CI-Spy: Designing A Mobile Augmented Reality System for Scaffolding Historical Inquiry Learning

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Abstract

Historical inquiry involves investigating compelling questions by analyzing historical sources to construct evidence-based accounts of the past. However, teaching students to do history is challenging. This paper discusses the design of *CI-Spy*, a mobile augmented reality system that explicitly teaches inquiry strategies and engages students to practice the doing of history in an augmented real-world context. As a case study for the design of the application, we designed and embedded multiple augmented reality activities within an instructional unit using a local historic site (the Christiansburg Institute, or CI). We conducted a pilot study with elementary students to learn how and to what extent AR technologies can support learning inquiry strategies and processes. After using our system, students demonstrated a greater understanding of inquiry and gained significant insight into the hidden history of CI.

Index Terms: H.5.1 [Information Technology and Systems]: Information Interfaces and Representation (HCI)—Artificial, augmented, and virtual realities; K.3.1 [Computing Milieux]: Computers and Education—Computer Uses in Education

1 Introduction

History is an inferential inquiry-based discipline that investigates compelling questions by analyzing historical sources to construct evidence-based accounts of the past. Preparing students to learn how to engage in the "doing of history" has long been advocated; however, the shift from theory to practice is not without its challenges [10, 11, 16]. Traditionally, the teaching of history is often reduced to the non-critical chronicling of the past via lectures, textbooks, and worksheets [3, 4]. As a result, many students find it difficult to conceptualize a past different from today, to understand changes over time, to place themselves within a historical context, and to understand how historical representations of events are constructed from the residue of the past [21, 16]. Providing avenues to scaffold and engage students as they learn to do history, while ambitious, is vital and necessary.

Activities such as field trips to historic sites and exposure to historical records and relics provide learners with important experiential connections to the past in more authentic ways than the rote memorization of historical facts [1, 19]. However, more often than not, historic sites are physically inaccessible; either they are destroyed, or many features of historical significance are lost over time [7]. In addition, learners are usually given an interpretation of history when they visit a historic site, rather than being given the opportunity to explore historical evidence on their own and practice inquiry.

We hypothesized that we could use augmented reality (AR) to combine an engaging experience of the past at a historic site with in situ analysis of historical sources to support the learning of historical inquiry. While we are not the first to use AR in the history domain (e.g. Schrier [18]) or for inquiry learning (e.g., Dunleavy et. al. [6]), our approach is novel because we not only provide an AR-based re-creation of a historic site and a visualization of change over time, but we also place historical sources within the augmented environment and provide cognitive strategy instruction. The approach provides explicit strategy to support historical source analysis within the AR application so learners can analyze evidence as they explore the site. In this way, the site itself becomes both a piece of evidence and a way to organize other pieces of evidence.

Using this approach, we designed and developed a mobile AR application called *CI-Spy* to explore the site of the former campus of the Christiansburg Institute (CI), a historic African-American school in southwest Virginia (Figure 1). The application supports multiple AR activities that are performed both in the classroom and at the site itself. In addition, the AR activities are embedded within a larger instructional unit on historical inquiry using CI as a case study. *CI-Spy* allows students to engage in the "doing of history" while using local history as a portal into understanding national history (i.e. the history of racial segregation).The instructional unit and application have been successfully pilot-tested in a local school.

Our work contributes not only a novel application category for mobile AR but also provides guidance for a number of technical, logistical, and design issues based on our experience designing and initially evaluating *CI-Spy*. Thus, in this paper, we discuss the practical use of AR at real historic sites, how to integrate AR into an instructional sequence, and how we obtained a consistent AR experience using consumer-level devices.

2 Related Work

Many educational applications have been developed to support cultural understanding and other social studies or history topics. For example, the *On-A-Slant Village* [14] was designed to help students learn about Native-American culture through experiences and interactions with virtual characters. As another example, an environment developed by the Foundation of the Hellenic World helped users learn about the culture of ancient Olympia and the history of the Olympic Games [8]. In the *River City* environment [5], students could work to integrate historical, social, and geographical knowledge in the critical thinking task of understanding the nature of illness within a virtual city.

