Mobile Learning in Museums: How Mobile Supports for Learning Influence Student Behavior

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ABSTRACT
Nomadic scientific inquiry – technology-supported authentic inquiry done on-the-go, across settings – has the potential to engage students in learning new concepts and practicing essential science skills. We developed the Zydeco system to support nomadic inquiry in part through enabling the collection and annotation of multimodal data (photographs and audio notes). The system was designed to bridge school and museum contexts through project-based science inquiry. In this study, we explore how Zydeco influences student behavior and sensemaking in the museum. We compared the behaviors of middle-school students who used either Zydeco or paper worksheets to perform inquiry in a museum, and found that, while both the worksheets and the system engendered heads-down behavior, the Zydeco system increased active sociocultural engagement.

Categories and Subject Descriptors
K.3.1 [**Computer Uses in Education**]: Computer assisted instruction (CAI)

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms
Design, Human factors

Keywords
Mobile learning, nomadic inquiry, scaffolding, informal learning, learner-centered design, mobile devices, museums

1. INTRODUCTION
Three main goals of STEM (Science, Technology, Engineering, and Math) education are prevalent: to create an informed and engaged citizenry capable of principled science-based decision-making and policy evaluation; to encourage the development of lifelong learners who have the ability, curiosity, and interest to pursue - in a self-directed manner - scientific topics, and to inspire talented students to pursue STEM careers with the ultimate goal of improving society and the world [1, 23]. Meeting these goals requires engaging students in the process of inquiry -- the cognitive strategies that drive STEM learning.

Inquiry is complex, and in schools is structured, sequenced, and supported by teachers. For example, Project-Based Learning (PBL) is one strategy used to engage students in meaningful inquiry in schools. PBL is based on four essential components: (a) a meaningful driving problem that drives student learning throughout the investigation, (b) collaborations among teachers, students, and the community, (c) investigations that support the development of artifacts to help students "learn content, represent information, and apply knowledge", and (d) technological support [16]. Although PBL-based learning environments can vary in terms of the amount of teacher guidance and student direction, they are designed to support students to develop inquiry skills and content understanding over time.

In contrast, the vast majority of scientific experiences people have in their lifetimes take place in non-supported, non-sequenced contexts outside of school [22]. Helping students conduct inquiry across formal and informal settings is a way of scaffolding students to practice inquiry. Additionally, it helps students understand the value of inquiry outside of school, while building knowledge and developing competence in using scientific ways of thinking and knowing. Nomadic inquiry – technology-supported inquiry conducted on-the-go, across settings – has the potential to scaffold students' capacity to use scientific ways of reasoning in everyday life by way of engaging students in meaningful PBL investigations that connect the content and skills students learn in school to real world settings [28, 33].

However, there are several challenges to using technology to mediate learning in informal settings. Some educators and museum professionals express concern that using handheld technologies can distract students with novelty and usability issues, and detract from the museum experience by encouraging "heads-down" focus on technology instead of exhibits and interpreters [30]. Furthermore, though new handheld technologies have many affordances that facilitate inquiry and provide cognitive and metacognitive support, few studies have demonstrated how these technologies impact student focus or sensemaking in the museum. Thus, more research is needed to determine how to best support nomadic inquiry and facilitate the development of conceptual understanding across settings [21].

To address this need we designed the Zydeco system: a tool to support nomadic project-based inquiry between the classroom and out-of-school settings such as museums, zoos, parks, and aquaria. The Zydeco system includes online and handheld tools to help students and teachers plan an investigation; collect and annotate evidence, and sort and analyze the evidence in order to make scientific explanations to complete their investigations. In class, before going on a field trip, the students begin to investigate a driving question or design prompt. This question or prompt is related to their science curriculum and is deep, interesting, open-ended, and feasible (i.e. it can be investigated through evidence collected during the field trip) to allow for sustained inquiry [17].

