Authentic Problem-Based Learning With Augmented Reality

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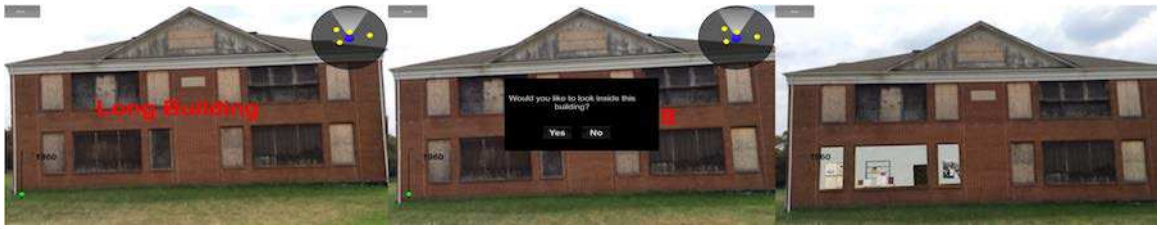
Abstract: This work resulted in an authentic problem based – and place based – historical inquiry unit utilizing augmented reality and an engagement-first approach to scaffold disciplined inquiry, facilitate student understanding of change over time, and motivate and sustain students through the inquiry arc. The design was guided by cognitive research that recognizes both the psychological and social aspects of learning. The outcomes represent both research findings across 14 participating classes as well as a more specific look at the activities of one student group, documenting their experience and perspectives in-situ. Data gathered include interviews, usage logs, student notes and student final projects. All interviews and video recordings were transcribed, indexed and underwent inductive content analysis to identify key themes around motivation to learn and explicit learnings and negotiations with the app. Our findings suggest that AR can facilitate and sustain an inquiry through making the invisible visible in authentic and challenging settings.

Keywords: augmented reality, place-based learning, historical inquiry, authentic problem-based learning

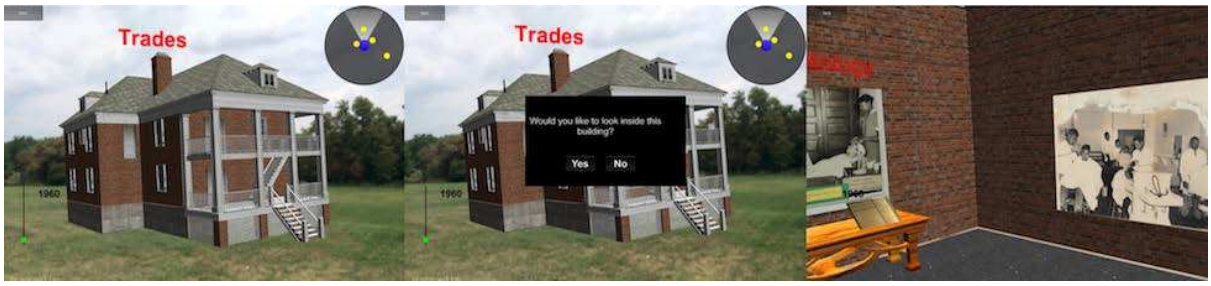
This paper reports on the outcomes of an augmented reality (AR) application designed to scaffold schoolchildren's investigation of the hidden local history of a former African American school – Christiansburg Institute. A transdisciplinary team of Virginia Tech faculty in History, Education, Computer Science, and Visual Arts, public school teachers, the school division's social studies supervisor, and Christiansburg Institute alumni worked together to build the place based/problem based historical inquiry unit of instruction that used AR to allow students - with little or no knowledge of what the historical site was – to engage in cultural fieldwork. The app, *CI Spy*, was part of a unit designed to introduce 5th grade students to the site's history, purpose, and significance while engaging with a range of historical sources in a place-based inquiry (See Johnson et. al 2017). At the initiation of this project we hypothesized that AR with a built-in explicit strategy/scaffold for historical source analysis (SCIM-C: Summarize, Contextualize, Infer, Monitor and Corroborate) could support in-situ analysis of various historical sources while leveraging the power of context and place to motivate and sustain students within and through a historical inquiry as they learned about school segregation. Currently, the site of Christiansburg Institute, once a thriving 13 building campus of over 180 acres, is little more than a single derelict building in an empty field next to an industrial park. Few in the community know of the school, and it is truly a hidden, difficult history that the school division is now seeking to integrate within the history curriculum.

