 2005) and the improvement of communications between new teachers, their peers and expert teachers (Kopcha & Alger, 2014). Other less longitudinal studies have focused on specific components of the model

such as interactive tool-based scaffolding (Fretz, Wu, Zhang, Davis, Krajcik & Soloway, 2002; Puntambekar & Hubscher, 2005; Seel & Schenk, 2003), self- explanation and social interaction (i.e., articulation) (Graesser, McNamara & VanLehn, 2005; Järvelä, 1995) and reflection (Davis, 2003). The present study leverages cognitive apprenticeship by creating an environment where participants (art novices) are active in the learning (Bouta & Paraskeva, 2012) and interact with expert performances (Dennen & Burner, 2008).

Collins (2006) outlines the importance of making the thinking visible to novices while progressing through specific steps of *modeling*, *coaching*, *scaffolding*, *articulation*, *reflection*, and *exploration*. Cognitive apprenticeship is well-suited as an instructional framework for this performance-based study. Building on the cognitive modeling of the experts (supported by AR), the instructional activity (described in more detail below) took participants through the model's steps while gradually fading the amount of support provided by each prompt. For example, the prompt following the first painting asked participants to view the painting again in search of objects they may not have previously noticed, an exercise nearly identical to that of the experts they just witnessed (*coaching*). The prompts in the subsequent paintings ask participants to notice how their eye travels over the painting, describe their possible interpretations, and reflect on how their impressions of the works change as they learn more from the experiences of the experts. While not a perfectly linear path through the model, participants continued to *articulate* and *reflect* as support was scaffolded away (i.e., fading) in order for them to potentially feel empowered to go off and view art on their own (*exploration*).

With regards to apprenticeship, the tasks of an art expert "at work" are not as observable as a mechanic for example (Cash, Stadt, Behrmann & Daniels, 1996). How she approaches, observes, considers, analyzes, and reflects on a painting is hidden from view even if some of her thought processes are spoken aloud. If a novice wishes to learn from an expert, it may require a deeper access to the cognitive processes the expert engages in. It may also require problematizing the art-based tasks in order to help novices see something as simple as observing art as something requiring attention and consideration they may not otherwise give (Reiser, 2004).

With proper design, AR technology could externalize those cognitive processes, contextually, and in real time. Mobile devices that enable AR applications hold additional value as interactive devices where users can move within a space to view works from different angles, from near and far (i.e. explore).

Novices and experts. Bransford, Brown, and Cocking (1999) discuss key principles of expert knowledge that can help frame the use of expert performances for the learning benefit of novices in this study. The authors explain how experts are able to effectively and efficiently recognize meaningful patterns of information and can often more quickly respond to the presence of such patterns relative to novices. This ability of the experts can be directly applied to viewing and appreciating works of art such as identifying elements of design like line, shape, and color. Experts' skills at organizing their knowledge around big ideas is also of value in understanding art, such as determining the role of said elements of design in the interpretation of a painting.

Experts, of course, have greater access to knowledge and context but the value is in the low demand of "fluent retrieval" when they may first try to better understand the

problem as opposed to strategize solutions as novices do. Access to knowledge, advanced organization of knowledge and the ability to recognize patterns and focus on big ideas all make expertise a worthwhile learning goal.

Self-identified novices, however, even students enrolled in an introduction to art course, may have little to no experience with art beyond textbooks and online images (Fowler, 2002). The present study focused on novices with hopes of providing a learning experience that will begin to develop skills performed by the experts, namely foundational observation skills. It is important to note that though the present study focused on the typical introduction to art learner, art novices in the general population are a very heterogeneous group with individuals who are often well-educated (Lachapelle, 2007). They just happen to lack the formal training and therefore may benefit from access to expert thoughts and processes.

Ericsson (1996) discusses differences in how experts and novices approach art. These differences are evident in processing various styles of art (Augustin & Leder, 2006), how they talk about art, (Soep, Cotner & Cotner, 1999), and even within art programs themselves (Winston & Cupchik, 1992). Koroscik (1996) points out that even with advances in access to information via technology, novices often have misconceptions and use strategies that lack direction or have poorly considered focus. Access to information, no matter how convenient or exhaustive, does not necessarily result in better understanding. Without formal training or a model to provide guidance, novices risk frustration and lack of engagement with content that seems irrelevant or even contradictory.

The brains of novices and experts may even function differently with regards to viewing and understanding art. With advances in neuroimaging, much work has been done to show the different brain activity between experts and novices in art. Studies include the creation of art (Solso, 2001), art appreciation, and aesthetic experience in general (Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011; Cupchik, Vartanian, Crawley, & Mikulis 2009), as well as affective states and self-reflection (Vartanian & Skov, 2014; Vessel, Starr & Rubin, 2012). Given this evidence and continued interest, it seems valuable to explore the possible learning benefits to novices from access to expert thought processes and observational techniques.

Scope of art skills. Though mentioned repeatedly above, the focus of the present study on the observational skills that form the foundation of art appreciation and interpretation warrants additional clarity here. Interpreting artwork is a very complex task that takes years of knowledge and practice to master and therefore is not a suitable goal for the scope of this study. Instead the focus of the present study is being able to see art more effectively, categorically including: subject matter, elements of design, and technical features. Other, more sophisticated aspects of art viewing such as artist intentions and art world viewpoints will appear in the expert performances but the scripted prompts and participant performance will be based on the aforementioned subject matter, elements of design, and technical features; the "seeing" aspects of art interpretation. These visual skills are crucial for the novice art viewer (Fowler, 2002) and for the twenty-first century learner in terms of visual literacies (Sandell, 2009). Observational skills may seem very basic but in their absence viewers are likely to struggle to make meaning or to enjoy their experience. In their study of how to make

viewing art more enjoyable, Csikszentmihalyi and Robinson (1990) interview museum professionals for insight into ways in which they interact with art. The perceptual dimension was often the first and most clearly articulate response (ahead of emotional, intellectual and communication dimensions). The authors later highlight a specific comment regarding the inability to see more than one is taught to see. This example typifies this study's stated purpose to develop observational skills in order to begin a path towards understanding and enjoying the art viewing experience.

Erickson and Clover (2003) outline five viewpoints for understanding art: non-reflective; beauty, realism, and skill; expression of ideas and feelings; art world, and plural art world. Unlike Parsons' related progression of developmental stages (1987), this continuum is not driven by one set of skills replacing another as a person develops, instead, as individuals develop their art understanding they can better utilize those viewpoints with greater sophistication. As novices, many participants in this the present study may only had two viewpoints available to them: non reflective (e.g., "I like it") and beauty, realism, and skill (e.g., "pretty picture," "looks just like it does in real life"). (This was reflected in many pre-activity responses.)

By focusing on observational skills within the context of authentic expert performances novices contextualized aspects of other viewpoints and incorporate them into their own growing skill set. The learning activity in the present study provided scaffolding to guide the novice to focus mainly on what is objectively viewable in the painting but also provided opportunities to take more responsibility in their learning by attempting to address feelings and ideas and perhaps even art world views of the artist (Dutch artist, Johannes Vermeer) and his works.

The experts modeled more sophisticated skills of interpretation using their extensive training and experience but one of the goals of the learning activity was to demonstrate how something as seemingly simple as *viewing* a painting can not only be interesting but is vitally important to understanding and enjoying art. Expert observation skills in the present study come in the form of audio recordings of conversations between two art experts as they viewed paintings in multiple museums. Participants in the present study listened to these audio recordings while viewing high-resolution reproductions printed to the exact dimensions of the original. The learning environment, described in subsequent sections, was designed to closely resemble a typical art viewing experience in a museum or gallery-like setting.

It is worth noting here that the measurement of learning outcomes in the present study required participants to perform a sort of practice interpretation, an activity likely to be beyond their abilities. Specifically, it included viewing paintings before and after the learning activity and to respond to the prompt: "*Describe what you see here. What do you think the painting is about? Use visual features of the painting to support your conclusions*." Though participants may have lacked art historical, cultural, and other knowledge required for a proper interpretation, it is how they identified features of the paintings for the purposes of supporting their conclusions that is of value and was therefore measured in this study. The possibility for somewhat clumsy interpretations was anticipated and accepted here.

Study Overview

This review represents existing research in AR relevant to the present study. Studies showed advantages of using AR in art-based classroom (Di Serio et al., 2013) and to capture expert performances for the benefit of novices (Hiyama, Onimaru, Miyashita & Ebuchi, 2013; Rosenbaum et al., 2007). As noted above, AR in educational settings is still in its early phases (Bujak et al., 2013; Chen & Tsai, 2012; Martin et al., 2011; Wu et al., 2013) and the present study aimed to contribute to the research by exploring the potential impact of using AR to make visible the thought processes and observational techniques of art experts for the learning benefit of novices.

AR is a natural support for cognitive modeling because of its ability to integrate digital information with real world objects via mobile devices. This information (annotations, visual overlays, side-by-side comparisons) was strategically implemented in order to create a learning experience that contextualized expert performances for the learning benefit of novice learners. The sequence of the instruction and the curation of the content was designed by the researcher and the AR application was developed specifically for the present study in cooperation with a team of computer science undergraduates completing their capstone project. The content of the instructional activity draws on situated and constructivist pedagogies and was presented using a cognitive apprenticeship instructional model.

Participants in the present study completed an art-based learning activity where they used mobile devices to listen to audio recordings of conversations between two art experts as they observed and discussed paintings by the Dutch artist Johannes Vermeer. (Paintings in the learning activity included *Young Woman with a Water Pitcher*,

Metropolitan Museum of Art; *The Art of Painting*, Kunsthistorisches Museum, Vienna; *Woman Holding a Balance*, National Gallery of Art, Washington D.C; and *The Glass of Wine*, Gemäldegalerie Alte Meister, Gemäldegalerie, Berlin.) The four to six minute discussions were recorded in front of the actual works while the pictures in the present study were high resolution reproductions printed to the exact dimensions of the originals. Participants listened to conversations about each of these four paintings as individuals, or with a partner, while using different technological support (audio-only, video, AR application). The audio-only conditions received no visual supports while the video and AR conditions included digital annotations, overlays, and side-by-side comparisons of other paintings. Notably, the AR application allowed participants to view the digital information directly on the physical paintings in the learning activity as opposed to viewing them separately as in the video conditions. The present study aimed to leverage spatial and temporal contiguity in a heads-up display (i.e., not looking down at tablet but instead at the real world) by using an AR mobile application to enhance a real world environment. It was the hypothesis of the present study that AR is an effective technology for increasing learning outcomes and motivation when used in a cognitive modeling learning environment.

The present study explored AR technology as an effective means of cognitive modeling in real world environments. Using a 2 x 3 factorial design, the present study compared differences in learning outcomes and motivation across AR, video, and audio-only versions of an art-based learning activity combined with whether learners work alone and in a dyad. Participants in the present study were self-identified art novices with no formal training or education in the discipline (drawn from a sample of undergraduate

and graduate students at Arizona State University and Mesa Community College). Measures include a pre- and post-activity task for learning outcomes and a post-activity survey. The task required participants to view a painting reproduction and explain (via think-aloud protocol) what they saw and what they thought the painting was about using visual features of the work to support their conclusions. (The pre- and post-activity paintings were *The* Milkmaid, Rijksmuseum, Amsterdam; and *The Music* Lesson, The Royal Collection, The Windsor Castle). The survey was a reduced version of the Instructional Materials Motivational Survey (IMMS).

Research Questions. The present study explored the use of augmented reality to support cognitive modeling in art education by comparing learning outcomes and motivation of participants who completed a learning activity in one of three technology conditions (audio, video, AR) as individuals and in dyads. The differences of these groups were analyzed relative to the research questions below.

1. How does AR technology affect learner outcomes relative to other technologies and across groupings in a cognitive modeling learning experience?
2. How does AR technology affect motivation relative to other technologies and across groupings in a cognitive modeling learning experience?
3. Is there an interaction between the type of technology to support cognitive modeling and whether learners work alone or with a partner?

Variables

Independent Variables.

1. Technologies
    a. Audio-only condition provided participants with audio recordings of art expert conversations for each painting in the learning activity. No additional visual supports were present though narrated opening and reflective prompts were included.
    b. Video condition provided participants with audio recordings of art expert conversations for each painting in the learning activity with specifically-timed visual supports in the form of an MP4 file playing on a mobile device that displayed digital information on a static image of the painting. Narrated opening and reflective prompts were included.
    c. Augmented Reality (AR) condition provided participants with audio recordings of art expert conversations for each painting in the learning activity with specifically-timed visual supports in the form of an AR application that displayed digital information via mobile device to appear directly on the physical painting. Narrated opening and reflective prompts were included.
2. Groupings
    a. Individual participants completed the learning activity with one of the preceding three technologies alone and were prompted by the

audio narration to only think about and consider their views of what the experts discussed.

b. Dyad participants completed the learning activity with one of the preceding three technologies with a partner and were prompted by the audio narration to share their thoughts and views about what the experts discussed.

Dependent Variables.

1. Learning outcomes measured by participants' response to an open-ended prompt about a painting upon completion of the learning activity.
2. Motivation as measured by a reduced IMMS motivational survey completed at the conclusion of the testing experience.

Moderating Variables.

1. Existing art viewing skills as measured by participants' response to an open-ended prompt about a painting at the outset of the testing experience.
2. Total time for completing the learning activity. This is measured from the completion of the pre-activity response to the beginning of the post-activity response.

Chapter 2: Method

Overview of Experimental Design

Using a 2 x 3 factorial design, the present study compared differences in learning outcomes and motivation across technology (AR, video, and audio-only) and groupings (individual, dyads), in an art-based learning activity in order to investigate three research questions (see Chapter 1). All participants were asked to complete the same pre- and posttest activity as well as the reduced IMMS motivational survey at the end of their experience. These measurements are detailed below.

Participants and Design

Participants were undergraduate and graduate students at Arizona State University and Mesa Community College. Participants were self-identified art novices or non-art majors who might enroll in an art appreciation or introduction to art course. This included people who frequent art museums to those who have never been, as long as they self-identified as novices (see Table 1 for specifics). In the recruitment of this study, extensive art education (e.g., visual art majors) was grounds for exclusion due to stated focus on the learning outcomes and motivation of novices. Participants needed to be able to physically see painting reproductions, hear audio instruction, and hold a mobile device for up to 30 seconds at a time (though one exception was made for a hear-impaired student who was provided transcripts of the audio and brought with her a translator).

Participants were recruited from introductory art history courses as well as graduate student listserv databases. Participants were also encouraged to invite their friends and classmates to participate with them. Referrals and requests for partners for the

dyad condition were derived from the recruitment intake form survey (Appendix A) and whenever possible formed the dyads that appear across technologies conditions: AR, video, and audio-only. Participants were randomly assigned into technology conditions while grouping assignments relied on scheduling availability of the participant and prospective dyad partner. Partners were either a classmate, friend, or family member of the recruited participant or were someone willing to be partnered with a stranger in a timeslot that worked for them.

Recruitment. Participant recruitment began with existing students enrolled in Introduction to Art History courses at Arizona State University and Mesa Community College and the students were offered extra credit by their instructors for their participation. The next round of recruitment included students from some computer science summer courses (Human Computer Interaction – HCI, Introduction to Informatics). These participants also received extra credit for participation. Regarding incentives, of the 182 participants, 79% (144) participated for extra credit; 44% (80) from introductory art courses and 34% (64) from computer science courses. The remaining 21% (38 participants) received a $10 Amazon gift card for their participation.

Demographics. As a total sample, 40% were females and 59% males (1% preferring not to disclose). Ninety-six percent of the participants were 30 years of age or younger (71% 18-24; 25% 25-30) with 38% reporting their ethnicity as “White (non-Hispanic),” 30% “South Asian (India, Pakistan, Bangladesh),” 10% “Hispanic / Latino,” 8% “East Asian (China, Japan, Korea, Malaysia),” 8% “Southwest Asian (Persian, Arabian Peninsula),” 1% “Black or African American,” and 1% indicating “Other” or “Prefer Not to Disclose.” Regarding highest level of education completed, 52% had

completed high school or GED, 8% had an Associate's degree, 29% had a Bachelor's degree, and 11% a Master's degree. These demographics are broken down by condition in Table 1 below.