The class defines sub-questions that will help them address the driving question or prompt, and predicts what they might find to answer the question. These predictions will be the preset tags that students use during their field trip. The subquestions and the potential annotations are entered into the online component. We designed the Zydeco application, which allows students to download their investigation - including the driving question, subquestions, and tags - onto a handheld device in the museum. There, students use Zydeco to capture evidence in the form of photographs and audio notes to address the subquestions. Once students collect a piece of evidence, they are prompted to record a voice note to explain why that evidence helps them answer the subquestion. Afterward, students are prompted to tag the photograph using either the preset tags they defined in the classroom, or by adding a new tag or voice note. Upon returning to the classroom, students can use the online component to access, organize, analyze, and construct explanations using the data they collected.

We conducted a pilot test to evaluate different components of the Zydeco system, in order to answer the following question:

- How does using technology to capture and annotate data in the museum impact student behavior?

To answer this question, students were videotaped engaging with exhibits at the museum, using either a worksheet or the Zydeco handheld program, and their behavior was evaluated for evidence of engagement with:

- Other people
- Museum exhibits
- The technology or worksheet

Our evaluation of students' behavior and talk using the worksheet: the traditional mode of connecting the classroom and the museum content that anchors our interpretation.

The first study we will discuss involved a pilot test of part of the system with four classes of 7th-grade students. Although school- and class-level information is not available, the school and classes are representative of a diverse district in which 56% of students qualify for free or reduced-price lunch.

In this paper, we first present the design principles and theory underpinning the design of the Zydeco system. Following this is the analysis of the enactment, detailing how the handheld program supports influenced student behavior and sensemaking in the museum.

2. BACKGROUND

According to the Contextual Model of Learning -- a framework for understanding the factors that influence learning in informal settings -- learning in museums is impacted by aspects of the personal, social, and physical contexts [8]. The personal context involves a learner's prior knowledge, interests, and experiences; including how much choice and control they have over their experience in the museum and their motivations and expectations related to the museum visit. The social context includes the social interactions that a visitor has with others within and outside of his or her own social group. The physical context involves all of the tools that mediate the learner's experience in the museum, including: the design and arrangement of exhibits, advance organizers that cognitively structure the experience, the physical space and architecture, and orienting devices such as signs and maps. Learning is also influenced by subsequent experiences that extend or reinforce the museum visit. Falk and Storksdieck (2005) further characterize learning in this framework as "an effort that is best viewed as a continuous, never-ending dialogue between the individual and his or her physical and sociocultural environment" [10].

The design of our system addresses multiple facets of this framework in order to facilitate learning in a museum (See Table 1). However, bridging the formal classroom and informal museum learning environments involves a delicate balance between structuring the experience in the museum to help students make connections to the content and skills of the school curriculum. This bridging involves giving students enough choice and freedom to allow them to explore their own interests in the museum; having social interactions around exhibits, and pursuing learning opportunities that are personally meaningful and intrinsically motivated [7, 8, 18].

Several research studies suggest strategies to help better bridge these gaps and to improve outcomes from field trips. Particularly, investigative field trips, which focus on problem solving, observation, and exploration of phenomena, these field trips elicit better learning and affective outcomes than confirmatory field trips, which focus on the re-visitation of concepts learned in school [25]. Zydeco's inquiry-based structure adopts this investigative model.

Within the investigative model, support for students during the field trip is essential for strengthening the conceptual, affective, and social outcomes of the museum trip. Helping students navigate the museum in a mindful manner - in alignment with their own interests, the social nature of learning in the museum, and with an open-ended conceptual agenda related to their previous knowledge and preparation from the classroom – can further ease the transition into the museum [13]. The use of open-ended questions or prompts, designed by the students in relation to the class curriculum, can allow students' choices in their exploration of the environment to be mediated through the lens of curriculum content [13, 19]. This mediation helps bridge the gap between the more structured learning environment of the classroom and the free-choice learning environment of the museum, giving them an agenda to guide their investigations while providing some freedom of choice in their exploration of the investigations [9, 19].

