An analysis of motivation and situational interest in a location-based augmented reality application

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Abstract. Research has provided evidence that augmented reality (AR) can be an effective tool to improve teaching and learning across multiple domains. Research is limited, however, in several key areas related to AR. For instance, motivation and situational interest are critical to student learning outcomes. However, little is known about the relationship between the two constructs and AR, particularly for AR that leverages location-based triggers. This study addressed this need by analyzing data from participants who used an application that delivers location-based, instructional AR content about the tragic shootings that occurred on May 4th, 1970, at Kent State University. Data findings showed significant decreases in motivation, but significant growth in situational interest and content knowledge. Implications for development of future location-based AR applications are discussed.

Keywords: location-based AR, history, situational interest, motivation, learning, teaching

1 Introduction

Interest and motivation have been shown to have a significant positive impact on learning outcomes [1]. Motivation has been described as an essential attribute that directs learner behavior towards positive outcomes [2]. Interest has often been conflated with motivation, but they are two distinct concepts. While motivation, specifically intrinsic motivation, underscores the innate desire for an individual to master a subject due to the subject itself being rewarding or carrying perceived value [3], interest focuses on the early stages of an individual being exposed to a subject matter [4]. Studies have shown that establishing interest in a topic fosters a significant positive influence on an individual's ability to endure, revisit, or re-engage on a set of topics, ideas, or events [5]. Once interest is triggered in an individual, it serves as a critical precursor to developing a sustained sense of intrinsic motivation [6].

Given the important relationship between interest and motivation, triggering interest is a topic that has been researched heavily [7]. Interest can be instigated using *seductive details* which can take the form of provocative text, photos, illustrations, sounds, videos, or other forms of media that are designed to call attention to a topic but may not be directly related to a learning outcome [8]. Interest can also be developed through learning environments that include technology, puzzles, and collaborative work [4]. Given the value of establishing interest, it is logical that researchers would continuously to explore approaches to inspire learner interest.

One such technology that may help establish interest is location-based augmented reality (AR). AR platforms have been around for several decades. The first proposed utilization of AR stemmed from the research done in 1992 at the Boeing company. Boeing researchers Thomas Caudell and David Mizell were looking to reduce costs and improve efficiency in the operations of aircraft maintenance through the use of AR [9]. Their approach included the use of a heads-up display that overlaid instructions or guidance on how to perform tasks overtop of the physical environment.

Boeing's approach to AR was limited to niche use cases and, as a result, AR as a general concept did not see much growth for a few decades. With the increase in computing capabilities, along with standard features such as cameras, gyroscopes, and GPS processors on modern smartphones, the adoption of augmented and virtual reality technologies has grown significantly over the past few years [10]. Moreover, with the introduction of AR-based games such as *Pokémon Go* (2016), this technological approach to multimedia delivery has transitioned into the mainstream [11]. According to a report [12], augmented and virtual reality content is anticipated to reach a market value of over $8.2 billion by 2023. And a survey of investors showed that 36% viewed education as the most applicable domain for AR, just below gaming and health care [13].

1.1 Rationale for the Study

The effectiveness of AR as an instructional tool has been investigated in numerous instructional domains like science, mathematics, language learning, art, design, and social studies [14], [15], [16]. Unfortunately, a thorough literature review yielded only a small number of studies looking at the intersection of motivation and AR [16]. There were no studies found on AR and interest; additionally, there were no studies found on AR, interest, and motivation. Only one study could be found in a literature review that covered motivation and AR explicitly [17]. The findings presented in that study are almost a decade old and focus specifically on a visual art course. Moreover, the results indicated that the technology was not mature enough to be used in education despite the students exhibiting a significant amount of enthusiasm with the innovation. A recent meta-analysis on educational AR applications further supported this claim [18]. This study indicated that while the capability of these tools has been largely accepted and widely demonstrated, understanding student success indicators such as motivation and interest as it applies to augmented reality are areas that need further consideration. Additionally, little research has investigated the use of AR in history [18], [19]; of the studies that do exist, little has been examined through empirical means [20], particularly as it relates to location-based delivery of such content.

1.2 Purpose of the Study

The purpose of this study was to explore the relationship between AR, motivation, situational interest, and student outcomes using an instructional, location-based AR application for learning history. The study proposed three separate research questions.

- RQ1: What is the impact on a users' motivation when implementing a location-based, AR application designed to provide content around an historical event?
- RQ2: What is the impact on users' situational interest when implementing a location-based AR application designed to provide content around an historical event?
- RQ3: What is the impact on users' knowledge acquisition when implementing a location-based AR application designed to provide content around an historical event?