AR has been used for inquiry learning in science in a number of projects. In an inquiry-based AR game [6], middle and high school students worked through an investigation designed to impart math, language arts, and scientific literacy skills. The findings included high engagement amongst the students and positive social interactions. However, student cognitive overload was found to be a major limitation for using AR in learning, where students felt overwhelmed with the task complexity of the system. Klopfer et al. [15] investigated design of inquiry-based AR systems for environmental simulation. They employed activities where students investigated the source of a chemical spill to determine environmental effects and travelled back in time to address effects of climate change. While these applications demonstrate the ability of AR to incorporate a variety of topics into engaging, educational inquiry experiences, our research aims to explicitly teach specific methods

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of strategic inquiry.

Many history-based augmented reality projects use a scavenger hunt model (e.g., [6]), or in the context of the University of Wisconsin-Madison's *Dow Day* game [17], a "situated documentary" designed to engage learners with answering a historical question. Typically with such approaches, the primary goals are learning historical facts and experiencing what it would be like to have been at the historical setting. In contrast, *CI-Spy* allows students to practice historical inquiry in the context of a real historic site. Similar in some regards, Schrier's *Reliving the Revolution* AR game also allowed learners to view evidence about the historic Battle of Lexington by traveling to different physical locations in Lexington, Massachusetts [18]. While *Reliving the Revolution* was designed to support critical thinking and teamwork, the game focused on evidence presentation. *CI-Spy*, in contrast, is designed to support not just the presentation of information but also the collection and analysis of evidence, while at the same time viewing the site as it existed in the past and visualizing change over time.

One of the most similar approaches to *CI-Spy* is not based on historical inquiry, but scientific inquiry [20]. Squire created a place-based augmented reality game that integrated content from the classroom with fieldwork that took the form of data collection (text, videos, chemical samples) via handheld computers. Though *Sick at South Beach* is a scientific inquiry project, *CI-Spy* is similar in spirit and design.

3 Using AR in a Historical Inquiry Learning Curriculum

Based on the prior work using AR for inquiry, our goal was to explore the use of AR for historical inquiry learning. One of our early realizations was that the use of AR needed to be embedded within a larger instructional sequence for historical inquiry – AR is only one of the tools we can use in the teaching and learning of inquiry skills. In this section, we describe the difficulties in learning historical inquiry and analyze how AR can be employed to address those problems. We then detail the design and development of an inquiry based learning unit that involves AR in multiple in-class and on-site activities.

3.1 Traditional Classroom Historical Inquiry Learning

Traditional history classrooms rarely provide systematic strategy instruction to support students' understanding of the inferential nature of history and ability to participate in the doing of history. However, as Barton [2] notes it is important to see a student's abilities to comprehend history and think historically as "a set of skills educators can nurture, not an ability whose development they must wait for or whose absence they must lament" (p. 80). Nurturing such abilities, begins with designing learning experiences that: (1) contextualize the past in authentic and meaningful ways for students, (2) provide intriguing historical inquiries and compelling, and accessible historical sources through which to investigate the past, and (3) provide cognitive strategy instruction through explicit scaffolds to guide students in analyzing historical sources in order to construct evidence-based accounts of the past [13, 16].

3.2 AR for Historical Inquiry Learning

The ability of AR to present virtual objects in-situ at a real world location provides the affordance "to enable students to see the world around them in new ways and engage with realistic issues in a context with which the students are already connected" [15]. Additionally, AR provides students with the experience of being at a real historic site. By placing virtual sources at the physical historic site, AR allows students to access and reflect on evidence in situ, leveraging the benefits of context. AR can also help students conceptualize the past and visualize changes over time.