Following the field trip, further support is needed to help students connect their experiences from the museum back to the classroom [2]. Providing opportunities for students to revisit their museum experiences; to build new understandings based on these experiences, and their prior classroom learning helps improve conceptual and affective outcomes of the museum visit [13, 20, 32]. Back in the structured classroom environment, students can build stronger connections between their experiences in the museum and science concepts learned in the classroom [2].

Handheld technologies that scaffold "nomadic inquiry" show great promise toward supporting both teachers and students during field trips [14]. New handheld technologies, such as the iPod Touch, enable students to collect multimodal forms of data such as photographs, video, voice notes, diagrams, and text. In combination with a learner-centered curriculum, handheld devices have the potential to provide just-in-time mediation and support for students during their field trip.

For example, the BioKIDS program used handheld devices to enable students to collect data about organisms in their schoolyard, providing a streamlined and scaffolded way for students to collect and categorize their findings [28]. This program was designed to support specific content goals. Several researchers have used mobile devices to support tagging, or the collection of data or experiences in museums for later investigation (i.e. [6, 15, 31]). For example, interactive guides and devices (e.g. RFID tags) enabling users to track, personalize, and record a museum visit for later online exploration have been shown to increase the motivation and engagement of learners, and to increase later visitation to museum websites [14, 24]. Furthermore, revisiting museum experiences by watching videos, looking at photographs, and reviewing personal observations and reflections, has been demonstrated to increase visitor learning and sense making of the museum experience [5, 29].

Additionally, the MyArtSpace program [31], allows students to use a mobile phone to take pictures, record sounds, write comments, and "collect" objects in the museum by typing in the object's code number. The researchers found that students using the MyArtSpace program were motivated to use the program to explore the museum, and that the program effectively bridged the gap between classroom and museum learning by providing a way for teachers and students to connect easily to the museum content after the visit. They found that more support was needed to help teachers prepare students for the museum visits, as many teachers did not orient students to the purpose of their investigations and use of the program until they arrived at the museum. In addition, students needed help organizing images, sounds, and ideas they collected. Students would often collect unwieldy amounts of information and struggle to make sense of this information when they returned to the classroom. The researchers suggested that students needed more structure and guidance to help them make meaning of the museum experience during and after their visit [26, 31]. These efforts have suggested a strong affective and conceptual value of having the opportunity to revisit museum experiences after a field trip [11].

The design of Zydeco has learned from and builds upon this previous research, utilizing a Project-Based Learning approach to bridge learning across different settings and engaging students in meaningful, student-centered, interesting inquiry, and employing handheld devices to enable students to conduct mediated multimodal data collection, annotation, and organization.

3. ZYDECO

In this section, we describe the design of the Zydeco program. At the time of the pilot studies, the handheld portion of Zydeco had been created, but the online supports for the pre- and post-visit activities had not been developed.

Zydeco's design is based on the principles of Project-Based Learning (PBL). The PBL framework is a strategy particularly suited to museums, as evidenced by its synergy with the factors of the Contextual Model of Learning [12]. Students are first introduced to a *driving question* or prompt to investigate. This driving question must be interesting, open-ended, deep, and able to be investigated by collecting data in the museum.

Next, students and teachers collaboratively create a plan based on their prior knowledge and experiences to help collect data to answer the question. First, they identify what they will need to find out to answer the driving question or challenge. The questions they need to answer are the mediating *sub-questions* that guide students in the museum. Next, the students use their prior knowledge and experience to hypothesize what kinds of answers and information they expect to see in the museum to answer the sub-questions. These answers become the *tags* that students use to annotate and label the data they collect. The sub-questions and the tags are uploaded to a handheld device, where they mediate student investigations in the museum (See Figure 1).