2 Literature Review

2.1 Motivation

According to Maslow, motivation is the result of a desire to satisfy basic human needs [21]. He posited that these needs could be arranged in a structured hierarchy. Maslow's hierarchy identified five categories of basic needs that included physiological needs (i.e., food, water, warmth, rest), safety needs (i.e., security), psychological needs (i.e., belonging and esteem), and self-actualization-based needs (i.e., achieving one's full potential). Expanding on needs described by Maslow, theorists Ryan and Deci [22] conceptualized and defined *Self-Determination Theory* (SDT). SDT explores motivation through the auspice of the human desire for positive developmental tendencies [22]. Under SDT, activities and actions can be described through the spectrum of extrinsically motivated and intrinsically motivated outcomes. Extrinsic motivation is a motivation type that is grounded in the promise of an external reward (i.e., earning a good grade, receiving a promotion, or some other tangible outcome) whereas intrinsic motivation originates from an internal need (i.e., wanting to do something either for subject mastery or enhancing personal understanding). With intrinsic motivation, there is enjoyment in the activity itself [23].

When it comes to the efficacy of motivational types (intrinsic versus extrinsic), research has clearly shown that intrinsic motivation has significant positive attributes. Intrinsic motivation generates sustained persistence, which can lead to a higher likelihood of success [24]. Ryan and Deci noted that intrinsic motivation contributes to happiness and satisfaction [3]. Perhaps most important, from an academic achievement perspective, intrinsic motivation is a key factor in the academic achievement of students [25], [26], [27].

John Keller tried to describe motivation under the ARCS model as an efficient way to understand the major influences on motivation, particularly around learning [28],

[29]. The ARCS model is grounded in the assumption that activities should enhance motivation to learn; it contains four conditions where materials and activities should align. The four major conditions of ARCS include *Attention*, *Relevance*, *Confidence*, and *Satisfaction* [28]. *Attention*, according to Keller, is an element of motivation and is necessary for learning. The learner must maintain a high level of engagement in the instructional materials to derive value from it. *Relevance* speaks to the need to understand why the information or instructional material applies to their lives. To trigger relevance, instructional content should contain some level of familiarity or relatedness to the concepts being presented. The third component of the ARCS model is *confidence*. Students need to be in control of their experience and should feel challenged, but not overwhelmed. Finally, *satisfaction* speaks to the need to make the learner feel positive about accomplishing success. Keller suggested that the first three categories are critical in helping learners being motivated to learn [30]. The fourth category of satisfaction is critical to maintaining a continued desire to learn.

There are some conceptual alignments between SDT and flow as it applies to the ARCS model of motivation. Attention has close parallels to the need to maintain a state of flow in learners. If learners are bored or overly anxious, they will not maintain their attention. Relevance has a direct correlation to SDT in that competence, or the feeling of mastery implies that it was a foundational knowledge source from which to draw on, hence having relevancy to prior knowledge. Confidence has parallels to both SDT and flow. Students need to be in control of their learning efforts, which has parallels to autonomy in SDT, as well as control in the concept of flow. Satisfaction is an element of being intrinsically motivated and is the same concept of feeling satisfied when completing a task in a state of flow.

The ARCS model has been mostly applied as a guideline for creating effective motivational strategies in instruction [2], [31]; because of this, it became necessary to measure and assess the student perception of a pedagogical approach. As a result, Keller created the *Instructional Materials Motivation Survey* (IMMS) as a method of evaluating numerous types of instructional interventions [30]. The IMMS is a 36-point Likert-like survey focused on measuring the major components of the ARCS model. It has been well used since it's induction and has served to measure the impact of interventions pertaining to computer-assisted instruction [32], [2], [31] web-based courses [33], [34], [35], and AR [17]. During Huang et al.'s [2] attempt to reduce the length of the instrument and validate the IMMS using structural equation modeling (SEM), they suggested that 16 of the questions should be excluded from the instrument largely because their analysis indicated that the items in question did not score high enough to be relevant in their exploratory factor analysis and confirmatory factor analysis (2006). In response, Keller [30] published an article describing his disagreement, largely because the subscales of the items identified for being omitted should remain as they can have high intercorrelations.

Loorbach et al. [36] conducted further investigation on reducing the length of the IMMS by integrating Keller's [30] feedback to Huang et al. [2]. The desire to reduce the instrument was based on the work conducted by Hinkin [37], who suggested keeping instruments as short as reasonably possible to minimize any potential biases caused by boredom or survey fatigue. To test the new instrument, the researchers executed a study on the motivation associated with self-directed cellular phone user instructions. Through thorough analysis and extensive validation practices, they were able to certify that their instrument, referred to as the *Reduced Instructional Materials Motivation Survey* (RIMMS), met all measurable indicators.