We created *CI Spy* to make the invisible past visible to students. That is, *CI Spy* was designed to help students see the growth and demise of the campus by using virtual buildings to provide a sense of its physical scale and presence. Additionally, *CI Spy* allowed students to "virtually" enter into the lone inaccessible derelict classroom building (Figure 1) and two of the virtual representations of buildings - long since demolished – (Figure 2) in order to collect and analyze historical sources (Figure 3) as part of a student-centered inquiry into the local history of school segregation.



(a) (b) (c)

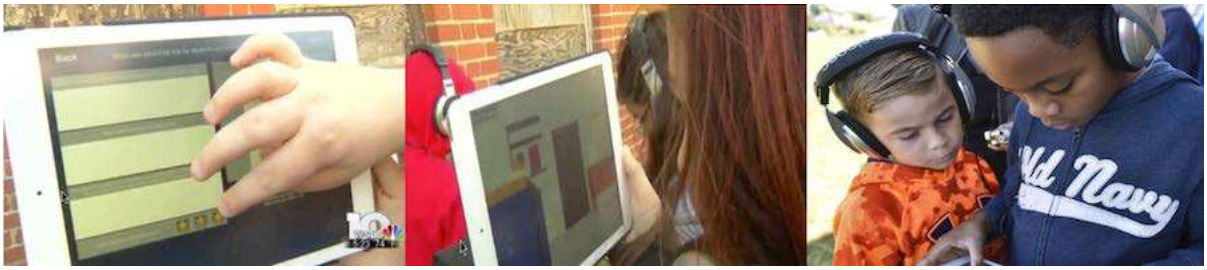
Figure 1. An inaccessible building (a) can be explored (b) with a virtual classroom via AR (c).



(a) (b) (c)

Figure 2. Students tap a virtual building (a), confirm they'd like to enter (b), and explore the evidence within (c).

Without the use of AR this fieldtrip experience, designed to foster an inquiry and also facilitate a sense of walking in the footsteps of others, would have been impossible. A sense of place, scale, and what once existed on the now abandoned site were provided via the app, while at the same time it integrated the explicit scaffold based on SCIM-C to support the students' inquiry.



(a) (b) (c)

Figure 3. Students use the scaffold (a), explore a virtual room (b), and work in pairs to record field notes (c).

Historical inquiry, explicit scaffolds and the importance of place

The teaching of history has been observed by generations of students and researchers as clinging to a very specific pattern of teaching: the teacher talks and students listen, read, and answer questions in textbooks. Students are then expected to memorize facts and details that for the most part are "removed from their intrinsically human character" (Goodlad, 1984, p. 212) and completely at odds with visions of powerful teaching and learning elucidated by the field. What is often lost or forgotten in such teaching is a clear goal of explicitly preparing students to actively engage in inquiry, perspective taking, and meaning making. Historical inquiry is the process of engaging in purposeful and reflective mental activities that strategically explore multiple perspectives through the reasoned drawing of inferences, the integration and synthesis of information, the evaluation of reliability and perspective, and the generation of possible understandings and interpretations (Bain, 2005; Levstik & Barton, 2005; Wineburg, 2001). History learning as a specific domain requires deep inquiry; considering and evaluating historical sources brings disciplinary rigor into the process and helps children develop the best possible arguments for whatever stories are formed. Further, the process of considering different pieces of evidence from varying sources can help elicit an understanding that alternative stories exist with varying perspectives, and the stories with the most support may not necessarily be the stories we would prefer to tell. The recognition for perspectives affected by critical inquiry can help students to achieve a deeper understanding of the importance of according people in the past the same respect as we would want for ourselves (Lee, 2011).