3.3 Learning Goals

Considering the problems of contextualization, cognitive overloading, and disengagement with traditional inquiry alongside AR's abilities to support contextualization and engagement, we aimed to develop an "ambitious teaching" case [9] using AR. Our learning goals for inquiry learning indicated that students should be able to: (1) engage with sources, ask deep questions, reflect on the meaning of sources, connect sources to one another, and develop an evidence-based account of the past, (2) develop an understanding of how a local historic site fits within the larger national historical context, (3) understand time, continuity, and change at the site, and (4) use historical thinking to cultivate a sense of perspective about local and national history.

3.4 CI-Spy Case Study and Instructional Design

To address the learning goals, we designed a unit that integrated an AR application with an explicit scaffold, SCIM-C, to support historical source analysis and inquiry. The SCIM-C method introduces a set of questions for students to ask about each piece of evidence and about how multiple sources connect [11, 12]. The unit was part of a new fifth-grade course called "My Place in Time and Space," designed to nurture the teaching of historical analysis skills through inquiry-based learning activities and to highlight the importance of local history as a window into national history. We developed our unit and AR application in collaboration with the local public school system.

Figure 1: A painting of CI during its heyday (top), present day CI (bottom left), and a historical photo of a residential building at CI (bottom right)

We sought to instantiate this unit for AR-enhanced inquiry learning using a case study with a local historic site: CI, a segregated school for African Americans founded in 1867 in the aftermath of the Civil War (Figure 1). The school was open for 100 years, closing in 1966 when schools in the area were integrated. The legacy and significance of CI in terms of racial segregation made it an ideal case study for teaching local history as a gateway to regional and national history. Over the years, the CI site has changed significantly; only three acres remain out of 180 and only two buildings (the Edgar A. Long building and the Scattergood gymnasium) currently exist out of the original 13, providing a perfect setting for AR augmentations to visualize the buildings that no longer exist.

3.5 Overview of CI-Spy

We designed a series of learning activities to guide elementary school students to learn about the history of CI while practicing their inquiry skills. To achieve this, we developed a unit that: (1) introduces the concept of history as mystery where students take on the role of junior history detectives to solve a history case, (2) invites students to participate in a local history mystery that used a AR-enhanced paper map of CI in the classroom and (3) physically transports students to the now dilapidated CI site to explore evidence using AR to construct an account of the history of the CI. To guide this exploration, we presented students with a general guiding question: "What was the experience like for students at the Christiansburg Institute?" To reflect the detective/mystery nature of the activity, we named the AR application *CI-Spy*.

CI-Spy is a mobile AR application, using handheld tablet devices (Apple iPads), that provides access to the CI site by presenting virtual representations of buildings and evidence both at the site and overlaid on the paper map. It also provides functionality to collect and analyze evidence at the CI site to support inquiry. The system allows students to access historical sources while engaged in historical inquiry that blurs the boundaries between formal and informal learning contexts. The SCIM-C historical analysis scaffold, integrated within the AR tool, allows students to focus on historical analysis and move toward developing their own evidence-based account, an activity which requires deep content understanding.

3.6 CI-Spy Learning Activities

In order to meet the learning goals the unit included the following learning activities:

1. Introduction to Inquiry: Students were recruited to become "junior history detectives" by a historian on our research team and asked to help him solve an important case. They were told that they needed to practice their history detective skills first, which they did this through a paper-based activity called the "Mystery of the Tired Old Lady," which focused on the story of Rosa Parks. By analyzing several sources (photographs and documents) using the SCIM-C method, students learned how to ask questions about sources and connect pieces of evidence together, while at the same time becoming attuned to issues of race and civil rights that are relevant to CI.

2. Classroom Site Orientation (Map Activity): An in-classroom orientation activity was designed to a transition students to more local history mystery that again dealt with issues of race and segregation by introducing students to CI, the layout of the campus, and the *CI-Spy* app. The orientation activity used a large paper map of CI and allowed students to practice using the app. On the map, the app overlaid virtual buildings (modeled based on historical photographs of CI), and students could view information about the buildings and visualize changes over time in the CI campus.