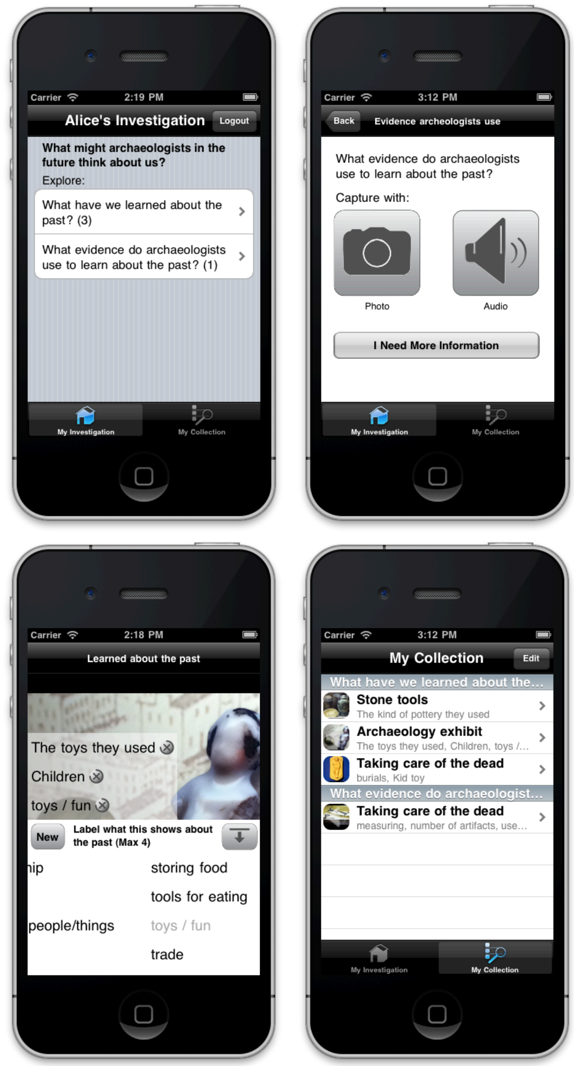

Figure 1: Parts of the Zydeco inquiry application. (top left) Driving question and sub-questions. (top right) Choosing how to collect data. (bottom left) Tagging data. (bottom right) Reviewing collected data.

During the field trip, students explore the museum, using the mobile device to collect and annotate data to respond to the sub-questions. When a student decides to collect data, he or she selects the sub-question related to the data, and chooses to take a photo or audio note. After collecting the data, the student is prompted to record an audio note explaining how the data relates to the sub-question. This prompt is designed to encourage students to be reflective and deliberate about their data collection and annotation. Next, students are prompted to tag their data using the tags they created in the classroom, or by creating a new tag to characterize and categorize the data. After tagging, students can review their data and revise their audio notes, photographs, and tags as desired. When the student is finished, they move on to collect further data, or review their collected data.

After the field trip, the data is uploaded to a website, where students can sort their data and the class data by tags and sub-question, and review, reorganize, analyze, and synthesize their findings in order to create a scientific explanation relating to the driving question. Students work together to explore and synthesize the collected data in order to create explanations, an authentic practice that supports skills for scientifically-based research and collaboration in lifelong learning (*supports for reflective data review*); they are supported by learning technologies throughout the experience that help students gather, organize, analyze, synthesize, and explain collected data (including the interactive outline, tag functionality, ability to *collect multimodal data,* and the reflective data review); and they create artifacts, including the interactive outline, annotated data, and scientific explanations [17].

4. COMPARISON: WORKSHEETS AND ZYDECO

4.1 Description and data analysis

The pilot study was conducted with 86 7th grade students from a diverse middle school in a district where more than 50% of the student qualify for free or reduced-price lunch. Pre- and post-visit activities were led by the students' social studies teacher. This study investigated a limited version of the Zydeco program (See Table 1).

Two 7th-grade teachers (including the social studies teacher), a museum educator, a science education researcher, and an archaeologist collaborated to develop the content focus of the Zydeco program. The group planned two sub-questions to help students collect data during the field trip: "What evidence do archaeologists use to learn about the past?" and "What have archaeologists learned about the past?" These questions were designed to encourage students to collect data about the types of physical evidence archaeologists find and use, and how they analyze and interpret this evidence.