2.2 Situational Interest

Krapp and Prenzel [38] suggested that interest "represents a specific and distinguished relationship between a person and an object" (p.31). An object, in this description, refers to a topic, idea, or concept. Given the proper circumstances, learners engaging in activities that are of interest to them may experience a state of flow [39], [40]. The amount of interest an individual wields towards a specific domain can have a significant influence on learning. In a 2000 study by McDaniel et al. [41], the relationship between interest and attention was analyzed. Six stories were selected and presented to 96 students, who had their interest in the subject matter of the texts assessed in a pretest fashion. Reaction time and recall were analyzed in this study. The findings provided evidence that there was a substantial relationship between interest, the speed at which an individual can recall information, and the accuracy of the recall. In a 1999 study by Wade et al. [42], learners were asked to rank their interest in various categories and review articles based on those categories. Participants of the study then completed assessments on knowledge retention and then ranked the articles based on importance. The researchers concluded that there was a strong relationship between interest and recall as well as interest and perceived importance. Numerous other studies exist validating the relationship between interest and attention [43] [44], [45], as well as learner performance [46], [47], [48].

Krapp [1] categorized the structure of interest by distinguishing between two types of interest: *personal interest* and *situational interest*. Personal interest refers to an interest that is innate in an individual. Situational interest is an interest type that occurs as a result of an environment or context. Given that instructors lack the ability to control personal interest, research suggests that a focused understanding of situational interest is critical to help foster a learning culture that leads to personal interest and intrinsic motivation [49].

One of the earliest modern investigations of interest comes from Mitchell [49]. In his model, there were two stages of interest development defined. There is a *catch* stage (which involves triggering interest) and a *hold* stage (which involves maintaining a learner's interest over a sustained period). Catching interest is something that can be facilitated through group work, computer activities, or puzzles. Holding interest is something that happens when the individual finds meaning in the topic or involvement in the activity.

Given the importance of situational interest, Linnenbrink-Garcia et al. [50] attempted to create a model of situational interest as well as an instrument to assess the components of that model. To achieve this, they defined four different models based on prior literature [51] [52], [4], [53]. The study attempted to determine the relationship between situational interest, feelings-related attributes, and value-related attributes. The first model consisted of a two-factor model consisted only of *Triggered Situational Interes*t and *Maintained Situational Interest*, which is comparable to Mitchell's catch and hold approach. The second model was a three-factor model which differentiated between *Trigged Situational Interest*, *Maintained*

Situational Interest Feeling, and *Maintained Situational Interest Value*. The third model was another two-factor model containing the components 'feeling' and 'value.' Finally, the fourth model represented a one factor construct suggesting that situational interest should not be divided into subcomponents. The researchers conducted several studies and determined that the three-factor model provided the most reliability in assessing situational interest.

2.3 Augmented Reality (AR)

According to Zhuravlov-Galchenko [54], there are two key types of AR applications available to mobile devices. The first type of AR is location-based. These sorts of applications rely on a smartphone's global positioning system (e.g., GPS) and accelerometer to know when and where to display AR content. One of the most popular apps that utilized location-based AR is *Pokémon-Go*, which had players traveling to specific locations to catch and train Pokémon characters. Marker-based applications are the second form of mobile AR technologies. Marker-based apps leverages image recognition, typically through quick response (QR) codes to trigger applications to display AR content. One of the most popular uses of marker-based AR is the Merge Cube, which has gained widespread utilization in the K-12 educational space [55]. AR has been used in a broad range of educational domains such as language learning [14], [56], vocational purposes [57], art and design [58], mathematics [15], and social studies [59]. The prevalence of AR technology in education has led researchers to examine the advantages, disadvantages, or challenges in using AR for education [14], [15], [57].

Akçayır and Akçayır [60] conducted a meta-analysis of AR and found 10 different studies suggesting AR can enhance learning motivation. However, they also found challenges related to AR-based instruction. The most common one described was that some AR applications were difficult to use. The authors argue that difficulty in use may be a result of non-intuitive, poorly designed user interfaces. Another problem comes from errors with the technology as some applications incorrectly assess location or may have low sensitivity in trigger (i.e., location) recognition. This finding was supported by Radu [61] in his 2014 meta-review and cross-media analysis. In several of the studies reviewed by Radu, AR systems were viewed to be "more difficult than their physical or desktop-based alternatives" (p. 1537). Radu also discussed other issues with AR in the classroom. One such issue related to learner differences; citing research by Freitas and Campus [62], Radu suggested that higher-achieving students do not attain the same outcome gains that lower-achieving students do when leveraging AR. Radu noted that this is likely related to the limitations of AR not presenting content that was challenging enough for high achieving students. Another limitation of AR pertains to cognitive overload. According to Dunleavy & Dede [63], "numerous studies have reported that students are often overwhelmed with the complexity of activities" (p. 739).

While these studies provide both promising results and future topics to consider, few research studies have examined the impact of AR on situational interest or motivation. A review of the literature found only a handful of studies that discussed motivation with AR. One such study was completed by Di Serio et al. [17]. This study investigated AR's impact on student motivation for a visual art course. To assess the impact on motivation, the researchers leveraged Keller's [30] IMMS. The findings did indicate a statistically significant positive impact on learner motivation between those consuming instructional materials via an AR platform versus those engaging in content through traditional lecture means. Despite these findings, the study did contain gaps. As the authors pointed out, given that this was new technology, they could not rule out the results being the result of novelty effect. The use case here was also very specific and without different domains or age groups; as such, it was not necessarily generalizable. The technology used was also over ten years old; technology has made significant advances since this study was published. Finally, their study did not address topics such as situational interest, which remains a knowledge gap [18].