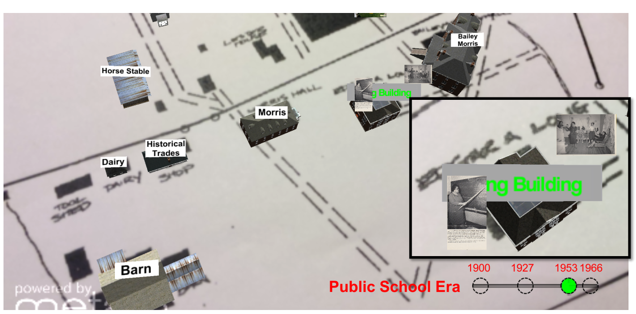

Figure 2: Virtual buildings overlaid on a paper map of CI during the Map activity. Inset: sources hovering above the Long building

3. Field Trip: Two activities took place during the field trip to CI that were designed to engage the junior history detectives in the doing of history. The timeline activity's main purpose was to acquaint students with the CI campus in its physical surroundings and allowed them to visualize changes in the campus over time. Because the timeline activity was the first on-site activity, an instructional video was presented at the start of the activity to provide context of exploration for the CI site. The video guided students to explore the CI site using the app's timeline slider.

Full-scale versions of the 3D models used in the map activity were used in both on-site activities (Figure 3). When looking at the campus through the iPad's augmented camera view, the buildings appeared at their original positions in relation to the real world. For easy identification of buildings, all virtual and real buildings were annotated with textual labels of their names.

To reflect the temporal changes, this activity used a similar timeline slider as in the map activity. By changing the slider value, students could see change over time, with buildings appearing and disappearing all around them. We restricted the time slider to four years representing interesting points in the school's history to guide students to views of the campus that were significantly different. Figure 3 shows a view of the augmented campus with real and virtual buildings through the lens of *CI-Spy*.

In the second on-site activity, called "junior detective," forty-three historical sources representing different aspects of a student's life at CI, including academics, trades education, and extracurricular activities, were located inside different buildings. Sources included photographs, videos, documents, books, and oral histories. While we initially gathered sources from over 100 years of history, our final design restricted sources to a single decade (1950-1960) to focus the educational activity. This time period was selected because of the availability of documented sources during this time period and to avoid overwhelming elementary school students with too much information from the entire time CI existed.

Figure 3: View of the CI campus during the timeline activity.

We wanted to place these sources at different locations at CI based on thematic groupings, hoping to help users organize the information spatially. This option revealed many issues that had to be addressed. We wanted to encourage students to physically walk to different buildings, collect evidence from inside the buildings, and analyze evidence in the field. Considering the size of the CI campus (most of which is physically inaccessible), the distance between different buildings, and the time needed to collect and analyze evidence, students would not have been able to finish all these activities within a reasonable amount of time. Additionally, the current site has a street with moderate traffic running through the campus, which could be dangerous for an activity involving students walking around while focusing on iPads.

After considering these factors, we decided to provide two different kinds of exploration experiences. Two buildings, the Trades building (virtual) and the Long building (real), were at locations that are easily and safely accessible and could be explored by walking within a few feet of the buildings. The other two buildings, the Historic Trades (virtual) and Scattergood gym (real) buildings, were at locations that are now physically inaccessible, so we implemented a method allowing virtual exploration of these buildings from 20-30 feet away.

The sources of evidence were virtually arranged inside the buildings based on the context and relevance. For example, sources related to cosmetology and barbering classes were placed inside the trades building, and sources related to sports were placed inside the gym building. The sources were organized inside virtual rooms based on the type of the source. For example, posters were hung from the walls, books were placed on shelves, and photographs of student work were placed on a table. This organization scheme was adopted to replicate a normal classroom that students could easily relate to.