Table 1

Participant Demographics

	Individuals			Dyads		
	Audio (n= 21)	Video (n= 21)	AR (n= 20)	Audio (n= 20)	Video (n= 20)	AR (n= 20)
Gender						
Female	33%	48%	45%	38%	43%	35%
Male	67%	48%	55%	63%	58%	63%
Prefer not to disclose	-	5%	-	-	-	3%
Age						
18-24	67%	76%	75%	80%	60%	70%
25-30	29%	19%	25%	15%	35%	25%
31-40	5%	5%	0%	0%	5%	5%
41-50	-	-	-	-	-	-
51-60	-	-	-	-	-	-
Over 60	-	-	-	5%	-	-
Prefer not to disclose	-	-	-	-	-	-
Ethnicity						
Hispanic/Latino	24%	5%	10%	13%	8%	8%

Black or African American	-	5%	5%	0%	0%	0%
White (non-Hispanic)	33%	57%	55%	30%	30%	40%
Native American or American Indian	-	-	-	-	-	-
East Asian (China, Japan, Korea, Malay)	5%	5%	5%	8%	8%	15%
South Asian (India, Pakistan, Bangladesh	24%	14%	15%	38%	48%	25%
Southwest Asian (Persian, Arabian Peninsula)	10%	14%	10%	3%	5%	10%
"Pacific Islander"	-	-	-	0%	-	3%
"White and Hispanic"	-	-	-	3%	-	-
"Mixed (South Asian and White)"	-	-	-	3%	-	-
Prefer not to disclose	-	-	-	3%	3%	-
Highest Level of Education						
High School or GED	62%	48%	70%	40%	45%	60%
Associate's Degree	10%	33%	15%	5%	-	-
Bachelor's degree	24%	14%	5%	35%	40%	33%
Master's Degree	5%	5%	10%	20%	15%	8%

Technology and Art Experience. The intake survey also including questions on technology usage and art expertise. Technology questions were intended to provide insight into participants' access to and experience with mobile devices including how many devices they regularly have access to and the types of applications they regularly use. Types of application (as opposed to frequency of use) was sought because of the unique experience of using AR, namely digital information interacting with physical objects when cued to do so by specialized software. Participants were asked to select all the devices they regularly had access to (desktop computer, laptop computer, tablet, smartphone, wearable technology) and to select the types of applications they regularly use on said devices (email, text/instant message, social media, search engine, location-based). No priority was given to one type of device over another nor type of application, therefore data in Table 2 reflects the total counts of each category reported by the participants.

Art expertise was included in the intake survey primarily to ensure the participation of self-identified novices (selections of Very Knowledgeable and Expert would disqualify participation in the study). Estimations of museum visits was intended to provide insight into participant experience viewing art and potentially into their motivation and interest in art, if only superficially.

Collectively, the majority of participants had access to multiple devices (76% had two to three devices, 13% had four devices; only 7% had one device and 4% had five devices) on which they used an average of four types of applications. These levels seem appropriate for students, particularly young people. (Each participant received scripted directions on using the assigned mobile device and there were no recorded usability

issues with devices in any of the conditions.) Seventy-five percent of the participants had been to an art museum "Fewer than 5 times" within the last five years, with 15% reporting six to ten times, 5% 11-20 times, and 4% twenty-one or more times. Most participants identified themselves as "Novice / Beginners" (69%) while 31% responded "Somewhat Knowledgeable." (Regarding participants self-identified expertise levels, no definition or distinctions provided to the participants. They simply self-identified according to their own view of the terms.) Technology usage and art expertise are broken down by condition in Table 2 below.

Table 2

Technology usage and art expertise

	Individuals			Dyads		
	Audio (n= 21)	Video (n= 21)	AR (n= 20)	Audio (n= 40)	Video (n= 40)	AR (n= 40)
Access to Devices (total count per participant)						
1 device	10%	24%	5%	5%	5%	10%
2 devices	48%	38%	50%	63%	43%	30%
3 devices	14%	24%	38%	28%	35%	38%
4 devices	29%	-	-	5%	18%	20%
5 devices	-	14%	5%	3%	3%	5%
Types of Applications (total count per participant)						
1 type	5%	10%	5%	-	3%	5%
2 types	14%	10%	5%	10%	3%	3%

3 types	24%	33%	30%	23%	13%	15%
4 types	24%	19%	20%	10%	13%	13%
5 types	-	29%	40%	58%	70%	58%
How many times do you estimate you have visited an art museum in the past five years?						
Fewer than 5	81%	67%	60%	68%	80%	85%
6-10	14%	19%	30%	25%	8%	3%
11-20	5%	10%	-	3%	13%	3%
21 or more times	-	5%	10%	3%	-	10%
Which category best describes your level of expertise in art? *						
Novice/ Beginner	67%	71%	50%	78%	68%	73%
Somewhat knowledgeable	33%	29%	25%	23%	33%	28%

*Responses of "Very Knowledgeable" and "Expert" were disqualified from participating.

In order to ensure sufficient statistical power, the study includes 20 data points for each of the six conditions. This is based on G*Power calculation for 2 x 3 factorial design with Cohen's f = .35, alpha = .05, and power = .80. For the three dyad conditions, this resulted in 40 participants per condition to form 20 data points. Thus, the study involved a total of 122 participants, 21 in the audio and video and 20 in the AR individual conditions and 20 in each of the three dyad conditions.

Experimental Design. The present research study took a quantitative approach to test the hypothesis that AR is an effective technology for learning outcomes and learner motivation when used in a cognitive modeling learning environment. Using a 2 x 3 research design, the present study compared differences in learning outcomes and motivation across the technologies of audio, video, and AR and groupings of individual and dyads in an art-based learning activity. The three levels of technology were: (1) audio-only with audio recordings of art expert conversations played on a mobile device; (2) video on a mobile device that displays static, digital reproductions of paintings edited with digital annotations and overlays in sync with the same audio-recorded conversations of art expert; and (3) AR mobile application that utilizes image recognition to display digital overlays to appear directly onto the painting reproductions in sync with the same audio-recorded conversations of art experts. The levels of the grouping variable were (1) individual, where participants completed the learning activity alone; and (2) dyads, where participants completed the learning activity in pairs. The participants were randomly assigned to each condition.

Learning Environment

Use of paintings in learning environment. The unique use and reuse of artwork warrants a clarification. The present study includes the use of six paintings from the Dutch artist Johannes Vermeer. All six actual paintings currently reside in museums, therefore each picture physically displayed in the learning environment is a reproduction of the original. A very high-resolution, printed to size reproduction, but a reproduction nonetheless. For each of the four paintings that appear within the learning activity (i.e.,

not the pre- and post-activity paintings) an audio recording of two art experts is provided to participants via mobile device. Each of these expert conversations were recorded as the experts viewed the actual painting within their respective museums. Participants saw only the physical painting reproduction versions of the works except for the video conditions, described below, who also saw digital versions appear on their mobile device. When the AR condition, also describe in more detail below, see "paintings" they are looking exclusively at the physical reproduction in the testing room, either directly or via the camera of their mobile device.

AR Application. The learning environment in the present study accommodates all three technologies (audio-only, video, AR) and groupings (individual, dyad) however it may be useful to provide an overview of the AR application that is the focus of the study. The AR application was designed by the researcher specifically for this study. The application had a very simple scrolling interface where the user is only required to tap a "Start" button beneath an image of the painting they wished to begin learning about. The user then aimed the device at the physical painting in the room and taps a "play" button when it appears. The application needs only recognize and search for the four images included in the learning activity of this study. This aids in processed time and in rendering very accurate digital information throughout the experience (compared to, for example, searching a library for 100, 1000, or millions of images).

The application was built to the specifications of the researcher by a team of five computer science undergraduate students for the purpose of fulfilling their capstone project as a requirement of completion for their program. Refinements were made as pilot testing was conducted by the researcher to ensure an effective and efficient user

experience. This included an administrator view into the app for testing and for changing from individual to dyad users (small adjustment to the audio recorded prompts).

Described in more detail below, the application allowed participants to listen to the audio recordings of the expert conversations (via headphones provided) and at designated times lift the device up into their gaze and view the digital information that is essence *augmented reality*.

Audio-only (in all conditions). Each participant, whether an individual or as part of a dyad, experienced the same content, namely, audio recordings of art experts discussing works of art by Johannes Vermeer. Four paintings by the artist were used in the learning activity. All participants viewed the painting reproductions while listening to a sequence of: narrator opening prompt, conversation between the two art experts, and an open-ended narrator reflective prompt for each of the four paintings. The audio-only conditions had no visual supports while AR and video conditions experienced the identical narration and expert conversations but with provided visual supports. Each participant used a mobile device (8-inch Samsung tablet) to listen to the recordings while they viewed the four paintings that were physically mounted on easels around the testing space as seen in Figure 2 below.

Figure 2. Four paintings, in sequence as experienced in learning environment.



Within the audio of each of the four paintings, the narrator opens with this prompt: "*Before we listen to experts, take a few moments to form a first impression. We can do this simply by looking at the painting and taking note of what you see and what you think the painting is about*." This cue intended to have a priming effect so the participants have a general familiarity with the paintings components and thus make the upcoming expert conversations less strenuous. It might also be argued that this behavior, a visual inventory of the picture, is encouraged within the discipline and modeled by the experts in the recordings.

Twenty to thirty seconds after the narrator prompt, the expert conversation begins between Dr. Steven Zucker and Dr. Beth Harris. Conversations are between four and six minutes and were recorded unscripted in front of the real life works in their respective museum setting. Both experts transition between different aspects of each painting in a natural way and do not take a didactic or checklist approach. Additionally, the expert conversations include components of interpretation that far exceed the scope of the present study such as the artist's intentions, culture of the time, and art world views of the artist and works. Despite the targeted novice audience, these components were included in the learning activity to maintain a high level of authenticity (experts may utilize skills

as they please) but also to give a richer context for the participants as they observational techniques intermingle with art-historical and other more complex information.

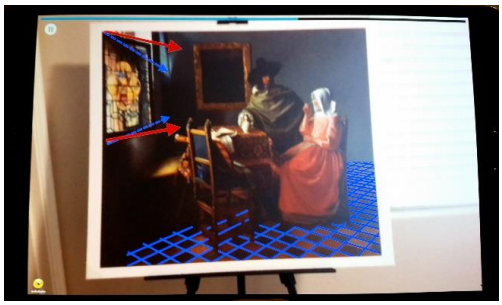
After each expert conversation was complete, the narrator returned with a prompt with an idea or feeling for the participant to consider. Individuals were asked to "think about" the answers to these prompts while dyads were asked to exchange and discuss their answers. After the participant had completed this concluding task they moved on to the next painting. The sequence of instruction for each audio recording was 1) initial narrator prompt, 2) expert conversations, and 3) narrator open-ended reflective prompts.

AR and video conditions. The AR and video conditions used the tablets for visual supports that were synced to the audio recordings of the experts. That is, as the experts mention the "ellipse of the basin" the visual supports highlighting that ellipse appear at that very moment and only for as long as appropriate relative to the progress of the expert conversation. Throughout the four to six minute conversations, the AR app used haptic response technology (the device physically vibrated) to prompt the participants to lift the device up into their gaze at the appropriate times in order to view the digital annotations, overlays, and side-by-side comparisons directly on the work itself using the device' camera and image-recognition software.

Another example includes a moment in the fourth painting, *The Glass of* Wine when the experts, talking about the placement of objects within the painting, draw attention to the "rectilinear lines" of the floor tiles. As the participant hears this they are already viewing the physical painting through the camera and screen of the device when the aforementioned "rectilinear lines" digitally highlight to emphasize that remark made

by the expert. The tablet had vibrated several seconds before allowing the participant to calmly lift the device into their gaze and view the digital enhancement.

Figure 3. Before (a) and after (b) appearance of rectilinear lines as shown in AR application

a.  b. 

The video condition provided identical visual supports (annotation, visual overlays, and side-by-side comparative works) however they were tied only to the audio not to the physical painting itself or any part of the learning environment. The participant had to remove her gaze from the painting in order to see the digital enhancements on the video before returning back to the painting upon the enhancement's completion.

Below are examples of the types of visual supports participants viewed in the AR conditions. Note that only after the mobile application recognized the picture and would the digital information appear at the designated time. Within the video conditions, the enhancement and the timing were the same but the connection between the visual and the real world object and environment was absent.

Figure 4. Example of *Annotation*

(2:04 DR. STEVEN ZUCKER: "*The souls at Christ's right would have been the blessed, the souls at Christ's left would have been the damned, and so this is the Last Judgement*…")

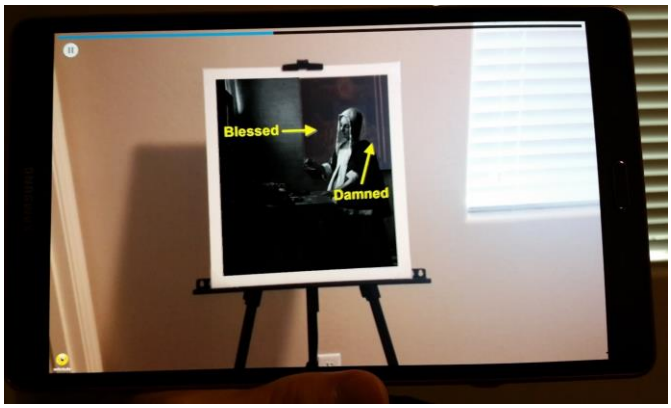


Figure 5. Example of *Overlay*

(3:41 DR. STEVEN ZUCKER: "*And I'm especially taken, I have to tell you, with the ellipse of that basin, which just is so extraordinarily convincing*…")



Figure 6. Example of Side-by-Side Comparison

(2:40 DR. STEVEN ZUCKER: "*It reminds me actually of the painting* Las Meninas *by Velazquez...where the artist paints a self-portrait. In that case we can see his face. But he's dressed in a very formal manner, in a way that is meant to please the artist within society at a very high level*…")



Just as in the audio-only condition, after each conversation is complete, the narrator returned with a prompt to share an idea or feeling with a peer or an open-ended question for the participant to consider. These prompts moved from coaching-like cues to those of articulation and reflection. After the participant completed this concluding task they will move on to the next painting. The standard sequence of instruction for each painting is listed here:

1. Artwork selected (by clicking play button)
2. Narrator prompts participant(s) to take a moment and view the painting

3. Expert conversation begins (screen is disabled with prompt to “View painting directly”)
4. One or two AR sequences occur
    a. AR event begins with single vibration cue to lift device into gaze
    b. Digital annotations, overlays, and/or side-by-side comparisons appear timed to designated times within the audio track
    c. AR event is concluded with double vibration cue
5. Narrator prompts participant(s) to articulate, reflect (dyads exchange answers)
6. Participant(s) moves on to next painting

Experts. The expert performances used for the purposes of cognitive modeling were repurposed as existing conversations of Dr. Steven Zucker and Dr. Beth Harris from Smarthistory.org, now part of Khan Academy. Drs. Zucker and Harris’s recordings are repurposed here with their permission (see Appendix E).

These art educators were selected for many reasons. Both currently co-Dean the Art and History department for the open-source education company Khan Academy which is where the researcher for the present study first came to know their recorded conversations from art museums around the world. They have extensive experience in teaching art history, both in a formal educational environment and as museum educators, and share a desire to provide art viewing skills and knowledge to people of all backgrounds, especially those who find art an out-of-reach subject. This pairing of art teaching expertise and their mission to make available art learning experiences is a far better fit for the present study than someone who may strictly be a Vermeer or Dutch

Golden Age expert. In addition to art expertise, the present study required experts with knowledge of pedagogical strategies and the needs of novice learners. Experts in Vermeer, for example, may only have detailed knowledge on Vermeer's oeuvre and exact techniques but this may exceed what a novice can fully grasp before they have the foundational observation skills sought after in this study. As with any effective learning activity, aligning the content to the needs and prior knowledge is imperative, especially when utilizing expert performances for cognitive modeling for the learning benefit of non-exert learners.

This point is illustrated in how Drs. Zucker and Harris model the expert thinking and observation skills the present study wishes to demonstrate for novices. Each conversation includes observations of subject matter, elements of design, as well as design principles and art historical information but they also provide context and direction by speaking their way through their processes. When the experts begin discussing *Young Woman with a Water Pitcher* for example, they talk about how typical the work is of its time and place, putting the painting into context for two full minutes before mentioning any details of the work. Before discussing specific features or trying to extract meaning from the painting they first think about where the artist and his work fit into existing knowledge. When viewing *Woman Holding a Balance* and *The Glass of Wine*, the experts begin their conversation with an inventory of the subject matter; literally listing people, places, and objects found in the painting, before building upon those observations with elements of design and surmising possible meanings behind subject matter. This models exactly what the present study hopes the participants can achieve. In *The Art of Painting* the experts open with the allegorical figure being painted

by the artist and suggest the main idea behind the painting, then proceed to defend that point of view using features of the work, and then moving into art historical information. Despite the variety in their approaches to each work, they continually exhibit expert-like processes in interesting and authentic ways. Their content knowledge, teaching experience, and modeling of expert skills and processes position them well within this study.

Measures

Recruitment survey. During the recruitment process participants were screened via an intake form (see survey in Appendix A) which included basic administrative information, demographics, technology use, and art expertise. Museum visitation frequency, highest level of education, and the source of their referral (peer, teacher, listserv email, etc.) were included in these categories.

Viewing art as pretest and posttest. The purpose of these measures was to account for participant's art viewing skills before and after the learning activity. Participants received a brief instruction on think-aloud protocols before being asked to look at a painting reproduction and answer the following prompt in that manner:

Describe what you see here. What do you think this painting is about?