Ongoing research on explicit scaffolds in history education and beyond has established that they can be effective in helping learners to understand the inquiry process and to analyze historical sources (Belland, Kim, & Hannafin, 2013; Hicks & Doolittle, 2008; Hicks et. al 2016). Currently there is only a small body of empirical research designed to examine how digital technologies can support the teaching and learning of the doing of history (Britt et al., 2000; Saye & Brush, 2002). Much of this research (Saye & Brush, 2002; Hicks, Doolittle & Ewing, 2004; Hicks & Doolittle, 2008) has sought to examine how multimedia tools can broadly scaffold the analysis of multiple and single historical textual sources as part of the process of engaging in problem based/historical inquiry.

Visitors to historic locations can experience intense engagement, a loss of the feeling of the passage of time, and a connection with others across time and space (Cameron & Gatewood, 2000; Maines and Glynn, 1993). This suggests that placing learners within real historic contexts where they can interact with people, material

objects, visual and spatial information (Schwartz & Heiser, 2006), and processes and scaffolds could enhance the quality of learning (Barron & Dobbs, 2015; Coulter & Polman, 2004; Dunleavy et al., 2008; Dunleavy & Dede, 2014).

Augmented reality as instructional application

Regardless of the affordances mobile computing provides, sound pedagogy and instructional design remain primary determinants of success. In a project using GIS (geographic information system) software and GPS (global positioning system) to engage students in inquiry-based learning, Coulter and Polman (2004) concluded that focused curricular planning led to a more successful implementation than an "activity exposure" approach. Citing cognitive overload and unproductive mental effort as risks to learning in discovery-based learning environments that rely heavily on multimedia, Clark, Yates, Early, and Moulton (2010) support the use of guided training methods instead. Nevertheless, in a recent review of AR teaching and learning Dunleavy & Dede, (2014) contend that, "as a cognitive tool or pedagogical approach, AR aligns well with situated and constructivist learning theory as it positions the learner within a real-world physical and social context, while guiding, scaffolding and facilitating participatory and metacognitive learning process such as authentic inquiry …" (p.737).

Research design

The provenance for our methodology is informed by design-based research, where specific curriculum or instructional treatments are iteratively tested within real educational settings, (Parker et. al, 2011; Saye & Brush, 2017), and protocols developed by Graham Nuthall as part of the Project on Learning (Nuthall, 2000; 2005). Our work was designed as a unit of instruction within a locally-developed ambitious 5th grade curriculum (Kracjcik & Blumenfeld, 2006, p. 326), entitled *My Place in Time and Space,* to investigate a forgotten local history via the site of a former African American school. Our research work is now in its fourth year and ongoing. Data for this paper is predominantly from 2014-2015.

Instructional treatment

Our perspectives for the design of instruction were guided by cognitive research that recognizes both the psychological and social aspects of learning (Anderson, 2009). Specifically, we pull from the How People Learn framework (Donovan & Bransford, 2005), situated learning theory (Anderson, Reder, & Simon, 1996; Brown, Collins, & Duguid, 1989), social constructivist learning theory (O'Donnell, 2012; von Glaserfeld, 1995; Vygotsky, 1978), the motivation to learn literature (Jones, 2009), and what Newmann and associates (1996) term Authentic Intellectual Work (AIW). As Shaffer and Resnick (1999) and Newmann et. al (1996) contend, authentic instruction occurs when learning is personally meaningful, relates to the outside world, provides opportunities to engage in substantive disciplinary conversations as a way to facilitate participation in a "knowledge creating culture," and supports higher-order thinking skills that can be assessed appropriately. Sawyer (2008) also speaks to anchoring "authentic knowledge in its context of use" (p. 9). The idea of leveraging digital technologies as part of the process of "authentic instruction" to build theoretically-based and contextually aware scaffolds to support tightly bound disciplinary specific work is also informed by the literatures on the value and impact of historic sites/buildings to "read" and engage with the past and others across time and space (Baron & Dobbs, 2015), and the potential of problem based learning and more specifically technology enhanced problem based historical inquiry models (Brush and Saye, 2017). Our design leverages the power of place, the context of a problem and an explicit scaffold to embed authentic practices (historical inquiry) in a meaningful context, reduce the complexity of those practices and make them explicit (SCIM-C), and build upon prior knowledge (Edelson & Reiser, 2006, p. 336).

