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Using Mobile Devices to Connect Teachers and Museum Educators

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Abstract The use of mobile devices is increasing rapidly as a potential tool for science teaching. In this study, five educators (three middle school teachers and two museum educators) used a mobile application that supported the development of a driving question. Previous studies have noted that teachers make little effort to connect learning experiences between classrooms and museums, and few studies have focused on creating connections between teachers and museum educators. In this study, teachers and museum educators created an investigation together by designing a driving question in conjunction with the research group before field trips. During field trips, students collected their own data using iPods or iPads to take pictures or record videos of the exhibits. When students returned to the school, they used the museum data with their peers as they tried to answer the driving question. After completing the field trips, five educators were interviewed to investigate their experiences with designing driving questions and using mobile devices. Besides supporting students in data collection during the field trip, using mobile devices helped teachers to get the museum back to the classroom. Designing the driving question supported museum educators and teachers to plan the field trip collaboratively.

Keywords Field trips · Mobile application · Teachers · Museum educators · Science education

Introduction

Informal learning experiences provide numerous opportunities for learning (Griffin and Symington 1997; Falk and Dierking 2000; Barton and Osborne 2001; Kisiel 2006b; Bell et

"There is no question that organizing a field trip can be quite a challenge." Kisiel (2006a, p.10)

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al. 2009). These experiences can include everyday experiences (e.g., walking in the woods), designed spaces (e.g., science centers, museums, zoos, or aquariums), or programs for science learning (e.g., after school programs) (Bell et al. 2009, p.2). This paper focuses on informal learning experiences in "designed spaces," specifically museums. As noted by Bell and colleagues (2009), these environments help students create an interest in science and build scientific knowledge by providing a great variety of real-world examples that students can explore. For instance, when students are exploring how engines work, a science center can provide a variety of engines in action; when these students are learning astronomy, a planetarium can present a vision of the Milky Way.

Field trips provide learning opportunities outside the classroom walls, but the influence of "designed settings" is considered as providing connections between classrooms and museums (Kisiel 2006b; Bell et al. 2009). In order to create this link, teachers and museum educators play a key role. To create this connection, teachers need to integrate their classroom lessons with the field trip and develop activities for after the field trip. Museum educators need to connect with the teachers before the field trip, and guide students and teachers during the field trip experience (e.g., leading the group in the museum). Both sides of the equation face challenges during this connection. In this study, our goal is to find out how using mobile devices, and creating a driving question collaboratively connects museum educators and teachers.

Several scholars used mobile devices to connect classrooms and museum (Vavoula et al. 2009; Cahill et al. 2011), and used driving questions to guide the field trip experience in this process (Vavoula et al. 2009; Cahill et al. 2011). What is new in this study is the development of the driving question supports collaboration between teachers and museum educators to design the field trip experience. Previously, Kisiel (2010) focused on making informal educators visit classrooms, and teachers visit museums to create a community of practice. In a more recent study, Kisiel (2014) discussed the importance of communication between teachers and museum educators by developing "practice-based connection" (p. 360). Kisiel (2014) also underlined that having joint enterprise is critical to support the communication. We focused on creating the "practice-based connection" (Kisiel 2014, p. 360) by supporting teachers and museum educators to use mobile devices to create the learning environment together. The joint enterprise in this study is designing the field trip by creating the driving question for the field trip.

Rennie (2007) noted the need to support teachers' content and pedagogical understanding when planning field trips. In this study, we worked with three experienced middle school science teachers, and we primarily focused on understanding how creating the driving question and using mobile devices would support the collaboration between teachers and museum educators. In this process, we focused on how the investigation designed by using mobile devices and developing driving questions supported the aspects identified by Bell and colleagues (2009) to create a successful field trip experience: (1) advanced preparation, (2) students' engagement with museum exhibits, (3) teacher and museum staff involvement, and (4) follow-up activities. Similar to Kisiel (2014), we also explored educators' (museum educators and teachers) previous experiences when organizing field trips by examining the following research questions:

1.   What challenges did teachers and museum educators previously experience when they attempted to connect classrooms and museums?