Use visual features of the painting to support your conclusions.

These performances were video recorded to ensure accuracy and comprehensiveness when scored using an Art Viewing rubric (see Appendix C). It is from these scores that learning outcomes were compared. The researcher hired two art education students to conduct the scoring of the participant's pre- and post-learning

activity participant responses. These students were recommended by a committee advisor and completed multiple trainings in the rubric and the associated tracking technologies for consistent and efficient scoring. Each scorer independently scored every video response (182 participants x pre- and post-activity performance) according to subject matter (e.g., people and place, objects, illusionist qualities), elements of design (e.g., line and shape, color), and contextual and comparative comments. More complex design principles (e.g., balance, contrast, repetition) are much more sophisticated and require more training than the present study is prepared to offer, however any related responses that include these principles (whether intentionally or incidentally) were accounted for as they might be of interest for future research.

Time spent in learning activity. Relevant data came from two main sources. First, the duration of each participant response is captured in the video runtime (i.e. how many minutes and seconds they spoke about each of the pre- and post-activity paintings). Second, in order to approximate how long participants took to complete the learning activity the researcher used the pre- and post- response video timestamps. The end of pretest response was the "starting point" of the learning activity and the beginning of the posttest was the "end point." For dyads, the researcher used the end of the second pretest and the beginning of the first posttest. (The AR conditions required a three to four minute tutorial and therefore times for participants in those conditions were reduced by five minutes.)

With 24 minutes and seven seconds of expert performance (additional 23 total seconds for dyads), the researcher could better compare across the conditions. Since each participant completed the same learning activity (in duration and sequence) and received

the same instruction read from a script, the researcher is confident in the use of these measures.

Instructional Materials Motivation Scale (IMMS). Keller's (2009) IMMS motivational survey, a survey widely used to measure motivation when interacting with educational materials, was put through an extensive validation process by Loorbach, Peters, Karreman, and Steehouder (2015), resulting in contains 12 items across the four constructs of Attention, Relevance, Confidence, and Satisfaction (ARCS). The aim of the authors was to unravel "statistical and theoretical strengths and weaknesses in relation to all aspects of the underlying ARCS theory" (p.4). This instrument was selected for the present study because of its alignment to the use of self-directed instructional materials and because of its efficiency in being completed by study participants.

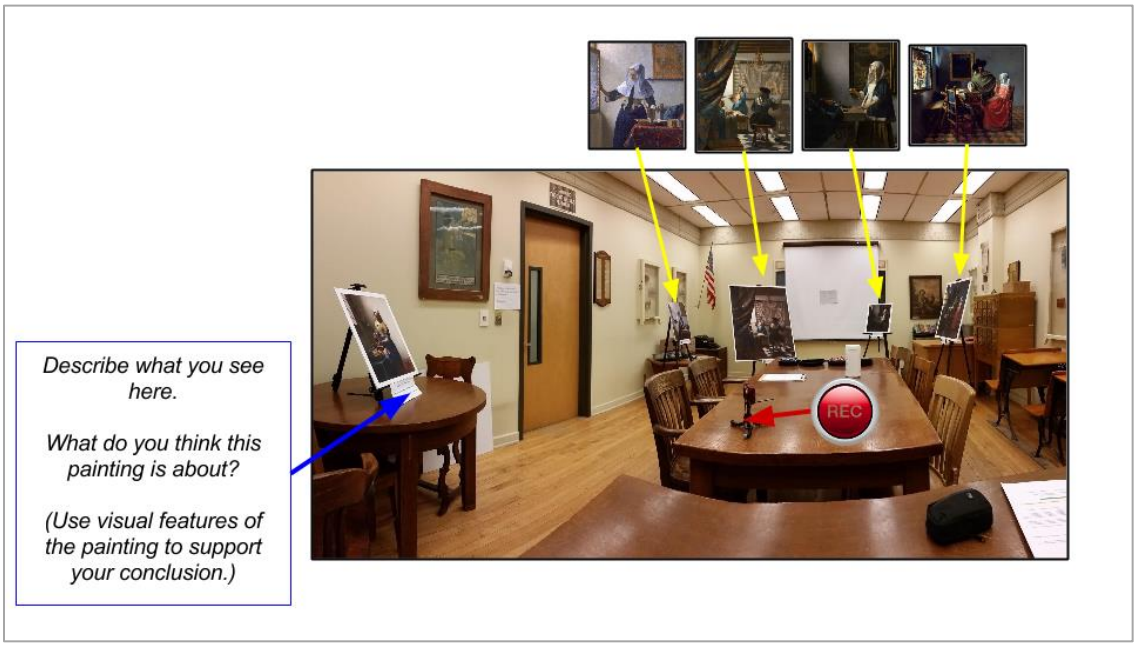
Scores from the survey were used in the present study to capture the experience of participants upon completing the learning activity and after responding to the recorded posttest response. Data pertaining to each element of the ARCS model is relevant for novices in art who may have had little, if any, interest in the subject before participating in the study. Examining student experience across the technology and individual/dyad conditions provides insight into the benefits and/or drawbacks of the instructional experience and helped determine levels of participant motivation upon completion of the instructional experience.

Procedure

The present study took place in one of three large conference rooms at Arizona State University and (for 20 participants) at designated area within a classroom at Mesa

Community College. The rooms had to be large enough to fit six full-size paintings (each approximately one to three feet squared) and have table space for participants to complete pre- and post-measures. The room was secured for safety of the art objects, the recording equipment, and the tablets, and to create a quiet environment for participants to view the art. Figure 7 below shows a typical room setup in this study.

Figure 7. Study Setup



The picture above is taken from the perspective of the researcher during the test when the participants are completing the learning activity. To the far left the reader can see where the pre- and post-activity recorded responses are taken (note the camera positioned on center table) as well as the learning activity consisting of the four labeled painting at the far end of the room (with reminder instructions taped to the wall or projector screen). A closer panoramic view of the four paintings, sequenced left to right, that each participant experienced is found in Figure 8.

Figure 8. Four learning activity paintings as experienced by participants



Participants completed the following sequence for the research experiment for a total of approximately 55-70 minutes:

1. Intake and Overview (five minutes)
2. Pre-activity Art Viewing Response (five minutes)
3. Device Instructions and Application Calibration (five minutes)
4. Learning Activity (30-45 minutes)
5. Post-activity Art Viewing Response (five minutes)
6. Reduced Instructional Materials Motivational Survey (IMMS) (five minutes)

Participant check in. Participants were welcomed by the researcher and asked to complete an informed consent form (see Appendix B) that included a short checklist of what the study entailed including length of commitment. The researcher then verbally confirmed the participants' willingness and ability to perform all tasks (view paintings, hear recordings, hold and aim tablet).

Pre-activity art viewing response. The first task participants were asked to complete was the pre-activity art viewing response. They received brief instruction on think-aloud protocols and a reminder of the recording before beginning. This exercise

required participants to look at a painting, *The Milkmaid*, by Johannes Vermeer, and respond to the following prompt in a think-aloud protocol:

Describe what you see here. What do you think this painting is about?

Use visual features of the painting to support your conclusion.

The researcher sought to put participants at ease with being recorded talking about art, with a stranger no less. Participants were told that there were no "wrong answers" and that "if you think you see something, you can say it. If you think it means something, you can say that too. Don't worry about being 'wrong' here." Participants were given as much time as they wished and were instructed that the researcher would not stop them. Instead, they had to tell the researcher when they thought they were done. The intention was to allow participants control of the task and to encourage thinking and consideration in their responses no matter how modest or inexperienced. (Additionally, were they to view art in a museum, there would be no time limit on how long they could speak about a painting.) Dyads received identical instructions, together, before the researcher explained the need for them to complete the task without the influence of the other and therefore one partner stepped out of the room during the other's response.

After instructions were given the researcher received confirmation that the participant was ready to begin, at which point he turned on the video camera and read aloud the aforementioned prompt hanging from below the pre-activity painting reproduction ("*Describe what you see here…*"). After individuals and both partners had completed their pretest responses the researcher explained that there would be another similar task after the learning activity but that nothing else would be video recorded.

Device instructions and application calibration. After completing the pre-activity response, participants were guided to the four paintings of the learning activity that were mounted on easels. The researcher explained that this was where they would learn more about the works artist Johannes Vermeer using the mobile devices (next to headphones on table). The researcher read a short overview (140 words) about the artist before transitioning to the mobile devices as the instruments through which they would learn more about the artist.

Audio-only. Participants in the audio-only conditions were provided with an eight-inch Samsung tablet with an otherwise blank home screen with four folders, one of which held the four respective audio files for the four painting. The researcher read the following instructions.

> *Here is your mobile device and headphones. If you'll tap the "C1-A/B" folder icon, you'll find a set of audio tracks. Notice that there are four tracks, one for each painting you will view. Notice also that each track name matches the respective painting. You can tap "Pause" any time you wish but I ask that you do listen to each track in its entirety.*
>
> *Each track will have three main parts.*
>
> *1. opening prompt*
>
> *2. 5 minute conversation of two art experts discussing the actual real life painting*
>
> *3. concluding prompt*
>
> *You'll learn more about the learning activity in a moment but I strongly encourage you to follow each prompt as you progress through the experience.*

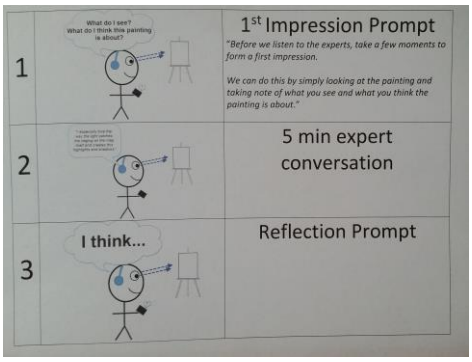
Any questions?

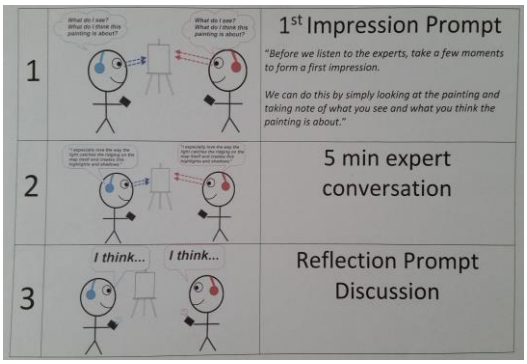
Dyads received the following instructions before being asking if they had any questions.

Since you are working together as a pair, you will listen to the content separately on your own device. However, I'll ask you to follow the prompts at the end of each painting which ask you to discuss or reflect on components of the painting with your partner. There are no time restrictions to these prompts so take as long as you need.

In support of these instructions, the visual supports below were taped on the wall as reminders for the sequence to follow for each of the four paintings.

Figure 9. Audio Individual (a) and Dyad (b)

a. 

b. 

Video. Participants in the interactive presentation conditions were provided with the same eight-inch Samsung tablet with an otherwise blank home screen with four folders, one of which held the four respective video files for the four painting. The researcher read the following instructions.

Here is your mobile device and headphones. If you'll tap the "C2-A/B" folder icon, you'll find a set of video files. Notice that there are four files, one for each

painting you will view. Notice also that each track name and thumbnail image match the respective painting. You can tap "Pause" any time you wish but I ask that you do listen to each track in its entirety.

Each track will have three main parts.

1. *opening prompt*
2. *5 minute conversation of two art experts discussing the actual real life painting*
3. *concluding prompt*

You'll learn more about the learning activity in a moment but I strongly encourage you to follow each prompt as you progress through the experience.

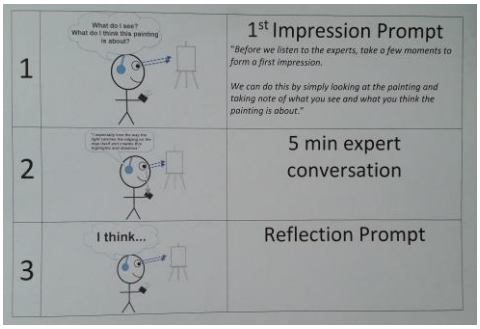
Any questions?

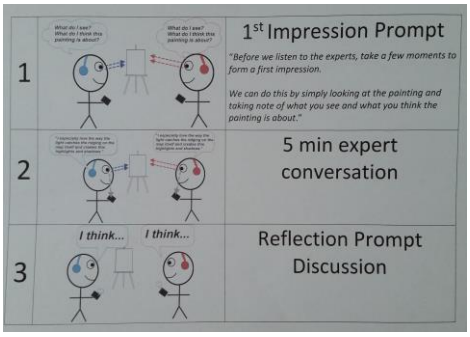
Dyads received the following instructions before being asking if they had any questions.

Since you are working together as a pair, you will listen to the content separately on your own device. However, I'll ask you to follow the prompts at the end of each painting which ask you to discuss or reflect on components of the painting with your partner. There are no time restrictions to these prompts so take as long as you need.

In support of these instructions, the visual supports below were taped on the wall as reminders for the sequence to follow for each of the four paintings.

Figure 10. Video Individual (a) and Dyad (b)

a. 

b. 

AR. Participants in the AR conditions were provided with the same 8-inch Samsung tablet with the AR application already opened by the researcher. Participants in the augmented reality conditions required an extra step in the description of the learning activity because of the required functionality. This extra step was an interactive tutorial that allowed the participants to practice using the application to view digital enhancements similar to those in the learning activity proper. The researcher read the following instructions.

> *To learn about these paintings, you will be using a mobile application. This mobile application has software that uses device's camera to recognize the painting and overlay digital information on the screen so that it appears to be directly on the painting. These "enhancements" are timed to support the observations made by the experts.*
>
> *In order to successfully use this application, you will need to complete a short tutorial.*
>
> [Tutorial opened on device by researcher] *Here is your mobile device and headphones.*

In this tutorial you will learn when to lift the device up in order to see digital enhancements to the real world paintings and when to lower it and view the painting directly. You will view each painting through the device only once or twice but I don't want you to miss the digital enhancements so we are going to practice with this tutorial.

And instead of a painting, we will use this illustration of a red house [on adjoining easel]. When you are ready, aim the device at the picture and tap the "Play" icon when it appears. The tutorial will take you through the steps.

Any Questions?

The participants then listened to a four minute audio track that took them through the experience of responding to a single vibration to lift the tablet into their gaze (in order to see the digital information) and a double vibration to indicate the enhancements were complete and that they should view the painting directly. The application reinforces this point further by defaulting to a dark gray screen (as to not distract) with a short line of text "Please view the painting directly" should they not lower devices after a few seconds.

The tutorial was designed to allow participants the opportunity to practice using the device and better understand how digital enhancements appear as if on real world objects. However, to limit cognitive load, the subject matter used for the tutorial was not Vermeer or particularly art-based. Instead a printed out picture of clip art (see red house in Figure 11 below) was used with a tree and small dog as digital enhancements to make clear the purpose of the exercise was to familiarize the technology not learn any content.

Figure 11. Second of two practice rounds of viewing digital information using the tutorial in the AR application



The red house below was printed out on photo paper and mounted on an easel. At designated times, coinciding with tutorial audio, the tree appears (on the screen of the tablet) to the right of the red house while the small dog later appears in front of the red house.

After the participants completed the tutorial, the researcher asked if there were any questions before preceding to explaining the sequence for each painting. The researcher read the following instruction.

> *Now that you know when to lift and lower the device we can continue. Each track will have three main parts.*
>
> *1. opening prompt*
>
> *2. 5 minute conversation of two art experts discussing the actual real life painting*
>
> *3. concluding prompt*
>
> *You'll learn more about the learning activity in a moment but I strongly encourage you to follow each prompt as you progress through the experience.*

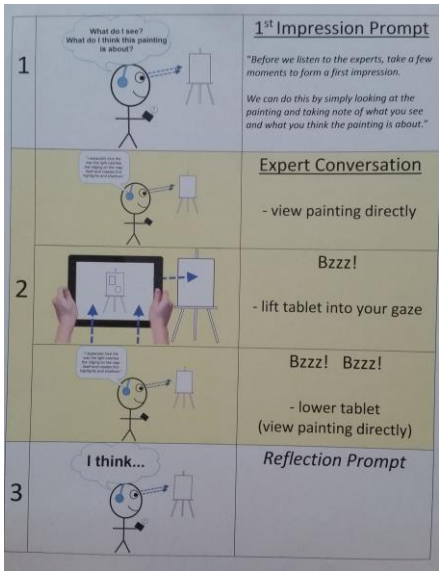
Any questions?