For this project, as detailed previously, a lone remaining building remains of the former 180-plus acre campus. This provided the basic context for our week-long fifth-grade unit. The unit itself would be framed around the question: "If this building could talk, what would it tell us about the people who were here 50 years ago and their experience?" In order to prepare students to explore this question on the site, the unit featured two separate in-class lessons that focused on harnessing requisite skills and digital literacies for the investigation. The fact that site was a segregated school was not revealed to students but rather reserved as part of the investigation and left to them to determine.

Data collection and analysis

The study included 14 fifth-grade classes, comprising 288 children within one local school division. Data collected included: field notes and video-recording of how the app was used in the classroom and on the field trip (this included student think-alouds as they used the app on the field trip); location data for each student group including

a log of the order of locations visited, time at each location, number of historical sources viewed, word count during analysis, and the number and range of sources students identified as significant; small group student interviews - post unit; student work samples generated as part of the unit - including detective journal and final products; teacher interviews - post unit.

All data was categorized by class and student teams so that interviews, data logs and student work could be aligned in order to trace the interactions and use of the app through to the final product. All interviews and video recordings were transcribed, indexed and underwent inductive content analysis to identify key themes around motivation to learn and explicit learnings and negotiations with the app (Sawyer, 2006, p. 13).

Findings

The project's findings reflect the complexity of capturing fifth grade students' capacities to think historically (both in-situ and post process) while tandemly assessing the role and impact of AR learning environments to support student historical inquiry and historical understanding. Our findings are considered within the context of the research question/perspectives guiding this work: Can we design an authentic problem based – place based – historical inquiry unit that utilizes augmented reality and an engagement-first approach to: 1) scaffold disciplined inquiry; 2) facilitate student understanding of change over time, and depth of understanding around school segregation; and 3) motivate and sustain students through the inquiry arc? The outcomes represent both generalized research findings across the 14 participating classes as well as a more specific look at the activities of one student group, documenting their experience and perspectives in-situ.

As part of the iterative design process, observations in the field and data log from our pilot test revealed the necessity to shift from the concept of unguided student exploration of the site (where students were tasked with simply exploring the site with the app), toward a guided exploration approach in order to sustain students within the inquiry arc. The guided exploration approach enabled many students to reach beyond the "wow" factor leveraged by the initial AR experience on site and sustainably engage with evidence through the process of inquiry on site. Once the higher level of guidance was in place, data log usage revealed a general increase in time spent with evidence and field observations noted a progression in sustained student engagement. The balance of guided exploration coupled with an appeal to student interest via augmented reality interaction on site proved a synergistic combination and contributive factor in sustaining inquiry with 5th graders.

With regards to artifacts, students identified photographs, newspaper clippings, and the daily class schedule as the most important evidence and these items were subsequently used most heavily in student work. Students placed less importance upon oral histories and transcripts and more text heavy sources and as such cited them less frequently within their final reports. Overall student final reports support the assertion that the AR unit contributed to student understanding of change over time and depth of historical understanding of school segregation further reflected in frequent empathetic stances invoked in student final reports.

Within many final reports, students make specific links to evidence and location as they develop a response to their question in a letter to the chief detective. What becomes clear in their final write up is that they directly connect to the evidence they investigate and also pay attention to the period and context from which the evidence emerged. Typically, and importantly, all groups were capable of identifying the space within which they were moving as previously being an African American School during the era of segregation that while prominent in the area was closed in 1966 as a result of integration.

Prior to developing their written reports, data collected also suggests that the built-in historical thinking scaffold (SCIM-C) within the app and the application of the engagement-first strategy helped students stay within the inquiry process and foster their understandings of the evidence in relation to the guiding question. In follow-up group interviews, students consistently voiced a positive interaction with SCIM-C and even reported they felt like historians working with evidence and interpreting the past. To this end, one student noted, "by taking the evidence through analysis, we weren't just given knowledge and that made it more fun. We had to think about it more – and if all we did was read about it in a textbook, it's really not going to stick in our heads."