All of the sources that students collected during the junior detective activity were placed into a "virtual backpack" within the application, along with any notes taken by the students and their ratings of the importance of each source. Students were asked to use the SCIM-C method to initially do only a shallow analysis of the evidence because of time constraints, the number of sources, potential loss of engagement, fatigue, and the slow speed of text entry on mobile devices.

4. In-Depth Analysis: Back in the classroom the following day, students looked at the sources and notes inside their virtual backpacks, to do a deeper analysis of selected sources using the SCIM- C scaffold. They were encouraged to think about how each source provided evidence to help them answer the guiding question, and recorded their observations in a paper-based "detective log." Students were also asked to think about how to combine evidence from multiple sources to deepen their understanding.

5. Presentation and Evaluation: Based on their detective logs, students put together presentations to share their own evidence-based accounts of the experiences of students at CI. The presentation could take any form students wished, but it was important that students used the sources they gathered on site as evidence for their interpretations.

4 CI-SPY APPLICATION DESIGN

We designed the *CI-Spy* application to support the instructional design, including the map activity, the timeline activity, and the evidence gathering and analysis of the junior detective activity. In this section, we describe the details of our UI design and implementation of *CI-Spy*.

4.1 CI-Spy Implementation

Because *CI-Spy* was targeted for elementary school students, an important requirement was that the device should be simple and intuitive. Thus we selected the iPad as the platform to develop the application. The iPad's built-in GPS, inertial rotation sensors, and camera can provide six degree-of-freedom tracking to update the AR scene view based on a user's perspective. For application development, we used the Unity3D game engine because of rapid prototyping and good performance on mobile platforms. For placing virtual models of the CI buildings, we used the Metaio tracking library for GPS, inertial, and point-cloud tracking.

4.2 Modeling and Visualizing the Campus

We created 3D models of the buildings based on historical photographs of the campus. For the classroom site orientation activity, the models were placed at their respective locations on a paper map using point cloud tracking. For the timeline and junior detective activities, these models were scaled and placed at the longitudinal and latitudinal positions of the corresponding real buildings using GPS/inertial tracking. For easy identification of buildings, all virtual and real buildings were annotated with textual labels of their names.

To support the junior detective activity, some buildings could be explored virtually by allowing students to view associated evidence within the buildings' interiors. To provide visual cues to convey whether each building could be virtually explored, we rendered text labels using black, green, and red. Black text indicated that the building could not be virtually entered. Green text indicated that the building could be virtually entered for viewing associated sources of evidence, and the student was close enough to virtually enter the building. Red text indicated that a building could be virtually explored, but the student needed to move closer to enter (we wanted to encourage physical movement around the site when possible to reinforce the spatial positions of the buildings/sources and to spread out student groups in different locations).

This same color scheme was reflected in a radar view, helping students understand where to find the buildings of interest. The radar view provided both directional and distance information about all the buildings relative to the location of the observer. This helped students contextualize their own locations relative to the CI landscape. To provide temporal context and visually convey change over time in the CI landscape, we implemented a timeline slider that ranged from 1900 to 1966.

4.3 Evidence Gathering Interface

In the junior detective activity, students could collect evidence from two real and two virtual buildings. Based on the types of the buildings and their physical accessibility, we implemented four different evidence-gathering modes:

(1) The virtual Trades building provided the simplest case for evidence gathering, as it was located in middle of an open field and it was possible to get physically close without any accessibility issues. Students would walk towards the building until the building label turned green. By tapping on the building, they were then transported inside the virtual building, where they could look around using inertial tracking to explore sources placed inside the building. They could then tap on sources to analyze them.

Figure 4: An x-ray view of the Long building during junior detective activity.