2. How, according to educators' views, did using mobile devices as data collection and organization tools help/hinder connections between classrooms and museums?
3. How, according to educators' views, did using the driving question help/hinder connections between classrooms and museums?

In the following section, we will discuss the challenges faced by teachers and museum educators, and how using mobile devices and creating driving questions would support the collaboration between these groups.

Teachers' Challenges

Although Kisiel (2005) noted the importance of making a connection between a teacher's curriculum and the field trip when organizing informal learning experiences; Griffin and Symington (1997) reported that teachers struggle to develop a connection between museums and classrooms. One source of this difficulty is that teachers need to make numerous preparations to provide a quality trip experience, yet have very little time for such preparation.

Another challenge relates to teachers' relationship with "designed spaces." Griffin (1998) noted that teachers have little control over informal learning environments. In another study, Tal, Bamberger, and Morag (2005) studied with 30 teachers to describe their field trip experience. Tal and colleagues (2005) found that teachers are not involved in field trip planning, and few teachers visited the museum before the field trip. As another challenge, Dillon and colleagues (2006) added that teachers' confidence in teaching informal settings would influence the quality of the field trip.

Two decades ago Orion (1993) summarized the challenges of connecting formal and informal learning environments by synthesizing previous studies including Mirka (1970), Fido and Gayford (1982), (McKenzie et al. 1986). Orion (1993) found three major challenges: (1) organizational limitations (i.e., funding), (2) lack of connection between the field trip and the curriculum, and (3) teachers' unfamiliarity with the informal environments. Similar to Orion's (1993) conclusion, after reviewing several studies focusing on informal learning environment, Morag and Tal (2012) noted the following challenges: the absence of classroom preparation, and the link between curriculum and field trip experience.

Museum Educators' Challenges

As designers of the exhibits, Falk and Dierking (2000) underlined that museum staff can support learning opportunities for visitors. However, a majority of studies focusing on informal learning experiences have studied teachers and students, but little research has been conducted to understand museum educators' perspectives (Falk and Dierking 2000; Tran 2007). Instead of working collaboratively, Tran (2007) noted that museum educators act as instructors, and they designate roles for teachers (i.e., taking care of discipline). In another study, Tal and Steiner (2006) added that museum educators connect with teachers, but this connection stays at the basic level and it does not involve teachers in the field trip planning.

Several studies underlined the lack of connection between teachers and museum educators (Tal and Steiner 2006; Tran 2007; Gupta et al. 2010; Morag and Tal 2012). One of the few studies in this area (Kisiel 2010) discussed a long-term relationship by creating a community

of practice between an aquarium and a school to overcome the disconnectedness between teachers and museum educators. Kisiel (2010) underlined the importance of sharing concerns, suggestions, and goals when creating connections across formal and informal environments.

Similar to Kisiel (2010) our goal is to connect teachers and museum educators, but we followed a different route since the opportunity to study long-term relationships is very rare. Museum educators and teachers usually connect for a short-term during field trips, and our aim is to investigate how we can use mobile devices to connect teachers and museum educators in this process.

Using Mobile Devices to Connect Teachers and Museum Educators

Several studies illustrated the missing link between teachers and museum educators, but the success of the field trip depends on the alignment between several aspects. Bell and colleagues (2009) noted these aspects as the following: advanced preparation, students' engagement with museum exhibits, teacher and museum staff involvement, and follow-up activities. In this study, we used these steps to design an investigation by using a new mobile application called Zydeco (Quintana 2012) that supported the development of a driving question to foster the connection between teachers and museum educators.

Mobile devices, including smart phones and tablets, have become popular in the last decade, and the widespread use of mobile devices has provided opportunities for learning outside the classroom. For instance, Maldonado and Pea (2010) used the Spark science learning systems in the *Let's GO* project, to enable students to collect pH, temperature, and dissolved oxygen data with latitude data for creating scientific explanations about water quality. After engaging in the data collection, students provided more scientific information in the post-questionnaire compared to the pre-questionnaire (Maldonado and Pea 2010). In another environmental study, Rogers and colleagues (2004) used PDAs and probes to test moisture and light in forest areas. Students collected data and created hypotheses on what happens to their findings when new organisms enter the habitat. This helped students to link their findings and explorations in the physical environment (Rogers et al. 2004).