Additionally, there is a lack of empirical research on the efficacy of AR-based instruction in delivering historical content. In a pair of meta-analyses conducted by Bacca et al. [19] and Garzon & Acevedo [18], most studies of AR in education focused on the domains of the sciences and the arts. Social studies and history topics were lumped in with other categories such as journalism, information, business, and law. Even with grouping these disparate domains together, the percentages of studies were much smaller than sciences, mathematics, and art [18], [19]. This is somewhat surprising considering the potential associated with AR in the history domain. Chang and Liu [59] investigated the use of AR as it applied to learning cultural heritage. They leveraged an AR application designed to provide supplemental information about monuments and statues across tourist locations in the city of Tainan in Taiwan. The focus of their study was around technology acceptance and knowledge growth. Results indicated that the AR experience was helpful in knowledge growth.

A comprehensive meta-analysis was completed by Challenor & Ma [20] on the use of AR across the discipline of historical education. This survey noted several reasons why AR might be beneficial to the field of history, including environmental immersion which is described as providing a sense of historical empathy, which the authors describe as not possible to achieve using a classroom with a textbook. Additionally, they suggested that AR provides the ability to explore spaces that no longer exist. The authors noted that across the research analyzed in their analyses, there was a "lack of empirical research performed within the area, signifying that there is still a great deal of potential study to be done" (pp. 16-17).

2.4 Summary of Literature Review

Motivation is a critical indicator of a learner's success [1]. Recent constructs of motivation break it into two key categories, intrinsic and extrinsic [22]. Intrinsic motivation is the more powerful of the two concepts and is described as an innate disposition towards a concept that manifests itself in learners as a willingness to revisit and master content [64]. The ARCS model of motivation defines four constructs that make up motivation: attention, relevance, confidence, and satisfaction [28]. These concepts can effectively be measured using the RIMMS instrument [36].

Situational interest is a type of interest that serves as an antecedent of motivation [6]. Early research of interest defined two key components: catching and holding [49].

Later understanding of interest further evolved into a three-factor model. The first factor is *Triggered Situational Interest*, which is like Mitchell's concept of catching. The second factor is *Maintained Situational Interest Value*, which can be described as a maintained sense of interest that is fostered through an individual's affective experience. The third factor is *Maintained Situational Interest Feeling*, which is best described as how individuals feel about a concept [50].

AR is a technology that has shown promise as an effective instructional tool, but little is known about its impact on situational interest, motivation, and ability to deliver instruction across the domain of history, particularly for applications that employ location-based triggers [18], [19].

3 Methodology

3.1 Participants

The authors' Institutional Review Board (IRB)'s approval was gained before engaging with participants. Students were recruited through faculty outreach and the university's undergraduate program research pool. A total of 46 students signed up for the study; 43 successfully completed the pretest. A total of 33 participants fully completed the study. Six students held the rank of Sophomore, or 18.2% of the participant population, fifteen were Juniors, or 45.5% of the population, and twelve of the participants were Seniors which made up of 36.4% of the population. The gender breakdown consisted of 25 females, or 75.8% of the population and 8 males making up the remaining 24.2% of the population.

3.2 The GLARE Platform and the May 4th Augmented Reality Project

The AR and location-based instructional materials for this tour were created as a prototype mobile web application (*https://may4th.xr.kent.edu*). The application conveys information about the shooting of Kent State University students by the Ohio National Guard on May 4th, 1970, and its aftermath. The goal of the app is to help foster an understanding of the events, its impact on the students and the University, and how the University changed after the tragedy. Content was adapted from existing content provided by the *Kent State May 4 Visitors Center* and *the Kent State University Library*.

The application is designed to guide visitors through seven location hotspots notable to the leadup, events of, and aftermath of May 4th. When users visit the website on their mobile device, they are presented with a map of the seven hotspots (see Figure 1). They can follow the hotspots in order, or they can visit any one they chose. When they arrive at a hotspot, they are instructed to hold up their phone; they see a current image from their camera as well as an overlay of what that location would have looked like in 1970. Figure 2 shows, for instance, an overlay of the ROTC building on the current Kent State campus. This example is salient because the ROTC building no longer exists. Users also can pull down two menus. On the lefthand side, participants can access a menu allowing them to see the location over key time periods. On the right-hand side, participants can access a menu that presents additional multimedia, text, and information about the location.

Fig. 1. The map integrated into the AR application providing wayfinding information for users.

Fig. 2. This is the AR App featuring the ROTC site.