To prepare for the field trip, students were presented with baskets of garbage from various classrooms in the school, and challenged to use the iPods to collect data to help match each basket of garbage to the classroom it came from. This activity was designed to help students develop an understanding of the nature of evidence, the purpose of tagging their evidence, and to give students practice in using the handheld devices. Students spent a sixty-minute class period practicing collecting and tagging the data, and fifteen minutes analyzing and critiquing the data collected by their classmates.

Students also spent forty-five minutes of one class period discussing what they already knew about the two sub-questions and determining what they wanted to learn about the sub-questions. The teacher did not discuss a driving question or the purpose of the Zydeco data collection with the students prior to the field trip.

The field trip took place during a special Archaeology Day at the museum. During the field trip, students visited archaeology exhibits and stations staffed with docents, archaeologists, and educators. Students visited stations on each of three floors, spending 35 minutes per floor. Each student used the Zydeco program on one of the three floors, and on the other two floors used a worksheet packet designed by the archaeologists and museum educators to match the school curriculum and the content of each station.

Table 1. The design of the Zydeco system in terms of the Contextual Model of Learning, and the components evaluated in this study

	Zydeco design	*Featured in pilot?*
Choice and control	Student choice mediated by the driving question	No
	Student choice mediated by sub-questions	No
	Multimodal options for data collection and annotation, including text (tagging), photographs, and audio notes	Yes
Prior knowledge and experiences	Students design their own subquestions to gather data to answer the driving question.	No
	Students create tags prior to visit, to predict what they will find during their investigation.	Yes
	During the visit, tags and sub-questions remind students of relevant aspects of their prior knowledge.	Yes
Prior interests, motivations, expectations	The driving question is designed to spark student interest, create expectations, and motivate the learner.	No
Within-group social mediation	Class-produced tags are a form of social mediation, and provide a potential conduit for conversation and connection-making.	Yes
	Voice prompts to encourage verbal reflection that may spark conversation.	Yes
Advance organizers	Driving question helps orient students to the task in museum.	No
	Sub-questions help students gather necessary and sufficient data to answer the driving question.	No
Design and exposure to exhibits and programs	Driving question designed to enable students to choose from a variety of exhibits of interest.	No

Following the field trip, students reviewed the data collected in the museum and created explanations responding to the driving question.

The worksheets used in this study were designed by museum educators and archaeologists, and are based on Michigan state standards. The questions on the worksheets included simple knowledge-oriented questions, (i.e. "2. Find two children's toys in the exhibit: How old are these toys?"), comprehension questions, (i.e. Why did archaeologists find these toys outside the Burnham house instead of inside of it?"), questions that required students to analyze evidence (i.e. Who do you think was buried in Grave 1? What artifacts make you say this?"), and evidence synthesis questions (i.e. "Assume that all graves were found in the same cemetery and dated to the same time, what do these graves tell you about the people of this ancient community?" [3]. The questions required a variety of inquiry skills and focused on the specific content featured at each exhibit. Most of the questions provided limited choice for students in terms of what to focus upon. For example, the question "Draw a tool that was used for hunting. What was this tool made of and how was it made?", allows students to choose which tool they wish to draw. [4].

In this pilot study, there are three primary differences between the worksheets and the Zydeco handheld tool. First, Zydeco mediates student choice of what exhibits to visit and artifacts to focus upon through guiding questions that are consistent across exhibits, while the worksheets limit students' choices by requiring them to visit certain exhibits. Second, Zydeco allows students to collect data reflectively and multimodally, through annotated photographs, audio notes, and tags, while the worksheets allow students to collect data through writing and drawing. Third, though both the worksheets and the Zydeco are connected to class curricula, Zydeco's tags were created by the students prior to the museum visit, and were intended to help students build new understandings on their prior knowledge.