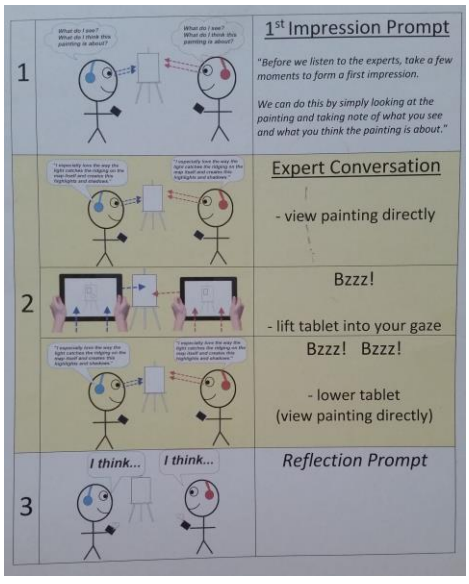
Dyads received the following instructions before being asking if they had any questions.

> *Since you are working together as a pair, you will listen to the content separately on your own device. However, I'll ask you to follow the prompts at the end of each painting which ask you to discuss or reflect on components of the painting with your partner. There are no time restrictions to these prompts so take as long as you need.*

In support of these instructions, the visual supports below were taped on the wall as reminders for the sequence to follow for each of the four paintings with a reminder about the single and double vibrations.

Figure 12. AR Individual (a) and Dyad (b)

a. 

b. 

Instructional activity. With a device in hand, participants were given an overview of the model of the learning experience: opening prompt, expert conversation,

concluding prompt. The researcher explained to the participants that while the "paintings" are in fact reproductions, they are printed from very high resolution images and therefore extremely close to what the experts were seeing when they recorded their conversations (including to the exact dimensions of the originals, with very accurate colors, and to the level of detail that even cracks are easily visible). Participants were encouraged to get as close as they like to the pictures and to view them from any angle they like. The researcher then read the following instructions.

> *This learning activity includes viewing these four paintings while listening to a 5 minute conversation between two art experts that was recorded while they viewed the actual painting in person.*
>
> *In order to get more familiar with each painting, before each conversation begins you will hear this prompt:*
>
> "Before we listen to the experts, take a few moments to form a first impression. We can do this by simply looking at the painting and taking note of what you see and what you think the painting is about."
>
> *You will then have 20-30 seconds to do just that (to yourself). If you'd like longer, simply tap the "Pause" button and take as long as you need.*
>
> *After each expert conversation you will be prompted to think back to certain parts of the experience and reflect. I strongly encourage you to follow these prompts.*
>
> *You will follow this sequence: form a first impression – experts' conversation – reflection prompt; for all four paintings.* [Participants reminded of sequence reminders hanging on wall (Figures 9, 10, 12)]
>
> *Any Questions?*

Tap the Young Woman with a Water Pitcher *icon to begin. I can help you at any time.*

In addition to the above, dyads were read the following instructions.

Please follow these prompts with your partner. Feel free to discuss for a long as you see fit.

Participants would then begin the learning activity at the first painting and upon completion of the concluding reflective prompt from the narrator would move to the next painting in the sequence and complete the same instructional experience.

Post-activity art viewing response. Upon completion of the learning activity, participants were guided back to the pre-/post-activity response area of the conference room. Similar to the pre-activity response, they received brief instruction on think-aloud protocols and a reminder of the recording before beginning. This exercise once again required participants to look at a painting, this time *The Music Lesson*, by Johannes Vermeer, and answer the following prompt in a think-aloud protocol:

Describe what you see here. What do you think this painting is about?

Use visual features of the painting to support your conclusion.

The researcher again sought to put participants at ease with being recorded talking about art, by reminding them that there were no "wrong answers" and that "if you think you see something, you can say it. If you think it means something, you can say that too. Don't worry about being 'wrong' here." Participants were given as much time as they wished and were instructed that the researcher would not stop them. Instead, they again had to tell the researcher when they thought they were done. The intention remained to allow participants control of the task and to encourage thinking and consideration in their

response no matter how modest or inexperienced. Dyads received identical instructions, together, before the researcher asked one to step out of the room while the other completed their response. After instructions were given the researcher received confirmation that the participant was ready to begin. At which point he turned on the video camera and read the aforementioned prompt hanging from below the post-activity painting reproduction ("Describe what you see here…"). After individuals and both partners had completed their posttest responses the researcher asked them to complete the reduced IMMS survey.

Reduced Instructional Materials Motivation Survey (IMMS). Participants were asked to complete a reduced IMMS survey composed of 12 statements from which the participant indicates on a 5-point scale whether that statement is Not True – Very True. Participants were told to be as honest as possible despite the fact that the researcher was present and their name was on the form. Dyad partners completed their survey individually (that is they did not discuss their answers while completing it). The researcher collected these surveys, verified their completion, and thanked the participants for their time and reminded them on the next steps regarding their incentives before being dismissed.

Scoring

Art viewing performances. Scoring of learner outcomes occurred in two instances: the pre- and post-activity responses. An art viewing rubric (described in detail below) was used by two art education scorers to score each participant response.

Participants' responses were video recorded before and after the learning activity as they responded to this prompt:

Describe what you see here. What do you think this painting is about?

Use visual features of the painting to support your conclusion.

The present study utilized two art education students that were well-versed in subject matter, elements of design, technical features, as well as design principles. They were trained on the scoring rubric categories and ratings (0-4 points), and scored each performance by following a protocol of first watching the video without making any scores, then watching again scoring relevant categories according to the criteria listed on the rubric, and last, watching the video a third time to make sure no instances of categories or details was missed. Scores were entered into spreadsheet tracker dashboard that provided each scorer with a link to the video and cells for each part of the rubric. Scorers entered data independently of each other to ensure integrity of the scores and fairness to the scorers. A Pearson product-moment correlation was conducted to account for the reliability of the raters in their scoring of participants pre- and post-activity responses. A strong correlation was found, which was statistically significant ($r = .967$, $n = 364$, $p < .001$).

Reduced IMMS. A total sum score was calculated as well as averages for each of the four subscales: attention, relevance, confidence, and satisfaction. The response scales for each of the (reduced) 12 items was one to five (not true to very true) resulting in a total score range of 12-60.

Art viewing rubric. In order to capture the various types and levels of observations by the participants a rubric was created. The rubric included three main

sections that are explained in detail below. Each section used terminology universal to the art discipline such as people, objects, line, color etc. (Barrett, 2011; Delahunt, 2010). In addition to securing validity for this study, the rubric's use of this terminology should prove compatible for future and comparative research in this area. Importantly, each art term included on the rubric was first demonstrated by the expert performances and subsequently judged (with the guidance of an art educator and committee member) to be achievable by novices within this study. Art terms that were not present in the expert performances, or were determined to be highly unlikely, namely design principles, reside in the third section of the rubric and captured only for future research.

There are three sections in the rubric: Descriptive Responses (which includes subject matter and elements of design), Contextual and Comparative Responses, and Design Principles. Descriptive Responses and Contextual and Comparative Responses both utilize a four-point scale while Design Principles (for reasons described earlier in this chapter) only have Yes/No classifications.

The four-point scale moves from Minimal responses (one point) to Specific responses (two points), Descriptive responses (three points), to Comprehensive responses (four points). This scale was created to capture anticipated novice performances both from a qualitative perspective such as identifying elements of design by descriptive characteristics (e.g., " *I love the shading of light to dark on the white wall*") and a quantitative perspective (e.g., multiple objects, such as "*I see a string of pearls on the table, a mirror on the wall, and a woman holding a balance in front of some kind of painting*").

Equivalencies were thoughtfully planned out to ensure fairness and accurate representation of scores. For example, a participant may receive a score of 3 points for accurately identifying an object by a descriptive characteristic *or* identifying at least two objects found in the painting. Either can be classified as "Descriptive" and therefore it is reflected in the rubric. The relativity between the scores on the scale also received much consideration. Identification of Illusionist Qualities, the illusion of form, space, and texture in a two-dimensional painting is more difficult than simply identifying the object outright. It marks the difference between statements like "*There's a bowl of fruit on the table*" and "*I feel like I could pick up that bowl of fruit*" and therefore its presence is a score of three points or four for multiple occurrences.

Participants were not shown the rubric at any time during the study. While they were aware of the general learning goal (learning to look at paintings using expert performances) this rubric was meant to capture a broad set of art observation skills with a degree of depth for the purposes of measuring learning outcomes, not as a traditional recall-based measurement of learning gains. Just as the experts' performances are based on natural thoughts and feelings derived from acute observation skills (and contextual knowledge), and not a checklist of possible art skills, so too are those of the novices.

Descriptive responses. This section of the rubric (Appendix C1) is the foundation of all the observation skills the present study aims to build with novices. The ability to determine what a work of art might be about begins with what is included within the piece: subject matter like people and places and elements of design such as line, shape, and color (see Csikszentmihalyi's perceptual dimension, 1990, p. 29-32). The scoring of the Illusionist Qualities section has been aligned (with consultation from an art educator

and committee member) to match the degree of difficulty of other subject matter-based identifications. This has resulted in any example of form, space, or texture to begin scoring at three points with multiple examples four points (Erickson, 2016). Each category of Descriptive responses is objectively observable in the painting reproductions used in the present study and form the core of the expert modeling. The rubric captures the degree to which novices were able to apply this knowledge from the expert performances to their own. As indicated above, this includes responses that accurately identify multiple examples as well as identifying examples using descriptive characteristics. Descriptive responses were also identified within the expert performances and therefore considered relative to what the participants might also use in their own viewing of the last Vermeer reproduction without the support of any of the technologies.

Context, meaning, and comparing artworks. This section of the rubric (Appendix C2) captures instances where the novice may recall parts of the expert performance that go beyond the goal of observation skills. Because the experts are modeling complete, naturalistic performances they included art historical comments about meaning, comparable works, and the context in which the real paintings were created. Participants may have recalled certain facts and context when explaining their views on the last painting and this data is of value when looking at expert and novice performances. Recollection of facts that happen to "stick" from earlier expert performances are important and are scored accordingly (three points), however using facts to explain features of the reproductions is a much more complex act and is therefore worth a full four points. An example of this difference would be between a statement like "*Vermeer's paintings often reflected middle class life*." and "*Vermeer's paintings often*

reflected middle class life, and on the table I see an expensive carpet and a jug of some kind." Incorporating art historical information in one's views of a work of art is much more expert-like and is therefore tracked in this section of the rubric.

Design principles. When conducting the analysis for which art terms to include in the rubric several were found to be scantly referenced by the experts (predictably, as experts are not obligated to comment on event aspect of art interpretation each time they discuss a work). This section of the rubric (Appendix C3) includes these aspects. Design Principles describe the artwork more holistically and require a more complex understanding than is practical for a single learning event as represented by this study. Eliciting comments about harmony and balance, for example, was determined to be beyond the scope of this learning activity but in time may be of interest to similar studies with more advanced students.

Additionally, if participants inadvertently made comments during their performance that included these complex concepts simply by using their own points of view it will be noted using this third and last section of the rubric. For example, though not explicitly discussed by the experts, a novice might explain the presence of warm and cool colors (contrast) or specifically what draws the viewer's attention (focal point). It would be interesting to see what kinds of naturally occurring expert-like comments might be included in the performances of novices having just witnessed modeling by experts.

Chapter 3: Results

The results for the two dependent variables of learning outcomes and motivation were analyzed as well as a more focused view of the art viewing subscale and the total time participants spent in the learning activity. Table 3 presents a summary of each test conducted. Interactions between technologies and grouping (i.e., Research Question 3) were included in each of the analyses of covariance conducted and are described in more detail below.

Table 3

Tests Conducted

Research Questions	Data Source	Analysis
Research Question 1: How does AR technology affect learner outcomes relative to other technologies and across groupings in a cognitive modeling learning experience?	Overall Learning Measure	Analysis of Covariance
Do any art viewing *subscales* differ between technology or grouping?	Pre- and post-activity response scores for Elements of Design subscale	Analysis of Covariance
Research Question 2: How does AR technology affect motivation relative to other technologies and across groupings in a cognitive modeling learning experience?	Reduced IMMS survey	Analysis of Covariance
Does total time spent in learning activity differ between technology or grouping?	Learning Activity Duration	Analysis of Variance

Overall Learning Measure

A two-way ANCOVA was used to compare the effect of technology (audio-only, video, AR) and grouping (individual, dyad) on participants' posttest performance (learning outcome) with their pretest score as a covariate. No significant main effects were found for technology $F(2, 115) = 1.93$, $MSE = 19.24$, $p = .15$, $\eta p^2 = .03$, with an observed power of .39. Neither were significant main effects found for grouping $F(1, 115) = .17$, $p = .68$, $\eta p^2 = .001$, with an observed power of .07. The was no significant effect for the interaction of technology and grouping factors $F(2, 115) = .81$, $p = .45$, $\eta p^2 = .01$, with an observed power of .19. Table 4 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 4

Learning Outcome

Technology	Grouping	N	Mean	*SD*	Adjusted Mean
Audio	Individual	21	12.10	5.26	12.26
	Dyad	20	12.01	4.43	11.59
Video	Individual	21	13.17	4.89	12.39
	Dyad	20	13.16	4.10	13.43
AR	Individual	20	14.58	7.45	14.53
	Dyad	20	12.31	3.09	13.17

Learning Measure by Subscale

Further investigation into the learning outcomes of art viewing subscales was conducted because of the possibility that the visual supports provided by the video and AR conditions may have had an effect within the post-activity responses of the participants. More specifically, because a majority of the visual supports were targeted at line, shape, and color an additional test was warranted. A two-way ANCOVA was used to compare the effect of technology and grouping on participants' learning outcomes within each of the subscales. This was measured by the post-activity subscale scores on the art viewing rubric with the pre-activity subscale scores as a covariate.

Subject Matter. Subject matter includes people, place, objects, and illusionist qualities. While these are objectively viewable by any sighted person, the visual supports of the AR application and video conditions only displayed one example of illusionist qualities ("depth of field" of room in painting 2). Objects were identified in the visual supports, however they were done so in order to emphasize line, color, or shape (i.e., elements of design).

Significant main effects were not found for technology $F(2, 115) = .31$, $MSE = 3.76$, $p = .72$, $\eta p^2 = .006$, with an observed power of .10. No significant main effects were found for grouping $F(1, 115) = 3.60$, $p = .06$, $\eta p^2 = .03$, with an observed power of .47. Neither was a significant effect found for the interaction of technology and grouping $F(2, 115) = .23$, $p = .79$, $\eta p^2 = .004$, with an observed power of .08. Table 5 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 5

Subject Matter

Technology	Grouping	N	Mean	*SD*	Adjusted Mean
Audio	Individual	21	7.48	2.54	7.59
	Dyad	20	8.09	1.45	7.95
Video	Individual	21	7.21	2.45	7.16
	Dyad	20	8.03	1.43	8.11
AR	Individual	20	7.85	2.55	7.66
	Dyad	20	8.14	1.55	8.32

Context. Context includes attributes of the artist's life and culture. This is discussed by the experts throughout the learning activity but is not supported by any visual supports of the AR application or video conditions.

Significant main effects were not found for technology $F(2, 115) = .14$, $MSE = 1.01$, $p = .872$, $\eta p^2 = .002$, with an observed power of .07. No significant main effects were found for grouping $F(1, 115) = .003$, $p = .995$, $\eta p^2 = .000$, with an observed power of .05. Neither was a significant effect found for the interaction of technology and grouping $F(2, 115) = 1.29$, $p = .28$, $\eta p^2 = .02$, with an observed power of .27. Table 6 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 6

Context

Technology	Grouping	N	Mean	*SD*	Adjusted Mean
Audio	Individual	21	.74	1.37	.72
	Dyad	20	.35	.83	.30
Video	Individual	21	.31	.98	.26
	Dyad	20	.49	.92	.53
AR	Individual	20	.33	1.00	.37
	Dyad	20	.45	.86	.49

Compare Artworks. Compare artworks includes the artist's style and themes like social status, love, or religious devotion. These, too, were discussed by the experts but were not part of the visual supports in the AR application and video conditions.

Significant main effects were not found for technology $F(2, 115) = .518$, $MSE = 3.927$, $p = .60$, $\eta p^2 = .01$, with an observed power of .13. No significant main effects were found for grouping $F(1, 115) = 1.30$, $p = .26$, $\eta p^2 = .01$, with an observed power of .20. Neither was a significant effect found for the interaction of technology and grouping $F(2, 115) = .06$, $p = .94$, $\eta p^2 = .001$, with an observed power of .06. Table 7 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 7

Compare Artworks

Technology	Grouping	N	Mean	*SD*	Adjusted Mean
Audio	Individual	21	2.07	2.18	2.07
	Dyad	20	1.80	1.59	1.82
Video	Individual	21	2.43	2.31	2.33
	Dyad	20	1.80	1.68	1.87
AR	Individual	20	1.95	2.46	1.93
	Dyad	20	1.35	1.44	1.39

Elements of Design. Elements of Design include line, shape, and color. These are discussed by the experts and are repeatedly included in the visual supports of the AR application and video conditions.