The AR experience was realized using the newly developed *Geo Located Augmented Reality Editor* (GLARE; *https://glare.cs.kent.edu)*. GLARE is a data agnostic and dynamic AR content design and delivery system. The platform permits the rapid and graphical creation of modular AR tours accessible from a web interface functioning on many types of internet connected devices. This was achieved by the use of a website platform harnessing the newest API's with excellent cross-platform (software and hardware) compatibility. This compatibility is constantly updated with new web standards as new functionality and technological changes occur.

GLARE is also modular whereby the interpreter will parse the user defined content and only populate those objects/media that exist within the configuration. This adds a degree of flexibility to the platform permitting any number of menus, library links and other content loaded in a modular fashion. This method also allows for the simple addition of new modules in the future (i.e., haptic interface) that are easily incorporated into the platform. The AR platform is controlled using an online editor with a graphical interface so new tours can be created visually and previewed on demand.

3.3 Methods and Instruments

Prior to being exposed to the AR application, participants completed a pretest measuring their subject knowledge, motivational levels, and situational interest levels. Participants were then provided with instructions on how to access the AR application and a map of the sites associated with the AR tour of the May 4th site. Participants were given one week to complete a site visit using the AR application, visiting all seven sites in linear order; they were also asked to log their times. Upon completion of logging their time, participants were again asked to travel through the tour and review content a second time. During the second visit, participants could visit any of the sites they wished and could complete the tour in any order. They were not required to visit all sites. Participants were asked to log their times for each site visited. Upon completion of the second visit and submission of their time log, participants were given a posttest remeasuring knowledge growth, motivational disposition, and situational interest characteristics.

This study used the *Reduced Instructional Materials Motivational Survey* (RIMMS; [36]), the *Situational Interest Survey* (SIS; [50]); and a knowledge assessment (created by the authors) as evaluation instruments for pre- and posttests. RIMMS is a 12 item, four factor scale. It focuses on the four attributes of motivation underneath the ARCS model. Participants were asked to complete each item using a 5-point Likert-like scale from ‘Not True’ (coded 1) to ‘Very True’ (coded 5). Higher scores from each sub-dimension indicate higher levels for each of the measured ARCS components. SIS, developed by [50], is a 14 item, three factor scale. It focuses on the three attributes comprising the situational interest model developed by Linnenbrink-Garcia et al. [50]. Participants were asked to complete each survey item using a 5-point Likert-like scale from ‘Not True’ (coded 1) to ‘Very True’ (coded 5). Two of the questions, modeled after the original SIS instrument, were reverse coded to eliminate acquiescence bias.

Loorbach et al. [36] validated the RIMMS instrument using a first-order confirmatory factor analysis. All components of ARCS tested above acceptable levels. Internal reliability for RIMMS was also measured using coefficient alpha. The coefficient alpha values measured at .9 for Attention, .82 for Relevance, .89 for Confidence, and .85 for satisfaction. Linnenbrink-Garcia et al. [50] validated the SIS instrument using confirmatory factor analyses and calculated Cronbach α values for each component: Triggered Situational Interest at .92, Maintained Situational Interest Value at .91, and Maintained Situational Interest Feeling at .92. A knowledge assessment was created by the author using instructional materials from the May 4th

AR application as the source (see Appendix A). The assessment was a 10-item instrument containing multiple choice and multiple select items.

4 Results

4.1 Location-based AR and Motivation

Each component of the ARCS motivational model was evaluated using the RIMMS instrument. To ensure reliability, a Cronbach alpha was measured on the overall score across the pretest; reliability was validated with a Cronbach alpha measuring .858 (indicating strong reliability). A paired-samples T Test was conducted to investigate any changes across the total motivation level as well as the individual components of the ARCS for the study participants. The mean of the pre-test total motivational score was 3.6614 (SD=.54044), and the post-test total motivation score was slightly less at 3.3411 (SD=.90523). Analyzing the components of the ARCS model, values declined as well; attention pre-test was 3.6869 (SD=.47827) with a post-test of 3.567 (SD=.88382), relevance pre-test was 3.7172 (SD=.88382) with a posttest of 2.9394 (SD=1.16206), confidence pre-test was 3.6061 (SD=.63713) with a post-test of 3.5556 (SD=1.07583), and satisfaction pre-test of 3.6563 (SD=.78738) and a post-test of 3.3333 (SD=.98374).

A paired-sample T test was conducted to determine significance. The decrease in mean from pretest to posttest for overall motivation was determined to be not significant (p=.0769; confidence interval from .01434 to .62661). The only sub-component of ARCS that was found to be statistically significant was relevance; the mean decrease in this category from pre-test (X=3.7172) to post-test (X=2.9394) was found to be statistically significant (p=.001; CI: .34384 to 1.21172). The mean changes in the remaining sub-components (attention, confidence, and satisfaction) were not found to be significantly significant.

In sum, the first research question asked about the impact of a location-based AR application on motivation. Results indicated that there was not a significant ($p<.05$) change in overall motivation using this AR application; however, the component of relevance significantly decreased from pre- to post-test ($p<.05$).