In analyzing sources using SCIM-C, students' analysis and engagement supported Nuthall's (2000) assertion regarding multiple stages of interaction and its relation to acquired understanding. In reflecting on the use of SCIM-C, one student added: "The questions helped a lot because it helped you see something that connects, so you want to go back and see and be like, oh, this connects with that." Similarly, another student added: "I think the questions were really helpful because you didn't just read about it on the other stuff. You read about what's in the questions and you went back and actually looked at it. That kind of helps you learn more, like, if you go back and do it again and read it again and reread. That's how I think the questions were really, really helpful."

While it was possible to trace many team's final written products directly to the evidence they noted in the virtual detective note books and stored in their virtual back packs it is important to note that the amount or level of actual written analysis stored in their virtual back packs was not necessarily always as detailed as we had

initially expected or envisioned. Analysis of response frequency within data logs showed that 94% of summarizing questions and 86% of contextualizing questions were attempted across all 14 fifth-grade classes involved; however, only 67% of monitoring questions and only 78% of corroborating questions were attempted (typed into the historical thinking scaffold within the app) in-situ. There was a clear discrepancy between how they talked through their analysis and what they actually recorded/wrote up on site. These results suggest that as scaffolding questions and phases of inquiry grow in complexity and sophistication, so too does the likelihood such phases will be abandoned or only minimally attempted when students are expected to record their ideas through typing.

However, for many groups, their final written reports clearly showed they had engaged with, paid attention to, and were now using and working across the sources to transform them into evidence to report that the site had been an African American school, while also providing details of these students experiences in the past at that site. What is also revealing is that even for those groups of students whose final written reports lacked the type of specific details that we hoped students would glean from working through the app our video recorded observations and accompanying prompted think-alouds of student teams reveals that even these students, through the use of the app could (1) identify and make reference to the buildings that were no longer there that formed part of the campus, and probably more significantly (2) verbally unpack individual sources in a systematic manner and (3) stay with and puzzle through evidence in order to draw thoughtful inferences. For example, videotaped observations of one group of students captures the moment that they struggle with the concept of "trades" as they investigated the virtual "Trades Building." The evidence in the Trades Building included photographs and oral histories of students learning barbering and cosmetology. The group directly access, and refer to, specific evidence prior to making the claim that the site may have been an African American school. What becomes important here is that both students actively interact with their shared tablet as they look around the interior of the virtual building and both tap on the screen to access and look at specific evidence.

Student A:	[holding tablet and pointing it across the street toward a construction site where the Trades Building once sat]. "So, we have to head toward the green one?" [At the same time student B touches the screen and hits the green titled trades building tab]. "Oh weird." [Student B is trying to keep up with student A as he spins to his left. They are now inside the virtual building]
Student B:	Are we inside? It looks like something at ... [both are touching the screen while student A is holding it and completes a 360-degree turn]
Student A:	This was called the Trades. Is trades a word for Barbershop or something like that? Hey, is it an African American? That might prove some-
Student B:	[Points at the screen] "Oh look, it's a barbershop."
Student A:	Yes, it's a barbershop. Why was it called trades? I wonder why it was called trades then? When it's got barbering. [Students continue turning around the virtual building interior while looking through the tablet] let's take a look at barbering … it might have been an African American school.
Observer:	What makes you think that?
Student A:	I think I might have found some evidence that proved it. There is like, here [points to photograph] there is barbering and it shows, like a picture of an African American, and there is like sound [oral history] … So, I'm going to listen to that. [signals partner to get close as they play the oral history]

Additionally, video recorded observations of student teams also provide examples of students corroborating across sources to make evidence-based claims. Such corroboration reveals that even when teams were confused by some individual sources, they were capable of referring back to previous examined sources to sharpen their understandings of what they were now seeing and reading. Such corroboration, for a number of groups, occurred after visiting the third and final building – the Gym. For many groups, the issue of race and who went to the school only began to percolate as they began to specifically investigate the photographs of student activities, starting in the trades building and then more systematically in the virtual Gym. However, the fact that the photographs were black and white served, at the time, as an initial stumbling block to making the inference that the site was a segregated school. Interestingly, it was only when groups started to read a short newspaper article – located in the virtual Gym – about a performance of the glee club and band that they slowly came to infer and make the claim that this was an all African American school.