Field notes, audio recordings, and video recordings of the students and class activities were collected during the pre- and post-visit activities. During the field trip, 30 students using worksheets and 30 students using Zydeco were audio taped during their 35-minute visit to a single floor of the museum. Stationary video cameras recorded student behavior at three of the exhibits on this floor.

Video recordings were coded for students' behavior at each of three exhibits. The video recordings were done using a rubric based on established systems for evaluating visitor behavior during museum visits [27]. All instances in which a student's behavior was directly observable for more than 95% of the time they spent at an exhibit were included in the analysis. This resulted in 25 instances of students using the worksheets and 20 instances of students using the Zydeco handheld program that were analyzed. The video data was synched with the audio recordings in order to determine the content of student utterances when necessary. Only on-task behavior, considered behaviors focused on the content of the exhibit, the worksheet, the Zydeco technology, or archaeology were coded; off-task behaviors and conversations were excluded from the analysis, and time spent engaged in these behaviors and conversations was subtracted from the total time students spent at an exhibit. An independent rater coded 10% of the data, and an interrater reliability was established with 94% agreement.

4.2 Analysis

This analysis investigates how student behavior is influenced by select aspects of the Zydeco program; including the creation of the tags from students' prior knowledge; the ability to collect and annotate data multimodally, and the reflective prompts to encourage reflective data collection. By comparing student behaviors using Zydeco to student behaviors using the worksheets, we are able to evaluate if these aspects of the Zydeco program significantly change student behavior relative to more traditional ways of connecting the museum to the classroom. This comparison also provides a baseline in order to empirically evaluate educators' and docents' concerns that handheld devices in particular cause students to spend excessive time with their heads-down.

Students' content-oriented behavior in the museum could be classified into three general categories:

- Active social behavior
- Passive social opportunities to learn
- Interactions with the physical context

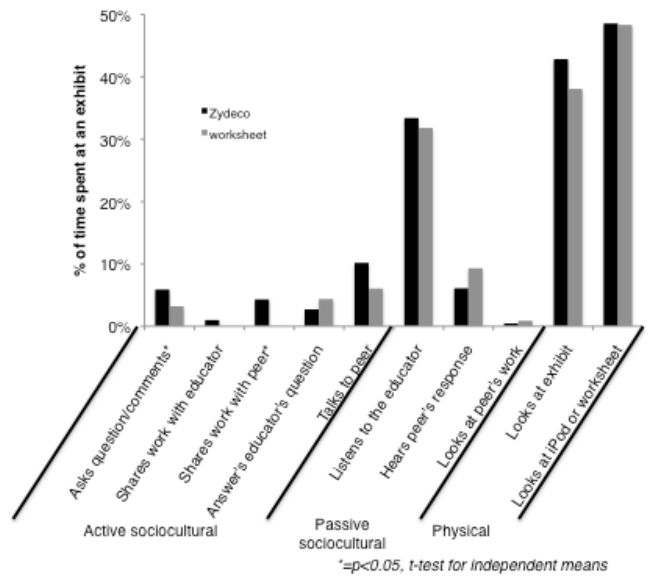

Figure 2: Percent of time students using a worksheet or the Zydeco program engaged in different behaviors during their experience at an exhibit

Active sociocultural behavior includes any on-task interactions during which the student is actively taking part, including asking and answering questions, making comments, sharing work, and conversing with peers. Only conversations and interactions in which students were discussing content were included in this analysis. Conversations focused on technology usability or off-topic subjects were analyzed separately and not included in this category. Passive sociocultural interactions include opportunities to learn from peers and docents, such as being a part of a group when an educator or peers are talking, or looking at peer work without actively engaging in conversation. Although it is impossible to discern whether students are attending to these opportunities to learn from others through behavioral interactions, they represent ways in which students may build understanding from the museum experiences. Interaction with the physical context includes when students focus their attention on an exhibit or on the worksheet or handheld device.