Significant main effects were found for technology $F(2, 115) = 4.49$, $MSE = 2.36$, $p = .013$, $\eta p^2 = .072$, with an observed power of .76. In a pair-wise comparison, AR was significantly higher than audio ($p = .004$) but not video ($p = .29$). No significant main effects were found for grouping $F(1, 115) = .61$, $p = .44$, $\eta p^2 = .005$, with an observed power of .12. Neither was a significant effect found for the interaction of technology and grouping $F(2, 115) = 2.60$, $p = .08$, $\eta p^2 = .04$, with an observed power of .51. Table 8 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 8

Elements of Design

Technology	Grouping	N	Mean	*SD*	Adjusted Mean
Audio	Individual	21	.761	.735	.78
	Dyad	20	1.10	1.32	.99
Video	Individual	21	1.40	1.53	1.40
	Dyad	20	1.75	1.40	1.67
AR	Individual	20	2.40	2.86	2.46
	Dyad	20	1.23	.68	1.34

Design Principles. Design principles include characteristics that encompass the entire painting such as balance, harmony, and focal point. Harmony is only briefly mentioned by the experts and indirectly supported by a single visual supports of the AR application and video conditions. During the design of the art viewing rubric, design principles were identified as complex concepts that went beyond the content provided by the learning activity (and the presumed skills of self-identified novices) and thus were only tallied for the purposes of insight into future research.

Motivation

A two-way ANCOVA was used to compare the effect of technology and grouping on motivation as measured by the reduced IMMS motivational survey with the total time spent in the learning activity as a covariate. No significant main effects were found for

technology $F(2, 115) = .35$, $MSE = 33.87$, $p = .71$, $\eta p^2 = .006$, with an observed power of .10. Neither were there significant main effects found for grouping $F(1, 115) = 1.31$, $p = .25$, $\eta p^2 = .01$, with an observed power of .21. There was, however, a significant effect for the interaction of technology and grouping $F(2, 115) = 5.06$, $p = .008$, $\eta p^2 = .08$, with an observed power of .81. A simple main effects test was conducted and identified a significant effect ($p = .01$) for individuals in the audio condition relative to dyads with the former reporting higher motivation scores. Table 9 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 9

Reduced IMMS

Technology	Grouping	N	Mean	*SD*	Adjusted Mean
Audio	Individual	21	51.95	6.40	52.07
	Dyad	20	46.23	5.95	46.16
Video	Individual	21	48.10	6.84	48.19
	Dyad	20	50.55	3.42	50.46
AR	Individual	20	51.55	5.56	51.60
	Dyad	20	49.43	5.88	49.31

Motivation by Subscale

Further investigation into the learning outcomes of art viewing subscales was conducted because of the possibility that the visual supports provided by the video and AR conditions may have had an effect within the post-activity responses of the participants. More specifically, the use of visual supports may have had an effect on the relative levels of attention, relevance, confidence, and/or satisfaction. A two-way ANOVA was used to compare the effect of technology and grouping on participants' motivation within outcomes within each of the subscales. This was measured by the reduced IMMS survey completed at end of study.

Attention. No significant main effects were found for technology $F(2, 116) = .59$, $MSE = .36$, $p = .55$, $\eta p^2 = .01$, with an observed power of .15. Significant main effects were found for grouping $F(1, 116) = 6.94$, $p = .010$, $\eta p^2 = .056$, with an observed power of .74. In a pair-wise comparison, individual was significantly higher than dyad ($p = .01$). No a significant effect found for the interaction of technology and grouping $F(2, 116) = 1.76$, $p = .18$, $\eta p^2 = .03$, with an observed power of .361. Table 10 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 10

Attention

Technology	Grouping	N	Mean	*SD*
Audio	Individual	21	4.17	.64
	Dyad	20	3.63	.54

Video	Individual	21	4.05	.74
	Dyad	20	4.00	.46
AR	Individual	20	4.17	.63
	Dyad	20	3.9	.64

Relevance. No significant main effects were found for technology $F(2, 116) = .559$, $MSE = .36$, $p = .57$, $\eta p^2 = .01$, with an observed power of .14. No significant main effects were found for grouping $F(1, 116) = 1.02$, $p = .315$, $\eta p^2 = .009$, with an observed power of .07. A significant effect was found for the interaction of technology and grouping $F(2, 116) = 6.48$, $p = .002$, $\eta p^2 = .1$, with an observed power of .90. A simple main effects test was conducted and identified a significant effect ($p = .02$) for individuals in the audio condition reporting higher attention scores than the dyads of the same condition. Table 11 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 11

Relevance

Technology	Grouping	N	Mean	*SD*
Audio	Individual	21	4.46	.69
	Dyad	20	4.00	.62
Video	Individual	21	3.92	.73
	Dyad	20	4.35	.30

AR	Individual	20	4.43	.58
	Dyad	20	4.13	.60

Confidence. No significant main effects were found for technology $F(2, 116) = 1.64$, $MSE = .34$, $p = .2$, $\eta p^2 = .03$, with an observed power of .34. No significant main effects were found for grouping $F(1, 116) = .93$, $p = .338$, $\eta p^2 = .008$, with an observed power of .16. A significant effect was found for the interaction of technology and grouping $F(2, 116) = 3.27$, $p = .042$, $\eta p^2 = .053$, with an observed power of .61. A simple main effects test was conducted and identified a significant effect ($p = .02$) for individuals in the audio condition reporting higher attention scores than the dyads of the same condition. Table 12 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 12

Confidence

Technology	Grouping	N	Mean	*SD*
Audio	Individual	21	4.29	.57
	Dyad	20	3.88	.60
Video	Individual	21	3.98	.63
	Dyad	20	4.19	.40
AR	Individual	20	4.32	.52
	Dyad	20	4.23	.53

Satisfaction. No significant main effects were found for technology $F(2, 116) = .257$, $MSE = .34$, $p = .774$, $\eta p^2 = .004$, with an observed power of .09. No significant main effects were found for grouping $F(1, 116) = 1.05$, $p = .308$, $\eta p^2 = .009$, with an observed power of .174. A significant effect was found for the interaction of technology and grouping $F(2, 116) = 3.92$, $p = .023$, $\eta p^2 = .063$, with an observed power of .7. A simple main effects test was conducted and identified a significant effect ($p = .008$) for individuals in the audio condition reporting higher attention scores than the dyads of the same condition. Table 13 shows sample size, mean, standard deviation, and adjusted means for the dependent variable.

Table 13

Satisfaction

Technology	Grouping	N	Mean	*SD*
Audio	Individual	21	4.40	.58
	Dyad	20	3.90	.57
Video	Individual	21	4.08	.71
	Dyad	20	4.30	.36
AR	Individual	20	4.27	.64
	Dyad	20	4.22	.58

Learning Activity Duration

A two-way ANOVA was used to compare the effect of technology and grouping on participants' total time for completing the learning activity as measured from the completion of the pre-activity response to the beginning of the post-activity response. The research purpose for this test comes from the potential value of art novices spending more time observing and discussing works of art.

Within groupings, dyads predictably spent significantly more time in the learning activity than individuals, $F(1, 116) = 194.68$, $MSE = 26.85$, $p < .001$, $\eta p^2 = .63$, with an observed power of 1.00. This is presumably due to the nature of the audio narrated dyad prompts to discuss each participant's response to the reflective prompts as opposed to the individuals who simply considered the prompts and thought to themselves. A significant effect was also found between technologies $F(2, 116) = 6.40$, $p = .002$, $\eta p^2 = .01$, with an observed power of .90. In a pair-wise comparison, AR was significantly higher than audio ($p = .001$) and video ($p = .03$). Table 14 shows sample size, mean, and standard deviation for the dependent variable.

Table 14

Learning Activity Duration

Technology	Grouping	N	Mean	*SD*
Audio	Individual	21	34.60	3.11
	Dyad	20	47.84	6.46
Video	Individual	21	35.75	2.82
	Dyad	20	49.85	7.00

AR	Individual	20	39.33	3.59
	Dyad	20	51.28	6.47

Chapter 4: Discussion

The present study did not show statistically significant effects between the independent variables of technology (audio, video, AR) and grouping (individuals and dyads) on the dependent variables of learning outcome (scored from participant's spoken response to a painting reproduction) and motivation (sum score of reduced IMMS survey). While there was no significant interaction for technology, one was found for grouping. A simple main effects test was conducted and identified a significant effect for individuals in the audio condition relative to dyads with the former reporting higher motivation scores.

Additional tests were conducted to further explore the subscales of the art viewing rubric and the total time spent in the learning activity. Each of these tests found significant differences in the AR conditions, specifically, higher response scores for the Elements of Design subscale and longer time spent in the learning activity. The research questions and the additional investigations are discussed in detail below.

Research Question 1

How does AR technology affect learner outcomes relative to other technologies and across groupings in a cognitive modeling learning experience?

Participants in the present study completed a learning activity that included viewing high-resolution and to-scale reproductions of Johannes Vermeer paintings while listening to audio recordings of two art experts discussing the real life versions of the paintings. Each of the four conversations (one per painting) in the learning activity, were bookended by a narrator who provided an opening prompt and a concluding reflective

prompt. Each participant heard the same audio files. The one exception was that individuals were prompted to *think about* or *consider* while the dyads were prompted to *share* and *discuss* their responses. The identical content and sequence of instruction provided the opportunity to test differences across technologies (audio, video, AR). Pre- and post-activity spoken responses to two other Vermeer reproductions were scored using an art viewing rubric created by the researcher with the guidance of a committee member with expertise in art education.

The goal of the researcher was to observe learning outcome differences between technologies to see how AR compared to other more commonly used technologies: audio and video. Would the visual supports found in the video and AR conditions aid in the viewing and understanding of art or might they instead be a distraction and a hindrance despite being specifically created (and timed) to complement to the expert conversations? Much more to the point, if the visual supports were indeed helpful, would the appearance of these supports directly on the painting via the AR application when seen through the mobile device be even more useful to the participants? Would "seeing what the experts see" help novices to be better viewers of art?

Regarding the groupings, would completing the learning activity with a partner have an effect on how well one might view works of art? The narrator's concluding prompts model, coach, and scaffold techniques and processes used in the expert conversations before encouraging participants to articulate and reflect on what they've experienced with each work of art. Would dyads, because of having someone to directing articulate to and reflect with, show evidence of more comprehensive art viewing skills?

Might they learn from each other and the differing perspectives (Facer et al., 2004; Perry, et al., 2008; Squire, 2010) throughout the learning activity?

Unfortunately, the answer to the aforementioned questions cannot be here answered in the affirmative. The results of the subsequent two-way ANCOVA indicated no significant main effects for technology with rather low observed power. The pretest score (using the art viewing rubric before learning activity) was used as a covariate to account for existing state or art viewing skill (or articulation thereof). While the results are encouraging, the lack of power appears to be a limitation in the execution of the present study. With a 2 x 3 factorial design, the present study would have benefited from sample sizes larger than the 20 or 21 data points. These modest sample sizes were vulnerable to participants' prior knowledge, self-confidence, and several other factors that may have impacted their spoken response after completing a learning activity with a mobile device.

Learning Outcome by Subscales

Rationale for varied subscales. The art viewing rubric was designed to capture a wide variety of possible types of statements art novices might make when discussing what they see in a painting and what they think the painting is about. The researcher aimed to have a comprehensive accounting of these open responses and thus, some subscales seem more or less likely to be impacted by the visual supports of an AR application. For example, the use of AR technology to support comments made by experts may not appear likely to impact whether or not the participant includes information about the artist's life or what movement or period he belonged in. This is a

valid point. However, there is a rationale for including these seemingly unrelated subscales.

The experts include much of this type of information in their conversations and often use features of the painting to help support those views (just as the participants are prompted to do in the pre- and post-activity responses). Seventeenth century Dutch culture might be represented in the form of a map on the wall or in the objects on a table. Vermeer's style may manifest in the domestic scene of the painting (e.g., woman preparing modest meal). Therefore, including varied categories of viewing artwork, even for novices, is appropriate here; particularly for this exploratory study.

Visual Support Tests. The visual supports experienced in the video and AR conditions often included elements of design (line shape, color) which may have had an effect on how those participants viewed the painting reproductions and possibly what they identified in their post-activity responses. This subscale is distinct from the Context and Comparative subscales (artist's life and culture and style and theme, respectively) and Subject Matter (viewing-based people, places, objects, but not highly represented in AR visual supports). Each subscale was analyzed using an ANCOVA with the dependent variable being the subscale's post-activity response score with the pre-activity score as a covariate.

Subject Matter. While any sighted person can view people, place, and illusionist qualities of subject matter, the visual supports of the AR application and video conditions only displayed one example of illusionist qualities ("depth of field" of room in painting 2). Objects were identified in the visual supports, however this was done so in order to emphasize line, color, or shape (i.e., elements of design). Significant main effects were

not found for technology, nor for grouping. Neither was a significant effect found for the interaction of technology and grouping.

Context. Context includes attributes of the artist's life and culture. This is discussed by the experts throughout the learning activity but is not supported by any visual supports of the AR application or video conditions. Significant main effects were not found for technology nor for grouping. Neither was a significant effect found for the interaction of technology and grouping.

Compare Artworks. Compare artworks includes the artist's style and themes like social status, love, or religious devotion. These, too, were discussed by the experts but were not part of the visual supports in the AR application and video conditions. Significant main effects were not found for technology nor for grouping. Neither was a significant effect found for the interaction of technology and grouping.

Design Principles. Design principles include characteristics that encompass the entire painting such as balance, harmony, and focal point. Harmony is only briefly mentioned by the experts and indirectly supported by a single visual supports of the AR application and video conditions. During the design of the art viewing rubric, design principles were identified as complex concepts that went beyond the content provided by the learning activity (and the presumed skills of self-identified novices) and thus were only tallied for the purposes of insight into future research.

Elements of Design. Elements of Design include line, shape, and color. These are discussed by the experts and repeatedly included in the visual supports of the AR application and video conditions. The emphasis on elements of design was due to the alignment of digital functionality of the AR application (annotating, highlighting, side-

by-side comparisons) and the transcripts of the expert conversation. This approach to the instruction design of the visual supports resulted in more instances of lines, shapes, and colors, being visually supported by the AR technology (and consequently of the video condition as well). Below are additional examples of Elements of Design as supported by the AR application (see Figure 3 for Line).

Figure 13. Shape

(2:53 DR. BETH HARRIS: "*And the way that she's very characteristically for Vermeer locked into that space by the rectangle of the window…*"

3:01 DR. STEVEN ZUCKER: "…*Of the map*."

3:02 DR. BETH HARRIS: "…*and the rectangle of the table and the chair behind her*.")

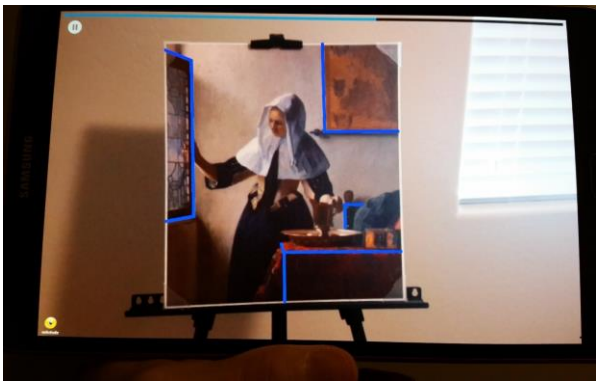
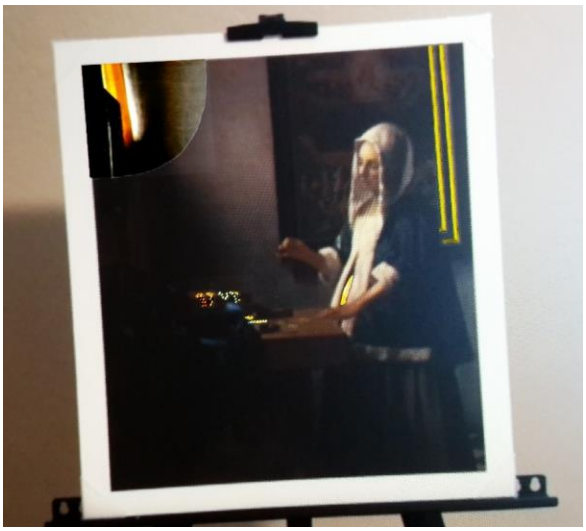


Figure 14. Color

(3:27 DR. STEVEN ZUCKER: "*Look at the way that the gold of the curtain is picked up by the two bars of the frame on the right side and then picked up again by the gold quality of some of the pearls and of her dress*."



A two-way ANCOVA was conducted to compare the effect of technology and grouping on participants' responses related to Elements of Design as measured by the post-activity subscale scores on the art viewing rubric with the pre-activity subscale scores as a covariate. Significant main effects were found for technology. In a pair-wise comparison, AR was significantly higher than audio but not video. No significant main effects were found for grouping. Neither was a significant effect found for the interaction of technology and grouping.