Using mobile devices provides new opportunities to investigate various ideas outside the classroom walls (Rogers et al. 2004; Maldonado and Pea 2010). Using mobile devices in "designed settings" could create a connection between classrooms and museums by allowing students to bring data back to the classroom. In an earlier study, Vavoula and colleagues (2009) used a system called Myartspace that enables students to capture photos and record audio notes during a field trip by using mobile phones. Before the field trip, the teacher creates an "inquiry question" to guide the field trip (Vavoula et al. 2009, p. 289); during the field trip, students collect their own data and also reflect on the data collection by explaining the reasons to capture data; when students return to school, they analyze the data by using a website to answer the inquiry question. By fostering students to bring the data back to the classroom, Myartspace connected the classrooms and museums (Vavoula et al. 2009). Despite the value of connecting museum and classroom, Cahill and colleagues (2011) found the time spent with mobile devices during a field trip varied across students (6 to 71 % of the time spent in the museum), but added that using mobile devices would influence students' engagement. When Cahill and colleagues (2011) asked the same group of students to use worksheets in the same museum, authors found no significant difference between the time spent looking heads down to mobile devices as worksheets.

In this study, the role of mobile application will serve a similar role to that described by Vavoula and colleagues' (2009) where they used it as a data collection and organization tool. The mobile application also supports development of a driving question to foster the connection between teachers and museum educators. The goal of the driving question is to guide the investigation by engaging students with a feasible real-world problem, and directing students to a diverse set of activities (Krajcik et al. 1994; Blumenfeld et al. 2000; Singer et al. 2000; Zhang and Quintana 2012). Similar to inquiry questions used in Vavoula and colleagues' study (2009), the driving questions used in this study guide data collection in the museum and data analysis in the classroom.

To make the use of educational technologies more effective, Bielaczyc (2006) underlined that "the design process must be extended beyond the tool itself" (p. 301). To achieve this goal we added another dimension and asked educators to design the field trip collaboratively when using mobile devices. In this process, teachers visited the museums and met with museum educators to design the field trip. Our main goal in this study is to find how this approach can be aligned with the aspects noted by Bell and colleagues (2009). Previous studies noted the lack of teacher involvement in field trip planning (Tal et al. 2005), the missing link between museum educators and teachers (Tal and Steiner 2006; Tran 2007; Gupta et al. 2010; Morag and Tal 2012), and teachers' challenges to connect field trip experience with the classroom (Orion 1993; Griffin and Symington 1997; Dillon et al. 2006; Morag and Tal 2012). The next section will discuss how field trip design addressed these challenges, and then we will report educators' experiences about this collaboration.

Methods

Designed settings are "intentionally designed for learning about science and the physical and natural world" (Bell et al. 2009, p. 127). Our aim in this study is to find a way to connect this experience to the classroom by focusing on the aspects underlined by Bell and colleagues (2009) with the use of mobile devices and driving questions.

Field Trip Design

This section discusses how we designed the field trips by focusing on the aspects underlined by Bell and colleagues (2009). This section also provides information about the museums.

Advanced Preparation and Teacher and Museum Staff Involvement

Before the field trip, the teachers and museum educators created an investigation together by developing a driving question/challenge (advanced preparation, teacher, and museum staff involvement). During this process they worked collaboratively with the research team, and visited the museums. Each teacher met with the museum educators at least twice to discuss their goals and consider how museum staff could help them. For instance, one of the teachers was focusing on electricity and one of the goals of the unit was to understand how different sources could be used to create electricity. The Science Center (SC) that participated in this study did not provide any exhibits directly focusing on electricity, but had plenty of examples of energy transfers. The teacher and the museum educator created a driving challenge that

focused on what the museum offered (energy transfers), and merged it with the teacher's goal (understanding how different sources can be used to create electricity). By focusing on the exhibits provided in these two museums, teachers and museum educators participating in this study designed two driving questions (DQ) and a driving challenge to guide the data collection process during the field trips in a Natural History Museum (NHM) and a Science Center (SC).