Student A: [Reading a newspaper report about a Glee Club performance aloud after telling the interviewer/observer that he thinks it might be an African American School, he quotes directly] "Negroes can excel in music and education" ... [looks at observer] [the school] is showing the public that Negroes can excel. Which means that to know this, they would have had to have Negroes at their school.

Observer: Do you see any other evidence that might suggest that it was an African American school?

Student A: Yes, because … um … [taps on tablet screen as both partners look at screen] in the other pictures [referring to the photograph in the virtual gym which is where they are now] and in some of the things inside of the Long Building, there was some talking about having African Americans here, or just colored people here at [the school]. And the pictures show that they are not white people. Although there are some white people in the picture. Like they look kind of white, but it is black and white pictures, so it is kind of hard to tell. Um … so, I think this is actually pretty important because all the other things like the newspaper [points at tablet screen], not the picture especially, but the newspaper [which he was reading earlier] is telling us that it is probably a negro or colored school. [begins one-fingered typing as part of analysis] so, errr … yep. [continues to type as partner watches]

What is also striking within the student's discussion around the sources is that as he read the article and began to use it to make sense of what this site was in the past, he began to use words such as *Negro* and *Colored* that came directly from the source. His use of such language as part of his think-aloud illustrates the extent to which he was paying attention to the details of the sources while trying to use the sources to make a claim. Importantly, given the nature of the sources the students would interact with, prior discussions were had based on how and why such language would not be used today, but as part of an historical inquiry, and working with historical sources, one has to pay attention to the language and context of the period being investigated. Our taped observations begin to reveal how these students used the app to access sources and persist with an inquiry in-situ, while also beginning to get a sense of this site as a place with a history that was no longer visible. Their taped analysis also begins to reveal how even these young fifth grade students were able to begin use individual sources as evidence, before working across multiple, and sometimes confusing sources, to verbally corroborate and engage in a level of disciplinary analysis that, without being recorded, would have been lost and not evident within their final write up.

Discussion and conclusion

By specifically seeking to illuminate the impact of an augmented reality app to support student learning and specifically students' abilities to think/express disciplinary thinking (both in-situ and post product), our findings reveal the complexity inherent in both designing instruction to support the inquiry arc and developing research protocols that make learning visible in terms of capturing the process of young students' disciplinary thinking. These issues are amplified by navigating place-based history education, hidden and difficult histories, elementary students, and an engagement first approach to the acquisition of historical knowledge. What is clear and methodologically important is that if our analysis had purely focused on student work products in terms of their detective notebooks and final reports our team would have missed vital and positive insights gathered through participant videotaped observations. Videotaped observations that followed students through their entire field trip clearly illuminate how they used the app to engage with the sources in terms of summarizing, inferring, and corroborating across sources in order to verbally make evidenced based claims to answer the guiding question. While some of these claims were clearly evidenced in their final reports, this was not always the case and without capturing/recording their thinking through observations such important emerging disciplinary thinking skills would have remained invisible/ephemeral. This significant insight itself highlights the need for further refinement of the app in terms of shifting from having young students with little hands type their analysis to: (1) providing them with the option of voice dictation to capture their ideas and analysis; and (2) developing the type of real-time actionable and explicit strategic feedback to support students' persistence and engagement as they unpack individual sources and look to corroborate across sources. Such feedback would replace the prompts from the researchers in the field that encouraged students to monitor their understanding as they progressed through the investigation.

Our findings illustrate the ability for AR, when combined with an explicit scaffold, to support young learners through an inquiry arc. The data collected illustrate a gap between the children's ability to produce evidentiary warrant for their claims and our ability to capture that processing through quantitative data points. Only by carefully reviewing observation and interview transcripts was the process through which our young learners unpacked evidence and made inferences revealed. Much of the terseness in the students' written responses was likely due to the simple fact that typing field notes on a tablet is not an easy task for a young person. However, despite hindrances like these students were capable of performing historical inquiry and creating their own evidence-based account of a local hidden history, as articulated through their think-alouds while on site (Sawyer, 2008, p. 6). The promise of this approach calls for further refinement of the experience and tools to better support historical inquiry and other problem-based approaches to learning.

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