4.2 Location-based AR and Situational Interest

Each component of the [50] situational interest model was evaluated with a paired-samples t-test. The SIS does not compute an overall situational interest score due to the high correlation between *Maintained Situational Interest Value* and *Maintained Situational Interest Feeling* [50]; therefore, this study used the individual sub-components of the SIS. Results were analyzed to identify any changes across the sub-components of situational interest.

The mean of the pre-test *Triggered Situational Interest* was 20 (SD = 3.112), and the post-test *Triggered Situational Interest* increased to 20.18 (SD = 3.459). The mean of the pretest of *Maintained Situational Interest Feeling* was 15.21 (SD = 3.423) and increased to 15.88 in the posttest (SD = 2.837). The mean of the pretest *Maintained Situational Interest Value* was 18.88 (SD = 3.990) and increased in the posttest to 20.12 (SD = 3.219). A paired-sample T test was conducted to determine significance. One component, *Maintained Situational Interest Value*, had a statistically ($p<.05$) significant change between pretest (X=18.88) and posttest (X=20.12) means ($p = .033$; CI -2.381 to -.104). Changes in *Triggered Situational Interest* and *Maintained Situational Interest Feeling* increased but were not found to be statistically significant ($p<.05$).

In sum, the second research question asked about the relationship between situational interest and the use of a location-based, AR application. In this study, *Maintained Situational Interest Value* significantly grew from pre-test to post-test. *Triggered Situational Interest* and *Maintained Situational Interest Feeling* had higher post-test means, but the changes were not statistically significant.

4.3 Location-based AR and Content Growth

Analyzing the overall results of the knowledge assessment, an increase between pre-test (X=4.58) and post-test (X=7.30) was observed to be statistically significant ($p=.000$; CI: -3.324, -2.131). To ensure reliability, a Cronbach alpha was calculated across the pre-test. The Cronbach alpha value measured at .452, which indicated low reliability. To understand which items in the knowledge instrument successfully measured growth, a Simes modified Bonferroni test was performed. This test is useful to perform when the Cronbach alpha results are low, as is the case in this study, and it is not appropriate to calculate an overall mean change (using multiple paired t tests in its place). According to Simes [65], traditional Bonferroni tests perform too conservatively, which this modification adjusts for by testing items at an individual level. The resulting Simes-adjusted test indicated questions where knowledge growth took place. This analysis validated that the knowledge assessment instrument had statistically significant improvements across six of the ten items.

In sum, the third research question asked about the relationship between knowledge growth and the use of a location-based, AR application. The AR application did impact knowledge acquisition; in this case, it positively affected growth overall and specifically for 6 of the 10 May 4th history questions (Appendix A; #2, 4, 5, 6, 7, & 8).

5 Discussions and Implications

5.1 Implications for Location-based AR and Motivation

There was a significant decrease in the *relevance* component of the RIMMS instrument. To understand this decrease, a review of the RIMMS instrument is useful. The questions from RIMMS related to relevance rely heavily on the perception of the enjoyability of the proposed application. Users of the application shared after the process that they had several usability errors and glitches including random crashes, navigational and wayfinding issues, and a difficult learning curve in using the application. One of the cognitive overload types described by Mayer and Moreno, is when the learners are overloaded with essential processing demands [66]. If participants leveraging the AR app are unable to focus on learning content due to the application presenting glitches, they would be unable to focus on the content, resulting in a cognitive load issue. This relates to earlier findings of AR in education, where cognitive load issues can occur when the participant feels overwhelmed with the information presented to them [63].

User experience is another factor to consider related to the questions in the relevance section of RIMMS. Unfortunately, there is little research in existence on user experience design as it applies to AR. *User eXperience* (UX) refers to “a person’s perceptions and responses that result from the use and / or anticipated use of a product, system, or service” [67, p.1]. According to Arifin et al. [67], “there are no standard measurements of UX for AR” (p. 648). Researchers have tried to perform UX studies on AR using constructs like AttrakDiff [68], [69], but have concluded that standard metrics should be created [67], [70], [71].

Another issue that manifested in this study that could be tied to UX is the difficulties associated with wayfinding in the application. Several participants indicated difficulty in finding locations to trigger the AR experience. This could be related to how the geographic areas are zoned in the application, it could be tied to wayfinding problems, or it could be the fact that some of the locations on the tour no longer existed. A literature review of location-based AR applications did not find any pertinent research on this specific subject. The only literature that could be found on spatial awareness and AR discussed AR’s ability to improve spatial awareness [72], [73].

Constructs of attention, confidence, and satisfaction were not found to have statistically significant changes. According to Keller [28], attention relies on using surprise, uncertainty, or variability with content to gain interest. Given that all participants in this study are Kent State students, they likely participated in the *First Year Experience* course, which covers the events of May 4th. The content presented to participants was likely not entirely new. It is possible that this reduced the ability for this AR application to fully trigger the construct of attention *or* satisfaction. Confidence describes the student’s likelihood for success. If the learner feels that they cannot successfully complete the material, their confidence will go down. Students did experience difficulties in using this application, and as a result likely had reduced confidence in their ability to fully explore the content. This validates the findings of Akçayır and Akçayır [60] and Radu [61], who both concluded that non-intuitive or error prone AR applications can lead to learning issues.