The first DQ investigated in NHM was "How is my animal related to other animals?" This question examined traits to discuss the similarities and differences across animals. Seventy-six sixth grade students investigated the first DQ. The second DQ used in NHM focused archeology: "What would archeologists of the future learn about us?" The second DQ focuses on understanding what archeologists use as evidence, and what students learn by examining the past. Ninety-eight seventh grade students investigated the second DQ. The driving challenge used in SC was "Design a way to use the exhibits at the museum to create electrical energy to charge your phone, mp3 player, etc." The driving challenge focused on understanding the energy transfers happening in the museum, and how students can convert energy to create electrical energy. Twenty-nine seventh grade students investigated the driving challenge.

After designing the driving question/challenge with museum educators, the teachers introduced the question/challenge to students. Then students worked with their teacher to define sub-questions (see Fig. 1a) to help answer the driving question (advanced preparation).

Students' Engagement with Museum Exhibits and Follow-up Activities

During the field trip, students used mobile devices (see Fig. 1a) to take pictures or record videos of the exhibits (students' engagement with museum exhibits). These photos and videos served as data that students could use to answer their sub-questions. Each student used a mobile device and worked in pairs during the field trip. In this study, one group of students examined energy transfers, and another group focused on collecting data about animal traits.

When students returned to school, they used the data they collected in the museum with their peers to answer the driving question, which led them to a post-field trip activity (follow-

Fig. 1 **a** Driving question and sub-questions. **b** Data review

up activities). After visiting the science center, one group of students participating in this study focused on designing a way for harnessing energy to charge their mobile phones. In another classroom, students reviewed the data to examine internal and external traits of the animals they observed in the natural history museum. Students had 3 to 4 days to complete their post-field trip activities. Students accessed all the data they collected by using a website or by using the iPad application (see Fig. 1b). Students could use the data collected in the museum by their team members, or they could select some evidence from other groups.

Data Collection and Analysis

To determine the role of using mobile devices and creating driving questions, we designed a descriptive study and conducted five semi-structured interviews with the educators who participated in the field trips.

Participants

This study was conducted in two different school districts in the Midwest and in two different museums (a Natural History Museum and a Science Center). In both school districts, the majority of the students were African-American. Five educators participated, three middle school science teachers and two museum educators. The number of student participants varied in each trip, and the total number was 203. As depicted in Table 1 (all names are pseudonym), all participants have a degree in education; however, their backgrounds are different.

Developing the Research Instrument and Conducting Interviews

After defining the research questions, the first author and the second author designed two interviews to understand the beliefs of this diverse group, one for the teachers and the other one for the museum educators. In these interviews, some interview questions differed slightly. For

Table 1 Participants and their background

Participants	Background
Museum educators—museums	
Ms. Baker—Natural History Museum (NHM)	Bachelor's in biology and a master's in museum education
Mr. Rice—Science Center (SC)	Bachelor's in mechanical engineering, an MBA in marketing, and a master's in secondary education
Teachers—school districts	
Ms. Paterson—major school district	Bachelor's in nursing and a master's in teaching, and 30+ hours in curriculum development and educational technology. She has been teaching for 21 years.
Ms. Philips—urban school district	Worked for 14 years as a para-educator. She has been teaching science and social sciences for 3 years.
Ms. Miller—urban school district	Taught 17 years in a child development center and then started teaching in a middle school.

instance, we asked both groups to evaluate what would happen if we did not have mobile devices: "How would the experience change if mobile devices were not used? Think about previous field trips with other groups. How did student's engagement change in the last field trip?" On the other hand, some questions prompted teachers to tie their experience with what happened in the classroom. When evaluating the role of DQ, we asked teachers: "In this project, you used a DQ. In what ways was this DQ helpful to you, if at all? In what way did it make the field trip experience/your teaching more challenging?" When we were examining the role of DQ for museum educators, we only focused on affordances and challenges: "In this project, you used a DQ. In what ways was this DQ helpful to you, if at all? In what ways is it more challenging?"