In total, students using the Zydeco program spent an average of 117 seconds at each exhibit, while students using the worksheets spent an average of 92 seconds at each exhibit ($p<.05$, independent t-test for means), although there were large ranges in the amount of time students within each treatment spent at each exhibit. Figure 2 shows the percentage of time students spent engaged in each type of behavior using the worksheets and using the Zydeco program.

Students often engaged in more than one interaction at a time, whether they were listening to the docent while looking at the exhibit, or pointing out a feature of the exhibit while conversing with a peer. When students were using the Zydeco program to take photographs, they were coded as attending to both the exhibit and to the device. Taking photographs constituted approximately 7.6% of the time that students were coded as focused on the exhibits.

In general, most of students' behaviors when using the worksheets were not observed to be much different from student behavior when using the Zydeco program. Students spent an average of nearly 50% of their time at each exhibit focused on either the worksheet or the handheld device, confirming that students' spend a significant amount of time "heads down" during the field trip. However, there was a high amount of variability in how individual students spent their time at exhibits. Using Zydeco, students varied from spending 6% of their time "heads-down" to 71% of their time "heads down", with a standard deviation of 17%. Using the worksheets, students varied 0 to 81% of their time "heads down," with a standard deviation of 19%. Thus, there is not a significant difference in "heads-down" behavior between the students using the worksheet and students using the handheld devices, showing that the technology does not increase this behavior compared with other strategies used to help students make sense of and connect their experience in the museum to the classroom. There was also great variability in the percentage of time students spent focused on the exhibits when they were using either the worksheets (mean=38%, standard deviation =17%) or the Zydeco program (mean=43%, standard deviation=15%). We further discuss the implications of the time students spent focused on either the exhibits or the mediating technology or worksheets in the discussion section.

Some students using the handheld device were observed to occasionally engage in two types of active sociocultural behavior not observed with the students using worksheets: sharing their work with peers and docents. With the handhelds, students were able to use the photographs collected on their devices to ask specific questions or share interesting findings. For example, one student took a photograph of a piece of pottery, and brought it over to a peer to show the observable fingerprints the original potter had left in the surface. In addition, students were occasionally observed asking their educators and peers for help or suggestions tagging their photographs. For example, one group of students, looking at a set of bone chips that had been used for ritual purposes, discussed whether it would make sense to tag the bones with the label "getting food," as they were unsure of the meaning of the ritual. This suggests that the process of annotating data has the potential for helping students engage in discussions to deepen their understanding of content by building new understandings from the prior knowledge embedded in the tags.

Although students were significantly more likely to engage in the active sociocultural interactions of asking the educators questions or making comments and of sharing their work with peers, these activities generally constituted a relatively small percentage of the time students spent at exhibits. Students using Zydeco spent an average of 8% of their time at the exhibit asking questions or making comments, and an average of 11% of their time having conversations with their peers. As noted previously, students varied greatly in the amount of time spent engaging in these behaviors. For example, it was observed that 30% of the Zydeco users and 60% of worksheet users did not ask any questions or make any comments. This suggests that both the mediating tools and student interest and personality type greatly influence behavior.

Finally, student conversations with docents and with peers about the technology were coded separately in order to measure how usability issues and the novelty of the technology influenced student talk during their visit. Half of the students engaged in brief conversations related to the technology. For the 50% of students who talked about the technology, these conversations occupied an average of 4% of their time at an exhibit. These conversations generally involved questions about how to navigate through the Zydeco system, asking how to retake photographs, listen to or re-record an audio note, delete a piece of data, or see a piece of data they had already collected. One student asked if he could send a text message using the program. This suggests that the usability and novelty of the technology did impact student talk, but in a limited manner.

5. DISCUSSION

Our analysis of student behavior using Zydeco during a field trip to the museum reveals several implications about student behavior using handheld devices designed to support sensemaking in the museum and to guide further research and the development of this system. In particular, this study has implications for ways of improving and increasing active sociocultural engagement during field trips.