With these findings in mind, there are a few conclusions that can be made with regards to AR-based applications in the future:

1. Stability and providing a reliable user experience is critical in delivering a compelling AR experience [60] [61].
2. Special care should be made to ensure that the applications respond to location markers reliably [60]. It may be useful for location-based applications to incorporate location-based wayfinding signs to indicate where an AR application will function.
3. AR applications should be designed with the recommendations provided by Mayer & Moreno [66] to address cognitive overload issues. This could be

achieved by ensuring the application is free from errors and content is well laid out through usability testing.

4. Incorporating a UX design approach to building AR applications would be useful [67].
5. The RIMMS instrument was successfully validated as an instrument for measuring motivation under the ARCS model [36]. Given that RIMMS provides the benefit of being only 12-items compared to the original 36-item instrument, RIMMS should be considered by AR researchers for future utilization. If a study is being designed to include multiple instruments, as was the case in this study, a reduced item set can help alleviate the risk of participants straight-lining answers to quickly complete a survey.

Application stability, improved way finding, spatial awareness, and optimizing the ease of use could contribute to a change in results related to motivation. Further research should also investigate approaches to UX as it applies to AR. Future studies should include consider including the AttrakDiff [74] user experience instrument to determine if it can accurately measure usability in an AR application. This instrument might prove helpful in shaping future revisions of the application to eliminate issues related to navigation and wayfinding, which were identified in the qualitative aspects of this study. This implies that AttrakDiff is appropriate for AR. It has been used in other studies; however, as all those studies have pointed out, there is not a standard instrument designed to measure UX for AR. Future research should be undertaken to validate various UX instruments to ensure fit and efficacy for AR-related projects.

5.2 Implications for Location-based AR and Situational Interest

There was a significant ($p<.05$) increase in the situational interest component of *Maintained Situational Interest Value*. Challenor & Ma [20] argue that environmental immersion provides a sense of historical empathy with the content. The authors also noted there is a lack of empirical evidence as it applies to historical AR. This study contributes to both comments, indicating that historical AR applications can provide a sense of interest as well as historical empathy. *Triggered Situational Interest* did not significantly change, which was somewhat surprising given that computers and technology are often effective at catching attention or triggering interest [49]. Given that *Triggered Situational Interest*, as described by Linnenbrink-Garcia et al. [50], "involves heightening the affective experiences individuals associate with the environment" (p. 2), it could be that the technical issues experienced with the application acted as a depressant factor on this category. A future study involving an improved, less error prone AR application is recommended to understand the impact of location-based AR on situational interest.

The changes from pre- to post-test *Maintained Situational Interest Feeling* were also not statistically significant, even though there was a positive change. Feeling-related attributes are ones that characterize "an individual's affective experience while engaging with the domain content (e.g., enjoyment, excitement)" [50, p. 3]. It is possible that this iteration of the application did not cover enough new or unknown content to trigger statistically significant growth in this area, particularly given the prior experience of students with the subject matter. Expanding the content and rerunning this study may provide significant changes between pre and posttest. Given the findings from this research, and the fact that no prior research on situational interest (SI) and location-based AR could be found, more investigation is also needed to determine why one construct of SI grew while the others did not. Additionally, more research is needed to fully understand the correlations between *Maintained Situational Interest Feeling* and *Maintained Situational Interest Value*.

Those who create AR content should use these findings to develop instructional AR content that is free from errors, is sufficiently deep enough content wise to not leave the learner wanting more, and should be intuitive enough to not require additional instructions or assistance to understand how to leverage the application. Those teaching with AR should take extra care to ensure that materials presented are appropriately challenging to ensure that learners are able to develop a richer understanding of the subject matter being delivered. Instructors should also ensure that learners are prepared with adequate information to engage with the application in a way where the technology does not steal the focus of the content being presented. Location-based materials should either provide sufficient guidance to lead users to the correct location for materials to present or physical markers should be employed to eliminate guesswork on the part of the learner.