It is worth noting that while still a descriptive response, there is much more sophistication required to identify elements of design that subject matter for example. Most viewers, novices or otherwise, can be expected to identify people, place, and

objects, however the untrained viewer will not likely notice the edge to an object, or implicit shapes and uses of color throughout a work. This added value within the art viewing experience makes the findings below much more important. The example below illustrates the difference in a response before using AR in the learning activity and after. In the following pre-activity response to *The Milkmaid* by Johannes Vermeer, the participant identifies people and objects (subject matter) and color (elements of design).



Participant: "*What I see here, I see a woman, probably pouring milk. I see bread. She's probably lower class and this little brown box, I notice this little brown box. I'm not sure what exactly it is. I think that the painting is just talking about a simple woman, performing a normal meal or getting ready for a meal with their family*."

In the following post-activity response to *The Music Lesson* by Johannes Vermeer, the participant identifies people and objects (subject matter) and multiple, descriptive uses of color (elements of design), and multiple occurrences of shape in the window, chair, and tiles.



Participant: "*Some of the first things that I see here, I see the light coming in off of the white wall. You can see the bright white and you can kind of see the colors start to fade over here. I notice that you see multiple different shapes. Rectangles (gestures to musical instrument), squares (gestures to floor tiles) in the flooring. I notice the cello, the pitcher of wine, maybe water. I notice the sunlight, maybe, reflecting off of it (the pitcher), giving it a different color. I like the bright colors in the rug. I also notice, with the shapes, that the back of the chair is square as well. I think this painting about, maybe someone had passed away. The woman seems to be looking inside of it, the man has a blank expression.*"

The significant finding for Elements of Design indicate that AR technology can better support the cognitive modeling of observational techniques than audio alone. The digital highlighting, in particular, seems to have had an impact on the ability for

participants to remember the lines, shapes, and colors of the paintings from the learning activity and apply them to the additional painting in their post-activity observations. While there was no significant difference between video and AR (the latter being slightly higher), the findings above still have value and perhaps in future studies, any differences between video-based visual supports and AR visual supports can be further examined.

There is always the possibility that the participants simply remembered the lines, shapes, and colors from their experience with the application. Additionally, this subscale might be easier for the novice to understand and immediately apply to their post-activity response. Multiple participants told the researcher that they were surprised that lines, shapes, and colors held so much meaning in art. This revelation, and its inherent simplicity (when prompted, most people could presumably see squares, intersecting lines, and shifts in color) might play a role in this effect.

But these results might also be evidence that spatial contiguity—that the lines, shapes, and colors where displayed directly on the paintings—played a role in the higher scores. This would be most interesting for future work, particularly in an art viewing sense where the AR visual supports specifically focus on elements of design in different types of artworks (e.g., abstract art). This could also be useful in classification exercises like those found in the life sciences. The identification of plants by their physical qualities and surroundings could be well supported by AR technology for example. This would certainly be an area for additional focus in future research.

Research Question 2

How does AR technology affect motivation relative to other technologies and across groupings in a cognitive modeling learning experience?

The goal of this research question was to build upon any learning outcome differences with motivational aspects of using AR technology to view works of art as an individual and with a partner. Motivation is important to learning, including in AR learning environments (Bujak et al., 2013; Chang et al., 2014; Liu & Chu, 2010), and art novices in particular might benefit from additional relevance or other attributes of motivation due to the support of different technologies. Viewing art in the real world also usually includes multiple people (Falk, 2009, Falk & Dierking, 2000) so motivation across groupings certainly warranted consideration.

AR technology having an effect on motivation, particularly in a single hour-long instance might appear ambitious. However, given four opportunities to view the painting reproductions while listening to the experts' conversation, participants in the AR conditions may have experienced changing levels of attention (e.g., "I can see what the experts see. Neat."), relevance (e.g., "I can relate to ideas represented in these paintings."), confidence (e.g., "The experts just talk about what they see and then try to figure out the meaning of the painting. I can do that."), and satisfaction ("Viewing art isn't that hard. I think I could do it again next time I go to a museum.") compared to the audio and video conditions. (Anecdotally, at least 10 separate people specifically stated to the researcher that they did, in fact, feel more confident in viewing art and felt like they could go to a local art museum and "know what to do" with the paintings. Many more

asked if the researcher recommended any art museums in town (Phoenix metropolitan area).

The motivational factors mentioned above could also be connected to the groupings. The opportunity to share views and insights with another art novice, nearly risk-free (participants were not being recorded during the learning activity) might have given them the chance to feel comfortable having opinions about art in general and the given reproductions in particular. The narrator prompts were designed to begin with simple tasks (e.g., sharing how one's gaze moved across the painting and comparing with your partner) before moving to more complex tasks (discussing possible meanings of a mirror using features of the painting to support one's view). This was intended to be interesting and challenging but also low stakes so the partners might learn from one another and thus be more motivated to view and think about art.

A subsequent ANCOVA test was conducted with the IMMS survey sum scores as the dependent variable, with total time spent in the learning activity as a covariate. This covariate was used to account for any impact due to simply spending more time in the learning activity might cause. Simply being exposed to the works of art and the technologies for a longer period of time could have affected attention, relevance, confidence, and/or satisfaction. The test, however, found no significant main effects for technology, nor for grouping. Once again, the sample size was quite low and resulted in very low observed power.

Another factor may have been the scores themselves. Described in more detail below, the learning activity was very well received. Many of the participants remained after they were dismissed to ask questions about the paintings, Vermeer, AR technology,

and to share what they liked about the experience. The learning activity purposely avoided traditional classroom activities like written questions and instead required participants to move around a space as if they were in an actual art gallery. Participants could walk right up to very detailed reproductions that were also sized to the exact dimensions of the real paintings the experts saw when they recorded their conversations (participants were made aware of these facts in the directions to the learning activity). This was intended to provide a level of authenticity to the learning experience (Bransford et al., 1999; Dede, 2014; Herrington & Oliver, 1995) and it may have played a part to the positive response.

AR had higher average scores than audio and video but in a survey with a maximum score of 60 (12 questions scored on a five-point scale) all scores were quite high with average score of more than four out of five per item. Participants may have genuinely enjoyed the activity, possibly despite any apprehensions about learning about art as self-identified art notices. The high scores could also be a result of the researcher being a PhD student and the study being for a PhD dissertation. Participants may have scored the activity very high to "help" the lone student running a study well into the evening and on weekends. (The researcher consistently expressed to each participant to answer the survey questions as honest as possible and not to worry about offending anyone or hurting anyone's feelings.) This "help" factor might be mitigated in future studies by taking a more longitudinal approach. Participant sympathy, for lack of a better term, would be difficult to maintain after days or weeks of learning activities.

Interestingly, individuals rated the activity slightly higher than dyads. Should this trend have continued with a larger sample size, possible explanations would include the

assigning of partners resulting in strangers meeting for the first time in a PhD study where they have to discuss art together and thus are distracted or less comfortable during the learning activity and/or using the technology. It may also be a result of the single instance of the test. Of course, it may also be that discussing art with others does not immediately impact motivation, and perhaps people have to develop a rapport before sharing their views and as a consequence feeling more confident about their knowledge and skills and the relevance of the art.

Learning Activity Duration

While the subscale investigations align to the learning outcome dependent variable, the question of how long participants spent in the learning activity is tied to motivation as a dependent variable. Total time for completing the learning activity was measured from the completion of the pre-activity response to the beginning of the post-activity response. (The AR conditions required a three to four minute tutorial and therefore times for participants in those conditions were reduced by five minutes.) The research purpose for this examination came from the potential value of art novices spending more time observing and discussing works of art.

The learning activity included viewing four painting reproductions while listening to audio recordings of two experts having a conversation in front of the actual real life paintings. The conversations were bookended with an opening and concluding prompt by a narrator resulting in around 25 minutes' worth of content (add a total of 30 seconds for dyads due to additional text in the prompts). All participants were required to move through the same spaces and view the paintings in the same sequence and

consider/discuss the same questions and prompts. Thus the question, given that dyads will likely spend longer in the learning activity, is there a difference between technologies?

A two-way ANOVA was used to compare the effect of technology and grouping on participants' total time for completing the learning activity. Predictably, within groupings, dyads spent significantly more time in the learning activity than individuals. Again, this is presumably due to the nature of the dyad prompts to discuss and compare views while the individuals simply considered the prompts and thought to themselves. More interestingly, a significant effect was also found among technologies. In a pair-wise comparison, AR was significantly higher than audio and video.

Much more data would be required to truly understand this phenomenon (follow-up interviews, versions of the study that *did* record the discussions, etc.) but perhaps seeing the digital annotation, highlighting, and side-by-side comparisons of the AR technology provided more points of reference to think about and discuss. One can appreciate, for example, that seeing the rectangles of the window, the map, and the chair highlighted in bright blue as they are being identified by the experts who are talking about "a sense of controlled composition," can encourage one to spend more time viewing and deconstructing the paintings. The visual cues of the AR application were much more than the spoken word or even a highlighted image on a tablet screen (i.e. video condition). Through the mobile device, they appeared on the paintings themselves in exact and distinct ways to emphasize features of the painting. Seeing the "rectilinear lines" of floor tiles in a painting illuminate *should* be a different experience from simply hearing the words spoken while viewing said lines in the painting (Chandler & Sweller,

1992; Mayer & Moreno, 2002). Whatever caused the participants in the AR conditions to spend significantly more time in the learning activity, it is a positive starting point to exploring AR as an effective technology for learning even if the result is as simple as novices choosing to observe artworks and engage with and peers longer than other more common forms of media.

Research Question 3

Is there an interaction between the type of technology to support cognitive modeling and whether learners work alone or with a partner?

The goal of testing for interactions between the technologies and the groupings was to rule out any specific case(s) where learner outcomes and motivation may have held a significant effect. Regarding learner outcomes, there was no significant effect for the interaction of technology and grouping factors but there was a significant effect with motivation. A simple main effects test was conducted and identified a significant effect for individuals in the audio condition relative to dyads with the former reporting higher motivation scores. Additionally, this interaction between individuals in the audio condition and the dyads of the same condition was evident across the motivational subscales as well (i.e. attention, relevance, confidence, satisfaction).

The cause of this narrow interaction might be found in the user experience. Playing an MP3 (with cover art matching each painting) and listening to experts discuss a picture in front of you, with no one else around, might be the least stressful of all the conditions in this study. People who have been to a museum know about “audio guides” and this condition most closely resembles that experience. The directions for this activity

are typically very simple: “Press play, listen and learn.” The simplicity of that experience may play a role here and comes as no surprise. There is likely an advantage to using a technology in a way one has hundreds or thousands of times before (i.e., walking around listening to people talk; audiobooks, audio editions of news outlets, podcasts, etc.) especially when compared to the facedown use case of watching a video and anticipating haptic responses that trigger digital information that appears on real world objects. Lastly, given the modest sample size, the present study is vulnerable to existing levels of enthusiasm from the participants. They may have simply been more excited to be involved in the study, to view art in the manner in which the study was designed, or just in what they learned from the expert conversations about the paintings themselves.

General Discussion

There are multiple studies that compare AR to other technologies (Radu, 2014) and even some within art education, however very few use AR technology to make visible the thought processes and observational techniques of experts as they perform complex tasks (Bacca, 2014). The digital information provided by the AR application was intended to support authentic expert performances for the learning benefit of self-identified novices. There was no lecture format nor a “teacher-voice” present here. Just a semi-structured conversation between two art experts as the might do on any given day.

This is different from using AR technology as a “trigger” to access online content (like a complex hyperlink) and it is different from a simple presentation of materials in a traditional classroom lecture-style manner. Though the functionalities are similar (annotations, highlighting, side-by-side comparisons), the application of them within the

natural context is where the value is held. Imagine being able to use a mobile device to look at a building and see what an architect sees. The novice might see the general shape, the many floors and the color but AR might be able to show the flow of pedestrian traffic, the lighting at any given time of day or season, and even the mathematical properties that dictate the size and shape of an overhang. This is quite a different learning experience from reading about those principles in a textbook or video. The situativity of the learning experience, plus the processes and strategies of the experts is enhanced by the AR technology that not only allows the learner to be in the real world context but to *see* that information tied directly to the real world context.

Real world art setting. A learning experiences where both the digital information and the real world object(s) are valued is an important part of this study. Google Art Project allows users to view very high-resolution images of thousands of works of art from around the world. Users can zoom in and pan in all directions. Users can even compare similar and influential works easily. The value presented here is more than being able to print life size images and display on easels (in itself potentially valuable to learning), it is in the way the AR application *augments reality*. It takes this somewhat natural setting, paintings shown in a gallery, and adds the audio narration of experts doing what they do (viewing and discussing art) and then adds digital information to appear as though it is directly onto the objects in the environment. Though seemingly rudimentary, this spatial and temporal contiguity is unique in learning and potentially a fertile area for traditional and informal learning alike. Imagine walking through a local park where a life science learner uses an AR application to listen to a botanist narrating her way through a similar area. The visual supports here might be taxonomical

information (class, order, family, genus, etc.) or comparative information (plant at different altitudes, points within life cycle, or contrasted with the non-edible version). This type of learning experience would be very interesting to explore across learning outcomes, motivation, or any other learning-related measure.

Study environment. Participants were recruited from introductory art classes, undergraduate courses in computer science, from student listservs, and by classmates, friends, and family. Of the 182 participants, 79% (144) participated for extra credit (44% (80) from introductory art courses and 34% (64) from computer science courses) while the remaining 21% (38) participants received a $10 Amazon gift card for their participation.

Participants were informed that their participation would take between 45 and 60 minutes in the intake form, the online schedule signup sheet, the consent form they signed upon arrival, and by the researcher at the beginning of the study. With the exception of one or two, all participants were patient and polite and in no hurry. Instructions were received and each instance of the study began quite smoothly with very few questions. The few questions participants did have were often about the lack of written test and to confirm that they were to simply view art using technology and (when applicable) discuss their thoughts with a partner. The researcher would then confirm and they would begin.

Much of the testing was conducted on weekday evenings and weekend afternoons (i.e., after traditional class hours) allowing for privacy and quiet for participants. The researcher would sit at either the far end of the conference room or just outside the door

(depending on which location the testing occurred). Participants were told they could ask questions at any time and to take as much time as they needed.

Participant enthusiasm. From the first week of the study, participants nearly always stayed after their scheduled time to ask questions of the researcher. This occurred after the post-activity response and the completion of the IMMS survey, of course. Participants asked about the paintings (e.g., "What do *you* think the mirror means?") and about the artist (e.g., "How did he paint a 'white wall with no white in it'?"). They asked where the nearest Vermeer was (New York, Washington, DC) if the researcher had ever seen any in real life (yes, in Amsterdam).

Both individual and dyad participants remained to go over the pre- and post-activity paintings, asking about their meaning and where they fit, chronologically, with those of the learning activity. They also shared which were their favorites and what they liked about each. Many also asked if the researcher could recommend a local art museum. (The researcher recommended ASU's art museum on campus and the Phoenix Art Museum downtown as ones likely to have paintings and free entry on select days.) Instances of remaining after the test caused the researcher to adjust the scheduling to 90 minute timeslots from 60 minutes at the beginning of the study. These unplanned but enthusiastic occurrences continued throughout the study despite late evening hours and weekend trips to campus to participate.

Possible explanations to this phenomenon include the paintings and artist selected, viewing art as an experience, and the instructional design of the learning activity.

Paintings and Artist Selected. The works of Johannes Vermeer are well suited for the present study because they are often found in introductory art courses, especially of western art. They also contain relatively simple and accessible subject matter that novices might more easily recognize and be less intimidated by (i.e., a woman holding a pitcher, a man painting a picture).

The accessible nature of these works may have allowed participants to lower any inhibitions and feel comfortable observing the features of the paintings and thus ask the researcher more questions about them. The works also appear quite realistic and participants often wanted to discuss how Vermeer achieved the related technical skills to paint the way he did. In the short background provided by the researcher, participants learned that very little is known about Vermeer and only around thirty paintings are attributed to him. This may have piqued interest in the artist and his works as well. Participants may have simply enjoyed these paintings as so many before them have in museums around the world.

Viewing art as an experience. Participants may have enjoyed viewing art, albeit somewhat artificially, for the experience itself. The study was presented in a gallery-like setting where participants listened to experts discuss the works they themselves were walking right up to and observing. The reproductions were very detailed, showing variations of color and even the very small cracks in the original works. They were printed to the exact dimensions of the originals as well. The goal of this environment and level of detail was to create a more authentic experience for all conditions including a social and physical context (Bransford et al. 1999). Participants were in a low stakes learning experience (e.g., no dates of places to memorize, no quizzes, no recordings) with

another self-identified art novice. This allowed them to simply think about what the art experts said, and reflect with their own views. None of which would be deemed "wrong" by anyone else, even if they disagreed. The learning activity for the present study may have provided enough scaffolding (i.e., explicit directions, repeated sequence of instruction for each painting, technology support) for them to have a positive experience viewing art.