After designing the interview questions, the interviews were pre-tested with a science education Ph.D. student who had field trip experience, to determine if the interview questions would elicit the intended responses needed to answer the research questions. Then, the educators were interviewed after completing the field trip. This enabled the middle school teachers and the museum educators to compare their experiences with using mobile devices and developing driving questions with that of previous field trips. All interviews were conducted by the first author.

When discussing previous experiences, participants were prompted to be more specific through follow-up questions. For instance, they were asked to provide examples from their last field trip experience since this would be the easiest to recall. These five semi-structured interviews (Glesne 2011) were audiotaped and took around 37 min on average; a professional transcriber and the first author transcribed all the data. The average transcription was around 5000 words each.

Data Analysis

During the analysis process, we used thematic analysis (Glesne 2011) and formed two teams to analyze the teacher and museum educator interviews. The team that analyzed the teacher data consisted of three research team members (the first author and two graduate students). The second team (the first and the second authors) focused on museum educator interviews. These teams analyzed the data in three steps: (1) coding segments and creating summary statements, (2) cross-checking segments and summary statements, and (3) creating themes for teachers and museum educators.

Step 1— Creating Segments and Summary Statements

In the first step of analysis each team member analyzed one of the interviews. In this process, the data were coded in segments separately for each code. The first and the second authors created five main codes for data analysis based on the research questions; (1) challenges of field trips, (2) affordances of using mobile devices, (3) challenges of using mobile devices, (4) affordances of using a driving question, and (5) challenges of using a driving question. These codes served as categories for the data analysis (Creswell 2007).

In this study "segment" refers to a quote from the interviews associated with a code. Glesne (2011) defined this process as linking the data with codes. Table 2 presents several quotes linked to the affordances of using mobile devices. After creating the segments by identifying the text that apply to the code during each

Table 2 Creating segments and summary statements (samples from Ms. Paterson's interview)

Code	Segments in relation to code	Summary
Affordances of using mobile devices	"The fact that they're just portable makes them, you can use them anywhere. So they're always available. They're small. You can record the data and save it."	(1) Engagement in data collection
	"You can literally take your field trip experience back with you."	(2) Getting the museum back

interview, the next step was to "summarize the coded material" (Glesne 2011, p. 188) by creating an interpretation of the segment (see Table 2).

Step 2—Reliability of Coding

After completing the coding process for one of the interviews, each team member cross-checked interviews: (1) Each member analyzed another interview by creating segments and summary statements. (2) In the first team, each member analyzed another teacher interview. The second team members analyzed the other interview that they did not initially analyze. (3) Each team compared segments and summary statements across team members. (4) Each team organized discussion meetings to resolve all the disagreements in relation to segments and summary statements.

Step 3—Creating Themes

After finishing the analysis and cross-checking the interviews, both teams created themes (see Table 3). As noted by Glesne (2011), thematic analysis helps researchers to identify the patterns in the data. Similar to Hsi's study (2003), themes enabled the identification of differences and similarities across participants. Each team explored the patterns for middle school teachers and museum educators in several discussion meetings. Table 3 presents a sample theme created for finding the patterns for the affordances of using mobile devices code. After completing the coding process for each participant (see Table 2), each team focused on the similarities and differences across individuals.

Table 3 A sample theme

Code	Segments	Theme
Affordan-ces of using mobile devices	*Ms. Paterson:* "The fact that they're just portable makes them, you can use them anywhere. So they're always available. They're small. You can record the data and save it."	All of the teachers mentioned that mobile application helped students to engage with data collection.
	Ms. Philips: "Yeah, the iPods, through the field trips, having the kids record what they're seeing and doing, is kind of like giving them a purpose and keeping them on task."	
	Ms. Miller: "It (mobile application) gave them a different tool to use to record, a different tool that was more engaging, to record their data."	