5.3 Implications for Location-based AR and Content Acquisition

Knowledge acquisition significantly improved when users engaged with a location-based, AR application. The knowledge assessment was not validated prior to the study and could have benefited from further review. There are at least three reasons why knowledge growth may have occurred. First, the application required students to go out and witness the ROTC building and Solar Totem statues firsthand. Going to a physical location to learn about the events associated with the location is an example of establishing historical empathy, described by Challenor & Ma [20]. Second, the demonstrated knowledge growth may also have been attributed to the shocking nature of the content, some of which discussed the total number of shots fired towards the students. According to Harp & Meyer [8], the inclusion of material that is of emotional interest such as discussions of violence, causes an elevation of emotional arousal which can influence the learners cognition, resulting in an increase of attention spent and a positive impact on knowledge retained. A third potential reason for knowledge growth is that the application provided a pathway for learners to engage with locations that have changed over the years or serve as cultural reminders of past events. Future research is recommended to further evaluate AR as an instructional platform with a knowledge assessment instrument demonstrating higher overall validity. Moreover, future research could build on the gaming aspect of current AR titles (e.g., *Pokémon Go*) to explore the relationship between gaming, AR, and sensitive knowledge acquisition. Future work notwithstanding and given the lack of empirical studies related to AR and history, this study provides validation that location-based AR is a useful instructional tool in the domain of historical content.

5.4 Implications for the use of GLARE

The successful development and deployment of the AR application and associated positive outcomes listed above support the use of the GLARE editor in creating and delivering engaging content. GLARE is a freely available, open-source and extensible platform that can support the development of engaging and positive AR experiences, as indicated by the current study (*https://glare.cs.kent.edu*). While the focus of this study was based around a specific tour, the platform can be utilized for any number of additional experiences. Indeed, the GLARE framework was designed from the outset to be data agnostic, user friendly, and modular. The reliance on run-time population of linked media content from the server-side configuration allows dynamic changes to be made to tours and insertion of additional media content or menu links. Effectively, new tours can exist as a text file on a server containing the relevant links that are loaded at runtime. The creation of the AR interpreter that runs within the user's browser provides access to any type of defined content or tour via the platform. The intuitive graphical interface means that programming skills are not required to rapidly create new AR tours with the potential for rich user engagement. Modularity within the GLARE framework further enhances flexibility and supports the addition of new features or suppression of unwanted features.

5.4 Limitations

There are several limitations to the study. First, as highlighted in 5.1, subjects observed in this study were using an early version of *GLARE*. Research subjects found several wayfinding errors that could have led to a decrease in motivation. Second, as described in 5.2, subjects were students that may or may not have had access to prior *May 4th* events at Kent State. That could have led to some impact on both their motivation and interest in the topic. Future research should also include subjects that vary in age and gender; it should also include non-student samples, larger samples, a longer intervention time, and potential control groups. Finally, the field lacks instruments to measure UX in AR [67]. Such instruments could have helped refine dynamics to create a more engaging and motivating exhibit.

6 Conclusion

This research supports the promise of using location-based, AR applications for knowledge acquisition and improvements in situational interest and historical empathy. It highlighted the importance of understanding interaction design on user motivation of such applications. Developing AR content is not easy and requires significant planning and vision. Determining the knowledge level of the intended audience is critical in developing content that is relevant, stimulates new knowledge growth, and captures the learner's attention. There are also significant technical considerations to keep in mind. AR applications need to be easy to use, provide appropriate guidance on where learners are to travel to if the application is location-based. Content should be of high quality. Supplemental materials, if they are presented, should be easy to find and relevant to the source material.

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Appendix A

Knowledge Assessment – Pretest and Posttest

1. *How many students were gathered at the victory bell on May 1st to protest the Cambodian incursion?*
    a. 250
    b. 100
    c. 500
    d. 850

2. *What building was burnt down on May 2nd, 1970*
    a. Taylor Hall
    b. ROTC Building
    c. The Gym Annex
    d. Terrace Hall

3. *True or False: All guardsmen fired towards the direction of Prentice Hall*
    a. True
    b. False

4. *How many shots were fired towards the Prentice Hall parking lot*
    a. 67
    b. 76
    c. 153
    d. 37

5. *Who created the sculpture 'Solar Totem #1'?*
    a. William Taylor
    b. James Rhoades
    c. Joe Lewis
    d. Don Drumm

6. *Why is the Solar Totem #1 notable?*
    a. It was created by one of the students shot on May 4th, 1970
    b. It was knocked over in the aftermath of May 4th, 1970
    c. A bullet pierced the statue
    d. It was made of bronze and stainless steel

7. *What are the names of the students killed during the shootings of May 4th, 1970 (check all that apply)?*
    a. Jeffery Miller
    b. Allison Krause
    c. William Schreoder
    d. Donald Drumm
    e. Sandy Scheuer
    f. Joe Lewis

8. What did protestors do in 1977 to demonstrate against the creation of the Gym Annex
    a. Burnt down the ROTC building
    b. Created a tent city on the proposed construction site
    c. Held sit-ins at the Student Center
    d. Sabotaged construction equipment

9. How many people gathered on Monday, May4th 1970 to protest
    a. 2000
    b. 3000
    c. 1500
    d. 5000

10. On every May 4th since 1971, the victory bell is rung 15 times at 11:00pm. Why?
    a. To commemorate each victim at Kent State University and the two men killed at Jackson State
    b. To commemorate each victim at Kent State University and the two men killed at the University of Washington
    c. To signify the number of protestors on campus at Kent State University
    d. To commemorate each victim at Kent State University