5.1 Student behavior in the museum

Our initial research question and the design of this study address the concern of museum educators and docents that mobile devices incur "heads down" behavior in the museum, reducing students' attention to the exhibits and interpretation. We found no significant differences between the percentage of time that students spent working on worksheets at each exhibit and the percentage of time that students spent focusing on the handheld tool, suggesting that the handheld tool does not increase the heads-down behavior in comparison to worksheets, the traditional methods of connecting the classroom content to the museum experience. In both treatments, students spent nearly 50% of their time at the exhibits "heads down," completing the worksheets or annotating or reviewing their data on the Zydeco program.

This concern about using technology may reflect the issue that the novelty and usability of the technology could detract students' attention from the content and experience of the museum. However, only half of students observed using Zydeco engaged in discussions or asked questions about the technology, and these discussions only occupied an average of 4% of these students' time at an exhibit (4 seconds), suggesting that the technology was relatively navigable. Although students had practiced capturing and annotating data using Zydeco in the classroom prior to arriving at the museum, more time practicing could help further reduce these discussions.

The time that students spend focused on the technology should be further investigated to determine how to streamline the activity structure and interface design in order to increase the amount of time that students spend actively engaged in productive discussions and focused on the museum exhibits. However, the annotation and data review activities that students engage in while looking at the technology are designed to facilitate sensemaking and to help students connect the museum experiences to their classroom experiences; thus, some “heads-down” behavior is both expected and desirable.

Although students were observed to be collecting and annotating data when using the handheld devices, informal conversations with some of the docents suggested that they felt that students were not paying attention to them when they were using the Zydeco program. This suggests that museum educators may perceive the “heads down” behavior of students using mobile technologies differently than they perceive the “heads down” behavior of students using worksheets. The handheld devices look similar to mobile phones and gaming devices; thus “heads down” interaction with the handheld devices may be interpreted as inattentive based on docents’ prior experience using handhelds in other contexts. In contrast, the act of writing on worksheets is typically with learning and note-taking, and may thus be perceived as more acceptable by docents and museum educators.

Students using Zydeco engaged in significantly more active sociocultural behaviors related to the content of the museum program than students using the worksheets. In particular, students using Zydeco spent more time asking questions or making comments than students using the traditional worksheets. Several observations, detailed below, suggest promising ways that Zydeco can encourage collaborative sensemaking.

5.1.1 Students share their photographs and interpretations

Some students using the Zydeco program shared their work with others and with docents. This behavior was not observed at all with students who used worksheets. The handheld device allows students to interpret the exhibit in creative and personally meaningful ways, and may create a sense of pride and ownership.

5.1.2 Students talk about how to tag data

Collaborative sensemaking through discussion is a powerful way for students to learn during field trips [22]. Although infrequent, discussions related to how to tag particular pieces of data offered fruitful ways of helping students build new understandings on their prior knowledge. Further research is necessary to determine ways of encouraging this type of productive collaboration and discussion during the museum visit.

6. CONCLUSIONS

The Zydeco system was designed to engage students in inquiry-based learning across the museum and classroom settings. In this pilot study, we investigated how the capturing, reflective voice notes, and tagging features of the Zydeco system influenced student behaviors in the museum, when compared to a traditional worksheet. We found that heads-down behavior occupied approximately 50% of the time students spent at exhibits, regardless of whether students were using the Zydeco system or the worksheets. Although students must focus on either the worksheets or the technology to take notes, capture information, and make sense of their observations, streamlining these processes can increase the amount of time students can spend on exploring and experiencing the museum exhibits. Future research should evaluate how to reduce the “heads down“ behavior through streamlining the activity structure and the interface design, and through better preparing students to collect data in the museum.

Nevertheless, we found that the Zydeco system encouraged students to engage in significantly more active sociocultural behaviors than the worksheets. In particular, there were students engaged in collaborative sensemaking discussions around how to tag their data, and shared their photographs and interpretations of the exhibits with their peers and docents. Further research is needed to determine how to harness these promising behaviors to encourage more productive, collaborative sensemaking.

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