When creating themes, the goal of each team was to find commonalities. If two or more teachers mentioned a similar affordance, this created a theme under the affordances of using mobile devices code for teachers. If both museum educators note the same affordance, this also created a theme under the affordances of using mobile devices code for museum educators. Table 3 presents a sample theme that was mentioned by all of the teachers participating during the interviews. All themes that emerged under this category can be found in Table 5.

Although the main goal of each team was to create themes to identify patterns, Glesne (2011) underlined that "Thematic analysis should go beyond identifying the general" (p. 188). Connected with this idea, the final stage of the analysis focused on understanding the individual differences. These are presented as individual notes under each sub-category. Besides depicting themes for teachers and museum educators, Table 5 also presented individual notes from Ms. Miller, and Ms. Baker.

Findings

Educators' Previous Challenges When Organizing Field Trips

In this section, we report the challenges educators faced in their previous experiences.

Challenges of Field Trips for Teachers

Five themes emerged when teachers discussed their previous challenges in organizing field trips (see Table 4).

Behavioral Problems

The first theme under this category is behavioral problems during the field trips. Two of the teachers (Ms. Miller and Ms. Paterson) discussed the behavioral problems that

Table 4 Educators' previous challenges when organizing field trips

Challenges	Mentioned by
Themes for teachers	
Behavioral problems during field trips	Ms. Miller and Ms. Paterson
Making students engaged in activities	Ms. Miller and Ms. Philips
Visiting museum beforehand	Ms. Paterson and Ms. Philips
The group size	Ms. Paterson and Ms. Philips
The need for extra materials	All teachers
Themes for museum educators	
Connection with teachers	Both museum educators
Funding problems	Both museum educators
The lack of resources	Both museum educators
Individual notes	
Funding problems	Ms. Baker
Behavioral problems	Mr. Rice

prevented them from utilising informal activities and from keeping everybody together to complete the task. Ms. Paterson summarized this problem as the following: (1) students' behavior in public, (2) students' interactions with people, and (3) lack of knowledge about how to use the facilities.

Students' Engagement and Group Size

As a second theme, two of the teachers (Ms. Miller and Ms. Philips) noted teachers' struggles to make students engage in activities during the field trip. As a third theme, two of the teachers (Ms. Paterson and Ms. Philips) noted the group size as a challenge. Ms. Philips believes that having small groups can provide a better experience: "… the biggest challenge is making sure that when you take field trips is having small groups get experience, because then it's more worthwhile."

Advance Preparation

Two of the teachers highlighted the importance of visiting the museum beforehand, instead of connecting with museum educators. When visiting the museum, Ms. Paterson noted that she always has a goal in mind. To elaborate on this idea, Ms. Philips added the need for advanced planning before the real field trip. She visits the museum beforehand with the purpose of previewing the field trip by herself; then, she creates the plan for the field trip. Ms. Philips also provided an example: "… when I took the kids to D.C. this year, I knew what to expect because I had been there four times."

Lack of Materials

The last theme under this sub-category is the lack of materials. All of the teachers noted the need for extra materials to prepare students for field trips. For instance, Ms. Philips pointed out the need for a set of materials that can be used to familiarize students with the museum settings: "If kids can see some visuals before we even take a field trip, this is what you're going to see, this is what it's going to look like, but when we get there, leaving it open enough that they still have to do some investigation."

Individual Notes

Individually, Ms. Miller did not mention visiting the museum beforehand, and she identified more challenges than the other teachers. She was honest about revealing that field trips are not her favorite teaching experience, and she continued by explaining the budget cuts and how field trips are becoming a luxury. Instead of organizing field trips, she is willing to replace them with virtual museums: "… I think with all the technology now, with the virtual things and everything, you can show and bring into schools without necessarily going to somewhere, might not be so necessary." On the other hand, Ms. Miller described a highly successful trip in which her goals and the museum experience were well aligned. This was an accidental experience for Ms. Miller, since she did not expect this alignment to happen.