Instructional design of the learning activity. Much thought and consideration went into the design of the learning activity; both for the integrity of the study and for the experience of the participants. The researcher aimed to create a learning experience that was focused on the thought processes and observational techniques of the experts for the learning benefit of the novices. This meant distilling the act of viewing as much as possible. Standing in a room, looking at art while listening to experts and using technology to "see what they see." That removed the need for taking notes, for answering multiple choice questions, and a host of other typical learning tasks. Taking into account potential attributes of art novices such as lower interest levels, prior knowledge, and relevance, the learning activity had to give them an opportunity to observe experts and follow the cognitive apprenticeship model. For example, once the experts modeled how they view and talk about art, participants were prompted to compare their first impressions with those of the experts (coaching). They proceeded to the next painting where experts provide more modeling examples and participants were then prompted to observe (and discuss, if partner present) as they had seen the experts do (scaffolding). As the activity progresses, participants articulated and reflected on not only the modeling of the experts but on their own experiences and that of their partners. Perhaps the post-study

questioning was evidence that the participants were prepared to attempt *exploration* and continue to apply their new skills and experiences; specifically, those in the dyad conditions who had already been discussing each painting throughout the learning activity.

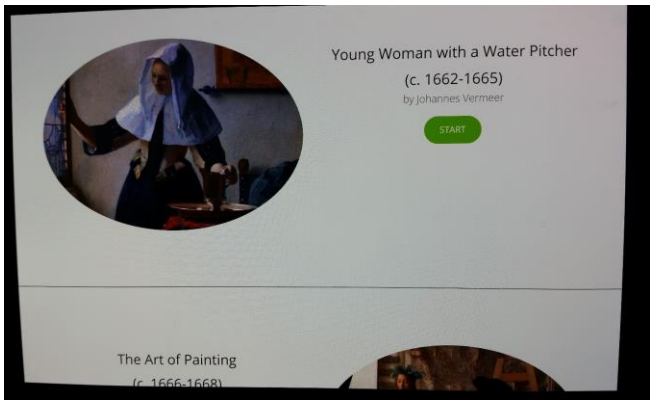
Interestingly, no less than five sets of dyads asked the researcher if they were required to speak English during the learning activity. It is the opinion of the researcher that each of these participants was quite fluent in English outside of the learning activity so perhaps they took the activity seriously and wanted to be able to express their views in their first language. (Perhaps they wanted to make sure the researcher wasn't listening.) This also highlights implications for future research as some participants were likely non-native English speakers which may have had some effect on their ability or confidence in listening to audio recordings, with no text supplement provided, of art educators discussing works of art. Future research efforts should account for this even if only in for the form of a survey item indicating first language. The present study did include text versions of each post-activity prompt as they were spoken by the narrator (and remained on screen for participants to reference), however, given the dynamic nature of audio and visual elements in a nearly text-free environment there is cause for considering the role of language in this type of learning experience.

The factors above are all potential departure points for future work in art education and in AR research. Maintaining a focus on the learning goals and setting the experience in an authentic manner appears to be especially important for novices and for using technology to learn from expert performances.

Using AR technology. The present study explores the use of augmented reality to support cognitive modeling in art education. As in previous studies usability is a very important factor upon which all else is determined (as evident in the design research of Klopfer & Squire, 2008). If the participants can't access and use the AR application as intended, they will not be able to experience the expert performances and the visual supports.

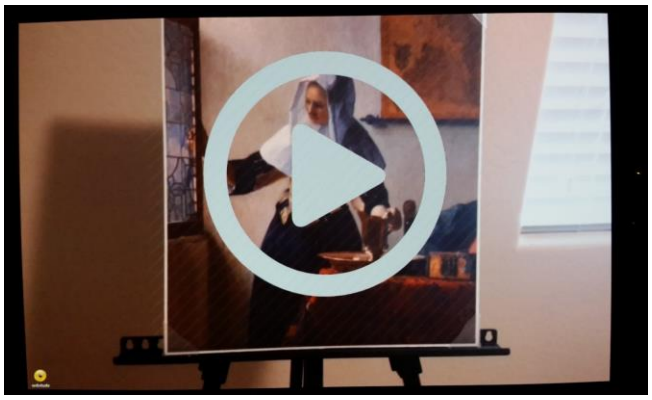
Interaction design experience. Within the application participants needed to know when to view the painting directly (i.e., not through the tablet) and when to lift the device into their gaze in order to see the digital enhancements in the screen of the device. This prompting needed to be as seamless as possible in order to limit extraneous cognitive load while maintaining focus on viewing the paintings while listening to the audio recordings of the experts. Additionally, not being able to use an application would likely cause frustration and confusion. The application was designed with these issues in mind. The user interface (UI) was a simple scrolling menu of the four paintings covered in the learning activity.

Figure 15. AR Application User Interface



Participants would tap on the image of the painting they were standing in front of, aim the camera, and tap the “Play” button that appeared.

Figure 16. AR Application



Once the audio began the screen turned black with a small prompt to “View the painting directly.” Participants were instructed to never view a black screen and to view the painting directly whenever a black screen appeared. As the audio of the experts played in their headphones, participants would view the painting while holding the device. When it was time for the application to be used the device would vibrate for approximately one second. With this vibration, the screen would turn from black to a “camera view,” displaying whatever the camera viewed, including the painting. The participant would have approximately three seconds to lift the device into their gaze before the digital information would appear. When the visual supports were complete the device would vibrate twice indicating that the device can now be lowered.

Haptic response replaced a chime sound effect in earlier iterations of the application. During pilot testing users either missed the chime completely or where

unsure if they had heard it which resulted in them asking the researcher or their partner. This resulted in missing the content of the experience and was determined to be too much of a distraction. The implementation of haptic response solved this problem.

Using a mobile device with haptic response was a result of limited processing power and functionality of most hands-free wearable technologies. Ideally, the participants would have simply worn multi-camera glasses that were able to render the digital information while tracking eye movement to ensure accuracy and overall effect. The wearable technology would have recognized paintings and played the audio as soon as they came into the viewer's gaze. Instead, tablet computers, devices most if not all of the participants had used before, were used in a manner which was also familiar–aiming the device to view an object through the camera. Wearable, hands-free technology is high among the topics of future research in AR technology.

Tutorial. In preparation for using the application, participants completed a tutorial that walked them through two sequences of feeling the vibration, lifting the device, viewing the digital information, feeling the double vibration, and lowering the device. Participants appeared very comfortable with his sequence and rarely had any usage questions. Confidence in interacting with the device and the technology was vital to the learning experience. The application had very strong image recognition capabilities which kept the digital annotations, highlights, and side-by-side comparisons rendering in the exact places they were intended despite the viewing height or angle. In short, the digital information looked the way it was designed to look for each participant in an AR condition.

Contributions

The goal of the present study was to find evidence that AR technology could support learning in a cognitive modeling environment. Accordingly, the primary contribution of the present study is in the differences found between AR and audio-only conditions as participants viewed the paintings. Those in the AR conditions scored significantly higher in elements of design, the category most represented by the digital supports. An additional contribution is the use of AR as mechanism for making visible the thought processes and observational techniques of experts for the learning benefit of novices. This is a departure from more common uses of AR to delivery information and (Bacca, 2014) by timing the digital information with the running audio of the expert conversations.

AR for viewing Elements of Design. When comparing the Elements of Design (line, shape, color) subscale scores across technologies, AR was shown to be significantly higher than audio alone. The ability to see the lines, shapes, and colors, highlighted directly on the paintings (via the mobile device) resulted in higher scores than listening to the audio of the experts alone. When participants saw digital representations of line, shape, and color appear directly on the paintings, they were more likely to identify those same features in the post-activity painting.

Seeing what the experts see, in a situated environment, resulted in evidence that participants began to view paintings in the manner the experts did, supporting similar findings from studies like Liu and Pedersen (2002). This has implications for educators everywhere who find value in using technology to support cognitive modeling and any apprenticeship or expert performance-based learning environment. The ability for novices

to experience real world objects and environments like experts do (given proper scaffolding and instructional design) is a contribution of this study.

AR for real time cognitive modeling. The present study created an experience where a novice learner was observing expert performances using AR technology in real time as the performance was taking place. The annotations, highlighting, and side-by-side comparisons appeared on the device at precise times in order to directly support the expert performances. The participants only saw the visual supports when they were meant to.

In many AR studies, AR is used as a tool to receive additional information, to complete a specific task, or engage in a scenario as determined by the teacher or professional. The present study instead directs the AR technology towards authentic expert performances (i.e., not scripted) in context as they occur. The use of AR technology to represent how a task is done, specifically, modeling expert thought processes and observational techniques, has not be examined thoroughly (Bacca, 2014) and requires more consideration.

Art education. Art educators may find value in the ability to help novices develop art viewing skills and the present study shows one example of AR having an impact on those skills relative to audio (or perhaps lecture) alone. AR technology as used may also aid in more sophisticated concepts like comparative works. Displaying of a digital version of Diego Velázquez's *Las Meninas* as the experts were comparing it to Vermeer's *The Art of Painting* (painting two in learning activity) was an example of how viewing and understanding art, particular outside of the classroom, could be enhanced by AR technology. There are many learning opportunities for an art educator who has the

ability to annotate, highlight, and provide side-by-side comparisons of art in support of lectures or the expert conversations used in this study.

Limitations

Statistical power. In order to compare technologies (audio-only, video, AR) across groupings (individuals, dyads), the present study had a 2 x 3 factorial design with 182 participants, analyzed as 122 data points, divided among the six conditions. This resulted in a relatively small sample size in each condition and thus statistical power was a limitation of this study. Despite higher AR means for learning outcome, there was no significant effect. With larger sample sizes an effect may have been found.

Early in the design process the issue of power was present, particularly with the inclusion of dyads and the resulting doubling to six conditions. Despite the risk of lacking power, the use of dyads in the present study was crucial to representing a typical art viewing experience and was integral to fully implementing a cognitive apprenticeship model for the learning activity. In order to have the opportunity to articulate and reflect with peers, partners were required. However, in future studies this may not be the case and researchers can focus on technology comparisons or other learning scenarios more directly.

Single testing event. All data for the present study was gathered in a single testing event. Participants arrived at a designated location at a scheduled time and within ninety minutes, the experience was complete. This gave participants only one chance to focus their attention to the task at hand, follow directions, and view and discuss art while interacting with a mobile device. This is logical for the dynamics of a single study but

there is potentially more to be understood from any longitudinal approach whether in a traditional classroom or an informal setting. It would be interesting to see if learning about different artists and types of art would differ between technology types and grouping. Perhaps the relevance and confidence aspects of motivation would continue to rise, at least temporarily, with a stronger knowledge base participants might build by learning to view art in this manner every week for example.

Artwork selection. The rationale for the selections of the artworks for the present study were given above but this too may have been a limiting factor. Some participants may have simply disliked or not understood the works. They may not have recognized the artist or might have had a stronger interest in different types of art like sculpture, photography, or tapestry. Despite considerations taken by the researcher to select art that minimizes cultural prior knowledge, seventeenth-century Dutch art is still western, and has Christian cultural contexts and constructs. Participants likely had very different reactions to the content of the art given the diversity of ethnicities and fields of study included in this study. The selection of artwork would be of particular interest to art and museum educators.

Future Research

As an exploration into using augmented reality for cognitive modeling there are several directions to consider. Within the structure of the present study, researchers may wish to use different types of art with participants whether they be university students or not (typical adult museum-goers, for example). The frequency and design of the digital information provided by the AR application to be manipulated to see when and why there

is a desired effect. (This, of course, would be better supported with larger sample sizes to avoid similar statistical power limitations.) Beyond these design adjustments there are three main areas the researcher believes would be of particular interest to future researchers: a more social and/or collaborative learning experience, a more longitudinal approach, and continued leveraging of technological affordances.

Collaborative learning. Whether viewing works of art or not, AR, like other learning experiences, can often be enhanced by providing learners opportunities to work together and learn together (Li et al, 2011; Lou, 2004; Lou et al., 2001; Weinberger et al., 2010). Learners can learn from each other by giving and receiving feedback, from creating and sharing content and ideas with others and this is a natural fit with AR.

As the present study demonstrated, AR technology can make visible the invisible thought processes and observational techniques of experts. It stands to reason that the technology should also be able to allow users to interact with that information, and provide their own, for the benefit of themselves and their peers. Depending on the learning goals, this might include adding comments and questions to features of the painting or to the digital information. For example, users could attach digital versions of paintings they have seen before to the side-by-side comparison provided by the AR application to ask or answer a question (e.g., adding Norman Rockwell's *Triple Self-Portrait* to Velazquez's *Las Meninas* when it is compared to Vermeer's *The Art of Painting* in the current learning activity). Learners might also benefit from being able to virtually communicate with others and share ideas and strategies (Lou, 2004) and experiences in real time via the AR application (as opposed to an assigned, face to face partner). Having a more flexible and creative voice for art viewers combined with a

larger network of peers may impact levels of motivation and even learner outcomes as they hear/see examples from peers.

The learning task could also be redesigned to give the partners and/or peer groups specific collaborative tasks that more closely resemble constructivist approaches and the demand for complex, authentic, learning experiences (Dede, 2014; Dunleavy & Dede, 2013). As AR allows the pairing of any digital information to any real world object and location then the idea of multiple learners as content creators in an AR experience warrants attention. Additionally, a system could pair participants according to specific proficiencies (viewing skills, art background, communication skills, etc.) as is found in intelligent tutoring systems and computer-supported collaborative environments (CSCL) (Stahl, Koschmann, & Suthers, 2014). This would allow participants to exercise strengths and work on weaknesses with the help of other novices or even their instructor or other experts depending on the learning task. Collaborative instructional design and functionality considerations could bring AR technology into the educational research space of video and other multimedia learning tools and experiences and build on the existing collaborative work like that of Squire and Klopfer (2007), Rosenbaum et al. (2007), and Kamarainen et al. (2013).

Longitudinal approach. The present study tested individuals and dyads across technologies in a single learning activity. This learning activity lasted between thirty and ninety minutes depending on time the participants took to observe, consider, and discuss the paintings. This is narrow view into the potential of AR to affect motivation and learner outcomes. Taking a longitudinal approach to this exact study design may be a worthwhile endeavor. Observing cognitive modeling over time would allow the

researcher to more comprehensively track specific instances of learning and motivational elements over the course of multiple iterations. From a series of three weekly learning activities (e.g., bookending the Vermeer paintings of the present study with Rembrandt van Rijn and Jan Steen) to a complete semester's worth of western artists, responses to prompts and accounting of motivational levels would be very interesting as participants become more comfortable (or bored) with the discipline and with the AR technology. Observing the use of AR over time also complements the above suggestion of collaborative learning opportunities. The dynamics of novices working together to learn from expert performances would be a very interesting next step in understanding the value of AR technology in learning environments.

Technological affordances. As a relatively new technology to educational settings (Bujak et al., 2013; Chen & Tsai, 2012; Martin et al., 2011; Wu et al., 2013), AR technology continues to develop. Future research in AR technology will almost certainly be impacted by the continued growth of software capabilities and processing power of devices (Feng et al., 2008, Martin et al., 2011; Squire & Klopfer, 2007). Software may soon allow for collaboration in AR environments and for shareable user-created content. Hardware advances such as Microsoft's HoloLens, a headset that can not only display 3D digital information ("holograms") but can do so while recognizing the physical environment. For example, a digital person can appear seated on a real world chair beside the user. Similar to HoloLens, the Meta 2 headset allows the user to control the 3D digital content using their hands such as building a pyramid of digital blocks on a real world table.

These technological affordances could be applied to the life sciences and architectural-based mathematics examples mentioned above and to a myriad of other disciplines and learning experiences. Visitors to world heritage sites could see how ancient temples were built and even "walk inside" to see how they were decorated. Students could see the effects of climate change in the past, present, and future on a trip to the shore or to the nearest park. Construction management students could collaborate to design commercial properties by digitally populating construction sites, to code, as a precursor to actual builds. AR can provide learners opportunities to access and manipulate digital information as they observe, inquire, and participate in real world environments (Dede, 2014) while also supporting the need for authentic social and physical contexts (Bransford et al., 1999).

These types of devices, with ever-growing supporting software will create more opportunities to make the invisible visible and to create digital information in authentic ways for learners to access, manipulate, and create with. Educators and educational researchers should build on the principles found in the present study and find ways in which the affordances of AR technology can help create effective, efficient, and enjoyable learning experiences.

Cognitive Load. The present study accounted for issues of cognitive load throughout the process of designing the learning experience as well as designing the AR application. Extraneous information and additional steps were mitigated as much as possible to ensure the participants could quickly acclimate the to the technology and proceed with the tasks given in the study. Future studies may choose to extend this consideration to the point of including a measure of cognitive load. This would be helpful

in further comparing the technologies in particular to have some measurement, either self-report or a more sophisticated form of tracking attention and such as eye-tracking or utilizing neurological engagement devices. These measures would help researchers and educators locate situations within a learning experience that are causing issues with cognitive load and give them the opportunity to resolve them effectively.