(2) To gather evidence from the real Long building, students walked within a few feet of the building. Since this is the only physically accessible building on the CI site, it would have been ideal to present sources inside a real room and physically walk inside the building to collect evidence. However, the real Long building is unsafe to enter and all the doors and windows are boarded up. Thus, we utilized AR's ability to show hidden infrastructure behind real surfaces (x-ray vision) to present virtual objects inside the Long building, based on point-cloud tracking of the building's exterior. We rendered a set of virtual windows that were aligned with the real windows to provide a real-world metaphor of looking inside a

room through windows (Figure 4). This setting allowed presentation of sources with perspective cues, to give a convincing effect of peering through the window into the virtual classroom. Students could then tap on a source of evidence to open it in the evidence viewer and proceed to analyze it.

(3) Gathering evidence from the real Scattergood gym building presented new design issues. This building is currently occupied and not available for student field trips. Also, a road with moderate traffic runs in front of the building, making it unsafe for children to walk closer to while paying attention to the iPad screen. To present sources inside the gym building, we considered a number of options. We decided to solve the issue by presenting an "x-ray" view through the gym wall (again using point-cloud tracking) but virtually zoomed in the view to support easy viewing. When students tapped on the green building label, the virtual room was translated closer to the student, which scaled up the view of the virtual room. The students could then walk sideways while pointing the iPad towards the gym building to navigate the virtual room. They could then tap on the presented sources to analyze them.

(4) The location of the virtual Historic Trades building was also physically inaccessible. Because the area is currently occupied by a grove of trees, we decided that students would explore the evidence from a distance. Initially we planned for students to be transported inside the virtual building, similar to the Trades building. This, however, resulted in a very noticeable dissociation between the virtual building and its location in the real world. Since this building had only two photographs as sources, we decided to simplify the evidence gathering process by displaying both photographs on the outside wall facing the student. Only GPS and inertial tracking was required in this case.

4.4 Evidence Viewer and Virtual Backpack Design

Whenever a student tapped on a virtual historical source, it was displayed in the evidence viewer (Figure 5). An important requirement for the design of the evidence viewer was that it should be simple enough to be used while exploring the CI buildings, which meant students had to use the app while standing. All the touch gestures for evidence analysis and note taking were implemented to be simple enough to be operated by one hand while holding the iPad with the other hand. All the touch gestures for evidence analysis and note taking were implemented to be simple enough to be operated by one hand (e.g., tap on a source object to open it in the evidence viewer, pinch to zoom in and out, tap to play and pause audio and video, and tap on a button to see additional information). Along with the on-screen keyboard, voice input with speech recognition was provided for note taking.

We also implemented a virtual backpack that students could use to save pieces of evidence and annotations so they could be reviewed later. As part of this process students used a five-star rating system designed to help them make a clearer connection between the guiding questions and potential value of each source to facilitate the development of an evidence-based account. Once students analyzed a piece of evidence, it was saved in the virtual backpack with all the user notes and metadata. The backpack provided a gallery view for all the collected sources for navigation and selection of sources for further analysis. Tapping on sources opened them in the evidence viewer with all the evidence viewer features enabled.

The onsite activity and evidence viewing were used to scaffold the early stages of the SCIM-C method (i.e., summarizing and contextualizing with also an aspect of monitoring based on the star system), while the later stages could be completed with deeper analysis back in the classroom.

5 Pilot Study

We conducted a pilot study to test our unit, to learn about any usability issues, and to improve the design of the app. Sixteen fifth-grade students participated in the study. The students were grouped as pairs in order to facilitate knowledge construction through dialogue and discussion and to connect their own prior knowledge with new materials and technologies. For the in-class map activity, four CI maps were provided; two groups (four students) per map. For the timeline and junior detective activities, each group of students was given one iPad, one audio splitter, and two pairs of headphones. Students freely explored the CI site, collecting and analyzing sources. All the analyzed sources were saved in the virtual backpack and were available for further analysis and recording any additional notes.

Figure 5: The evidence viewer and evidence analysis screen

Upon returning from the field trip, students further analyzed those sources in the classroom and then prepared and presented a report about CI history. The research team then discussed the *CI-Spy* app with students and their teacher.