Challenges of Field Trips for Museum Educators

The museums and museum educators that participated in this study have different goals. Ms. Baker, the Director of Education in Natural History Museum (NHM), stated that the goal of the natural history museum is to empower learning, helping students learn from the museum and create excitement and interest about the natural world. Mr. Rice, the Director of Science, Technology and Math in the Science Center (SC), stated that the mission of the science center is to support students and help them pursue careers in engineering, technology, and science, especially the under-served population. Table 4 presents the three themes that emerged when museum educators discussed their previous challenges when organizing field trips.

Connection with Teachers

The first theme is related to the different roles of teachers and museum educators during the field trip. The museum educators who participated in this study did not organize the field trips. To support creating a connection between museums and teachers, both museums contacted the teachers prior to the museum visit. Both museums have assigned people to coordinate the classroom activities and the museums exhibits. NHM sends teachers pre-visit activities and information about what will happen on the day of the field trip. But this information is just at the introductory level; it only explains the structure of the field trip, as Ms. Baker explained: "… we send them pre-visit activities to do … we send them information about what will happen on their field trip." Unfortunately this information (connection) does not go beyond this point for both museum educators.

Funding Problems

The second theme is related to funding problems. Both museum educators talked in depth about budget cuts in K-12 public education, and Ms. Baker added the cuts in the university's funding, since the natural history museum is affiliated with a university. She also explained how No Child Left Behind affects the funding: "… the fact that in Michigan, science is not one of the things that necessarily counts towards whether schools are, how schools are rated … as a result, because those scores are not important for many at risk schools, they are unable to place as many resources towards science education and that affects us in lots of ways."

Lack of Resources

The last theme under this category is about the materials. Although teachers noted the lack of materials, both museum educators believe that the museums provide sufficient resources for students. At the same time, they would like to have more opportunities, and they complained in relation to the lack of resources (e.g., lack of personnel, absence of connections with other museums). Ms. Baker would like to improve the quality of field trips by adding more inquiry and providing personalized worksheets but she does not have enough staff members to make it happen. On the other hand, Mr. Rice noted the lack of connections with other museums. He would like to build collaboration with one of the museums to support the learning experience in the science center: "… children's museum can provide artifacts that can really enhance a visit to the science center."

Individual Notes

Similar to the teachers, Mr. Rice addressed students' behavioral problems at the science center as a challenge.

Use of Mobile Devices to Help/Hinder the Connection between Classrooms and Museums

To investigate the role of mobile devices, we will focus on the affordances and the challenges of using the mobile devices as data collection and organization tools when connecting classrooms and museums. Similar to previous studies (Vavoula et al. 2009; Cahill et al. 2011), our goal was to investigate how using mobile devices supports data collection in the museum, and helps teachers to take the museum data back to the classroom.

Affordances of Using Mobile Devices for Teachers

As presented in Table 5, three themes emerged from the teacher interviews when discussing the affordances of using the mobile application.

Students' Engagement with Data Collection

The first theme is related to students' engagement. All the teachers mentioned that mobile devices helped students to engage with data collection, which in turn helped them achieve the learning goals (e.g., investigating traits, how different types of energy can be used to create electricity). Ms. Miller summarized these points as: "It (mobile application) gave them (students) a different tool to use to record, a different tool that was more engaging, to record their data)… Anything that is going to engage them (students) is going to help facilitate your goals." Similarly, Ms. Paterson stated, "So they're always available; they're small; you can record the data and save it; they're so engaging… It (mobile application) facilitated the learning goals because they (students) could collect data." Teachers also added that engaging in data collection provided a purpose during the field trip by keeping students on track.