Conclusion

The present study demonstrated that AR technology in a cognitive modeling learning environment resulted in statistically higher learner outcomes of elements of design, the specific types of visual supports provided by the AR application to support the thought processes and observational techniques used by the experts. Participants who used the AR technology also spent a statistically significant more amount of time in a learning activity that intended to encourage viewing, considering, and discussing works of art. Despite a lack of effect found for overall learning outcome and motivation, the results of the present study suggest potential for AR technology to be an effective tool for cognitive modeling and other authentic learning environments.

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APPENDIX A

STUDY RECRUITMENT SURVEY

Thank you for your interest in our study. Please complete the following questionnaire.

BASICS

1. First and Last Name
2. Email
3. How did you hear about this study?
4. Name of your instructor for that course.
5. This study includes viewing art, listening to an audio recording, and holding a mobile device. Do you require any assistance to complete any of these tasks?
6. What times work best for you to participate in this study?

DEMOGRAPHICS

7. Gender
8. Age
9. Which of the following best describes your ethnicity?
10. What is the highest level of education you have completed?
11. What is your major(s)?

TECHNOLOGY USE AND ART EXPERTISE

12. Which of the following devices do you have regular access to?
13. Which of the following types of application do you use regularly on any of the devices above?
14. How many times do you estimate you have visited an art museum in the past five years?
15. Which category best describes your level of expertise in art?

PARTICIPATE WITH A FRIEND

16. Do you have a friend, family member, spouse, or classmate that might be interested in participating in this study with you?
17. Partner's Name and email address:
18. Email address of anyone else you think might be interested in participating in this study:

(NOTICE OF VIDEO RECORDING)

APPENDIX B

PARTICIPANT CONSENT FORM

Participation is voluntary. Participants must be 18 years or older to participate.

Title of research study: Exploring Cognitive Modeling in Art Education

Investigator: *Dr. Bob Atkinson, Dan Shapera*

Why am I being invited to take part in a research study?

We invite you to take part in a research study because we are seeking art novices.

Why is this research being done?

We are exploring the role technology has on making art more accessible and enjoyable to novices like you.

How long will the research last?

We expect that individuals will spend 45-60 minutes participating in the proposed activities.

How many people will be studied?

We expect about 300 people will participate in this research study**.**

What happens if I say yes, I want to be in this research?

Self-identified art novices (i.e., non-experts) who are willing to participate in this study will complete a learning activity where technology is used to support learning about art. No lectures, no quizzes, no deskwork. Just you, a mobile device and a small gallery of paintings for 45 minutes to 1 hour.

Participants will be compensated for their time with a $10 gift card provided by the student researcher. The student researcher will provide the funds for the compensation.

You are free to decide whether you wish to participate in this study. Instead of being in this research study, your choices may include simply referring others to this effort.

What happens if I say yes, but I change my mind later?

You can leave the research at any time it will not be held against you.

Are there any risks?

The study is aimed at self-identified art novices and there are no "wrong" answers so there are no risks involved. The one clarification, captured in the intake form, is the requirement for participants to be able to physically view art and to hold a tablet computer for up to 60 seconds in one of the study conditions.

Will being in this study help me in any way?

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits include an opportunity for art novices to learn how to look at a painting by observing experts and understanding how they think. Additionally, your participation helps progress research in cognitive modeling and technology in art education.

What happens to the information collected for the research?

Privacy and confidentiality will be taken very seriously throughout this study being gathered and stored digitally by an onsite computer using ASU cloud storage. Survey and video data will only be seen by me (the student researcher), the principal investigator, and the student scores.

In addition to completing short survey (your opinion on the experience of the learning activity) you will be asked to respond to a brief prompt before and after the

learning activity. In order to closely review your spoken responses to these two prompts I would like to video record them.

Please let me know if you do not want to be video recorded. These video recordings will only be viewed by me and student scorers, people with art history expertise who I hired to help me better understand your comments. The scorers participate separately from the study, viewing the video recordings at a later date in order to classify your comments from an art education perspective.

Some participants will work with a partner, due to the group nature of this dynamic complete confidentiality cannot be guaranteed. However, your responses in this study will be kept strictly confidential by the research team, stored digitally in the ASU cloud with access controlled by the student researcher and principal investigator solely.

The video data will be kept only until the reporting of the dissertation has been completed and successfully defended (Fall, 2016) after which it will be deleted.

What else do I need to know?

This research is being funded by the student researcher so your participation is much appreciated.

Who can I talk to?

If you have questions, concerns, or complaints, talk to the research team at daniel.shapera@asu.edu or Robert.Atkinson@asu.edu.

This research has been reviewed and approved by the Social Behavioral IRB. You may talk to them at (480) 965-6788 or by email at research.integrity@asu.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.

- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide input about this research.

Your signature documents your permission to take part in this research.

Signature of participant

Date

Printed name of participant

Date

Signature of person obtaining consent Date

Printed name of person obtaining consent Date

APPENDIX C

ART VIEWING RUBRIC

Appendix C1: Descriptive Responses

		Minimal (1pt)	Specific (2pts)	Descriptive (3pts)	Comprehensive (4pts)	POINTS
SUBJECT MATTER	**People**	accurately identifies presence of people within the painting	accurately identifies a **specific** person within the painting	accurately identifies **at least 1** person in the painting by **at least 1 descriptive characteristic** (e.g., a tall soldier; front, back, side, 3/4 view; sitting, standing, kneeling; woman wearing a dress)	accurately identifies **at least 2** people in the painting by **at least 1 descriptive characteristic** accurately identifies **at least 1** person within the painting by **at least 2 descriptive characteristics** (e.g., a long-haired man wearing a sash; back view of a rich woman; a young man leaning on the table)	
	Place	accurately identifies a place represented within the painting (e.g., "*indoors*")	accurately identifies a **specific** place represented within the painting (e.g., "*kitchen*," "*studio*")	accurately identifies a **specific** place by **at least 1 descriptive characteristic** (e.g., "*old kitchen*," "*artist's studio*")	accurately identifies a **specific** place by **at least 2 descriptive characteristics** (e.g., "*old, dirty kitchen*," "*cluttered artist's studio*")	
	Objects	accurately identifies presence of objects the painting (e.g., "*There's some furniture…;*" "*I only see a few things in this picture*."	accurately identifies a **specific** object within the painting (e.g., food, chair, window; "*there's a bass (viol) on the floor*")	accurately identifies **at least 1** object within the painting by **at least 1 descriptive characteristic** (e.g., basket of bread, string of pearls, mirror on the wall) accurately identifies **at least 2** objects within the painting	accurately identifies **at least 2** objects within the painting by **at least 1 descriptive characteristic** accurately identifies **at least 1** object within the painting by **at least 2 descriptive characteristics** (e.g., basket of crumbly bread, shiny string of pearls, wrinkled map on the wall) accurately identifies **at least 3** objects within the painting	

	Illusionist Qualities	**form** - the illusion of volume, depth, or weight of an object **space** - the distance or area between, around, above, below, or within things **texture** - a perceived surface	accurately identifies **at least 1 examples** of the illusion of a 3D quality such as form, space, or texture (e.g., **form** - "*heavy carpet*," "*The window is open*," "*I feel like I could pick up that bowl of fruit*," "*…a very fine balance*") (e.g., **space** - background/ foreground, flat/deep; "*The woman appears locked in between the map and the table*," "*...it's almost as if this painting has a depth of field*") (e.g., **texture** - "*crumbly bread*," "*smooth tile*")	accurately identifies **at least 2 examples** of the illusion of a 3D quality such as form, space, or texture (e.g., **form** - "*heavy carpet*" "*The window is open*" "*I feel like I could pick up that bowl of fruit.*" "*…a very fine balance*.") (e.g., **space** - background/ foreground, flat/deep; "*The woman appears locked in between the map and the table*," "*...it's almost as if this painting has a depth of field*") (e.g., **texture** - "*crumbly bread*," "*smooth tile*")	

		Minimal (1pt)	Specific (2pts)	Descriptive (3pts)	Comprehensive (4pts)	POINTS
ELEMENTS OF DESIGN (part)	**Line**	accurately identifies the use of line (a mark with length and direction, edge of space or shape, possibly made by brushstroke)	accurately identifies **a specific use** of line (e.g., "*Look at the fine lines making up the balance*;" *"If you look closely, you can see a bevel on the mirror*!")	accurately **identifies at least 1** use of line **by a descriptive characteristic** (e.g curved, diagonal; thick, thin; dashed, broken)	accurately identifies **at least 2 uses** of line **by a descriptive characteristic** (e.g curved, diagonal; thick, thin; dashed, broken)	
	Shape	accurately identifies the presence of shape (e.g., an enclosed space defined and determined by other art elements)	accurately identifies a specific example of a shape (e.g., "*rectilinear lines*," "*the ellipse of the basin*")	accurately identifies **at least 2** examples of the use of shape	accurately identifies **at least 3** examples of the use of shape	
	Color	accurately identifies the presence of color (e.g., "This is colorful.") Includes **hue** (color name), **intensity** (bright - dull) and **value** (lightness and/or darkness of color)	accurately identifies **a specific example** of color by **hue, intensity, or value** (e.g., **hue** - "*I like the gold in her hair"*)	accurately identifies **at least 1** example of color by **intensity or value** (e.g., **intensity** - "*the fabric has spots of bright blue*;" **intensity** - "*I love the shading of light to dark on the white wall,*" **value** - *"the brown gets darker under the window*")	accurately identifies **at least 2** examples of color by **intensity or value** (e.g., **intensity** - "*the fabric has spots of bright blue*;" **intensity** - "*I love the shading of light to dark on the white wall,*" **value** -*"the brown gets darker under the window*")	
				accurately identifies **at least 2** specific examples of color by **hue, intensity, or value**	accurately identifies **at least 3** specific examples of color by **hue, intensity, or value**	

Appendix C2: Contextual and Comparison Responses

		Description	Recall a Fact (3pts)	Recall a Fact *to Explain Painting* (4pts)	POINTS
CONTEXT (factual)	**Artist's Life**	Family; Work; Education; Travel; Personal life experiences; Other	e.g., "*Vermeer worked very slowly*."	e.g., "*Look at the carpet (or "piano"), **I see why it took him a long time to achieve that level of detail***."	
	Artist's Culture	Values and Beliefs; Heritage and/or ethnicity; politics; Economic situation Cultural considerations of artist's beliefs and values growing up as member of a culture in a time and place. (subject matter that indicates high price, obvious meaning; is easily recognizable)	e.g., "*Vermeer's paintings often reflected middle class life*." e.g., "Holland was a growing economic force"	e.g., "*Vermeer's paintings often reflected middle class life, **and on the table I see a carpet and a jug of some kind***." e.g., "Holland was getting richer, **and it shows in these fancy tiles on the floor**."	
			e.g., "Possessions were important expressions of one's place in society."	e.g., "*I see a bunch of expensive things in this room, **which means the painting was for a wealthy person***."	
COMPARE ARTWORKS (conclusions)	**Style**	Set of distinctive qualities, including those discussed by art experts. (artist's style, style of art movement or period, cultural style)	e.g., "*His subjects were often locked into space*."	e.g., "*His subjects were often locked into space, **just like the man behind the table (or next to the painting on the wall)***."	
			e.g., "*Vermeer focused on light*."	e.g., "***Just like the other paintings**, there's a focus on the light coming through the window*."	
			e.g., "*Vermeer often painted indoor, domestic scenes*."	e.g., "***It looks like a Vermeer because** it's a domestic scene; I just a see a man and a woman standing in front of a piano (virginal).*"	
	Theme	Broad cross-cultural themes include: people and nature, strength of family, religious devotion, status, love, cultural pride, overcoming obstacles etc.	e.g., "*Vermeer reminds us of the beauty of what's around us every day*." e.g., "*Vermeer paints females at work on a task*."	e.g., "*This scene is simple. Just an everyday scene, **like Vermeer liked to do***." e.g., "*Here is **another of Vermeer's ladies** busy playing an instrument*."	

Appendix C3: Design Principles

(Collected but not expected)		Definition	NO	YES
DESIGN PRINCIPLES (whole)	**Balance**	the way the elements of art are arranged to create a feeling of stability in a work (e.g., tension vs. equilibrium, symmetry vs. asymmetry)		
	Harmony	A union or blend of aesthetically compatible components (e.g., agreement between colors, shapes, and visual elements; somewhere between monotony and dissonance)		
	Contrast	a large difference between two things (e.g., opposing colors or textures, light and dark, hot and cold, smooth and rough)		
	Repetition	a way of combining elements of art so that the same elements are used over and over again (e.g., shapes, lines or colors; "*...warm whites of the wall against those cruel, sharp blue-whites of the headdress*")		
	focal point	portion of an artwork's composition on which interest or attention centers (e.g., the balance a woman holds, a weapon on the table, the convergence of colors or lines)		
	Movement	act or process of moving, either actual or implied (e.g., lines, shapes, forms, moving eye over the work, possibly towards the focal area)		
		TOTAL		

OTHER	List here:

APPENDIX D

REDUCED INSTRUCTIONAL MATERIALS MOTIVATION SURVEY (IMMS)

Please indicate the degree in which you agree or disagree with the following 12 statements.

a) Not true

b) Slightly true

c) Moderately true

d) Mostly true

e) Very true

1. It is clear to me how the content of this material is related to things I already know.
2. The quality of the narrative helped to hold my attention.
3. As I worked on this lesson, I was confident that I could learn the content.
4. I enjoyed this lesson so much that I would like to know more about this topic.
5. The way the information is presented helped keep my attention.
6. I really enjoyed studying this lesson.
7. The content and presentation style of this lesson convey the impression that its content is worth knowing.
8. After working on this lesson for a while, I was confident that I would be able to pass a test on it.
9. The variety of audio conversations, prompts, and visuals, etc., helped keep my attention on the lesson.
10. The content of this lesson will be useful to me.
11. The good organization of the content helped me be confident that I would learn this material.
12. It was a pleasure to work on such a well-designed lesson.

APPENDIX E

PERMISSION TO REPURPOSE EXPERT PERFORMANCES

BH Beth Harris [redacted]
Thu 3/19/2015, 11:16 AM

Hi Dan.
We've read this over and it sounds very exciting. You have our permission to use the videos as you requested for your research. our only request is that you keep in touch with us regarding your progress and any research findings - since this is obviously important to what we do!

Best of luck!

Beth & Steven

DS Daniel Shapera [redacted]
Wed 3/18/2015, 4:21 PM

Hello Beth and Steven,

Thank you for the opportunity to share my research with you and apologies for the somewhat clumsy introduction via Twitter.

I'M A BIG FAN OF SMARTHISTORY
While I consider myself a novice when it comes to art, I do have a history background so my approach to art has long been to read the artist biography, watch everything I can find on Smarthistory, then go to the museums to see for myself.

You've helped me and my family go to museums with purpose and confidence. Hundreds of the views on YouTube are us learning and planning those museum trips and when traveling the last few years to Paris, Amsterdam, Florence, and Rome. I'll be in London next month with my sights on the Tate Britain and the National Gallery.

I also happen to be a PhD student at Arizona State University in the Educational Technology program, and Museum Studies certificate, and as an educator I'm so grateful and supportive of the work you do not only in the field of art education but the open source materials you and the Khan Academy have trail-blazed.

MY RESEARCH
I promised Beth I would keep it brief so here is an outline of my PhD research...

I'm interested in the use of augmented reality technology for cognitive modeling. In short, making the thought processes of experts visible to novices so they can better understand the real world application of specific skills. **I want to leverage this technology to make art more accessible and relevant to novices and those without formal training in the arts** (like most people I know). I would like to remedy those statistics about people looking at art for only a few seconds because they lack the context and/or basic skills to even know how to look at a painting.

Imagine a novice standing in front of a painting and listening to experts discuss subject matter, form, technical features, comparable works etc. and as they do so the novice sees what the experts sees.

Many of the Smarthistory videos use annotation, highlighting, side-by-side views and other instructional techniques. **My research would explore the effectiveness of those techniques when applied directly on the painting itself (digitally of course) via mobile device.**

FORMAL REQUEST
I can provide more context and a summary of the methodology if that will help, but my main question for you both is regarding the use of Smarthistory videos for this study. I did see the Share/Adapt permissions on the site but wanted to make a more formal request just to be sure.

With your permission, I would like to create a learning experience/research study where novices view paintings listening to the audio from Smarthistory videos (i.e. experts in authentic environments) as they use the mobile device to see visual elements that support the expert conversations. The vanishing point on the little finger of a *Woman Holding a Balance* or to highlight the last judgment on the wall behind her, for example. Or pointing out how a camera obscura could be utilized in *The Art of Painting*.

I'm willing to expand on what is here or go through any additional vetting process you'd like as well. Nothing would be required of you beyond your permission (I do wish we could download scripts however:)). I just want to be sure I'm following whatever protocol you might require and do nothing to harm the open source movement.

thanks for your time and consideration,

Dan