We found that the design of the *CI-Spy* facilitated a rich AR experience and students were easily able to follow all the steps of the activity. After using the app, their teacher noted that her students demonstrated a greater understanding of inquiry and gained significant insight into the history of the CI through using *CI-spy* and working as junior history detectives.

> "*Kids LOVED walking on the grounds and seeing inside the buildings. They made great discoveries about what life was like at CI in the 50's and 60's. So many connections were made.*" [Teacher's on site lesson reflections- 10/21/14]

> "*. . . I feel that they made a connection with the students who went there; they've seen pictures of them, they've walked in their grass, they've seen their buildings.*" [Teacher's on site lesson reflections- 10/31/14]

The idea of connecting with CI students in the past was further evidenced during student presentations at the end of the unit. The SCIM-C strategy initiated many of these connections for students; many reported the "Corroborating" phase specifically helped illuminate connections across evidence within the app. Students were able to intuitively utilize the in-app tools and begin to feel part of a historical mystery. This point was reinforced by their teacher, who noted:

> "*. . . they said today they liked that you could go into different buildings, but they were craving the fact that they wanted to be able to find things . . . they are essentially being able to look and touch and turn pages of things even if they are not there any more*
> *. . . we're going to walk where they were and lets find out a little bit more. And that was the hook.*" [Teacher interview 10/31/14].

During the site visit, we observed that different students employed different exploration strategies. While many students attempted to collect as many sources as possible, others focused on collecting only a few sources and thoroughly analyzing them. These two approaches are complementary and raise interesting questions. Which of these strategies is better in terms of inquiry learning? How could we design the application to encourage students to follow one strategy or another? For the next iteration of the application, we are considering reducing the number of sources to balance out these two approaches. Fewer sources would encourage students to collect all the sources, while still having enough time for thorough in-field analysis.

Even though there was a difference in the level of on-site analysis, almost all the students were able to recall from which building they collected each source. Students reported that they could mentally connect different categories of sources to each other by remembering at which location they collected them at CI. It is notable that students were able to recall the locations of various sources even though the presentation discussion took place a week after the site visit. We also observed that students were referring to various pieces of evidence by pointing their hands towards a mental location. Students also reported that the timeline was an important tool that helped them understand the changes in the CI. Moving and switching the timeline slider to different years greatly helped them visualize the change in the CI campus.

We also found that any physical constraints that restricted student movement affected the engagement of students. Students had some tracking problems for the gym building. In this mode, students were required to point the iPad towards the building from across the street. Any movement outside the boundary area caused the application to stop displaying the scene and resulted in a break in the experience. Another break in engagement came from the intermittent GPS tracking of the iPad. In our next iteration, we plan to use a hybrid approach for tracking by using physical markers along with GPS tracking.

6 Conclusion and Future Work

In this paper, we described the design and development of a mobile augmented reality application (*CI-Spy*) and associated learning activities that focus on teaching inquiry skills. In *CI-Spy*, we combine the engaging experience of the past at a historic site with explicit inquiry learning strategies. We used a local historical site as a case study to provide an on-site AR-based experience along with historical artifacts within the augmented environment to provide contextual information.

Our work makes significant contributions to the AR community by successfully applying AR to the novel area of inquiry learning in history. This research enabled deeper understanding of historical inquiry for younger students by combining AR experiences with strategic learning along with a framework to support in-field inquiry. Our work contributes not only a novel application category for mobile AR, but also guidance for a number of technical, logistical, and design issues based on our experience designing and evaluating *CI-Spy*. The app supports context-switching between the outdoor campus view (with traditional augmentation of the real world with virtual content) and virtual interior views of the buildings for collecting historical sources. In our pilot study, students were able to intuitively use the in-app tools and successfully complete all the activities without difficulty, and feedback was overwhelmingly positive.

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