Table 5 Affordances of using mobile devices

Affordances	Mentioned by
Themes for teachers	
Data collection	All teachers
Connecting classrooms and museums	All teachers
Comparisons with worksheets	Ms. Miller and Ms. Philips
Themes for museum educators	
Data collection	Both museum educators
Individual notes	
Taking the museum back	Ms. Baker
Role of supervision	Ms. Miller

Connecting Classrooms and Museums

As a second theme, all teachers mentioned that using mobile devices helped fostering connections between the classrooms and the museums. Using mobile devices engaged students in the data collection process, and students took the museum back to the classroom to work on the follow-up activities. Ms. Philips noted that using mobile devices also gave students a purpose, which helped students to connect classrooms and museums by providing a reason to interact with the exhibits: "When they (students) were there (museum), … they didn't just seem to wander through aimlessly, really engaging in the displays." Besides engaging students with museum experience, Ms. Paterson added the value of taking the museum experience back by bringing all the data students collected to the classroom: "You can literally take your field trip experience back with you… Instead of just saying remember, it's like look, we did this and you can see it. And you have recorded what you were looking at and thinking about when you saw it. I think that is very cool." After getting the data back to the classroom each teacher created different follow-up activities. For instance, In Ms. Paterson's classroom, students were asked to discuss energy transfers in the museum, and find a way to charge their phones.

In this process, one of the student groups used a pulley by drawing foot pedals working like an exercise bike in a gym. Later in their poster, the group focused on transferring creating electrical energy by including a generator. Another poster used mechanical energy coming from a windmill, and transferred it to turbines to create electrical energy. Final products created in this study presented energy transfers clearly; however, they lacked the discussion of how different types of energy can be converted to electrical energy. This lack of understanding can be linked to middle school students' understanding of electricity. Another possible explanation could be related to a lack of exhibits discussing how this process occurs.

Comparisons with Worksheets

The third theme compares the mobile experience with previous field trips. Two of the teachers (Ms. Miller and Ms. Philips) made comparisons with worksheets. Ms. Philips added that students don't like writing, and mobile devices provide an easier way of documenting and collecting data: "They (mobile devices) give the kids something to do while they're there (in the museum). Kids hate writing. So they're able to document their findings quickly, easily, and then move on. They don't get stuck or frustrated or give up early on, because it's easy to take a picture and put a tag on it." These comments are connected with Ballantyne and Packer's (2002) study that discussed students like note taking or using worksheets the least during field trips.

Individual Notes

Under this category, Ms. Miller individually added that supervision coming from graduate students made this experience better. In the Zydeco project, graduate students were present in the classroom when the teachers needed help, and it helped the teachers resolve their problems quickly:

"I think with a lot of supervision (coming from graduate students), I think it's (using mobile devices) a great thing, a great tool… We have so much technology but we don't have good or enough support for it. I mean they have a support staff but you look at all there is in all the schools, there's no way they can keep everything going and we're not techie enough to know if this pops up, what are we supposed to do with that? … It's hard enough to just teach, and keep up, and so adding all those are great but it's really hard."

Affordances of Using Mobile Devices for Museum Educators

Only one theme emerged from the museum educator interviews when discussing the affordances of using mobile devices (see Table 5).

Data Collection

Both museum educators focused on the value of collecting data in the museum to answer the driving question. The museum educators summarized that recording audio notes, capturing videos, and taking photos are the value of using mobile devices. Ms. Baker defined this process as "Having a sense that you can record, things that interest you … having little something that you can take with you photos, notes etc. I think that's really valuable." By using mobile devices, students can find their own interests and capture information they can utilize.

Individual Notes

Individually, Ms. Baker highlighted that mobile devices enable students to take the museum back. She described this as a "concrete takeaway." In addition, mobile devices also helped students to refresh their memories when they returned to the classroom, as Ms. Baker added: "Well, I think that it forces the students to make something out of the knowledge that they have acquired in the museum and I really like that aspect of it … it forces them to build something to answer a question." When students returned to the classroom, they used museum data in the follow-up activities.

Teachers' Challenges When Using Mobile Devices

Besides providing benefits, the mobile devices also raised challenges (see Table 6).

Table 6 Challenges of using mobile devices	Challenges	Mentioned by
	Themes for teachers	
	Distraction of using mobile devices	Ms. Philips and Ms. Paterson
	Themes for museum educators	
	Distraction of using mobile devices	Both museum educators
	Individual notes	
	Amount of data collected	Ms. Paterson
	Focusing on different ability levels	Ms. Miller

Distraction

The only theme that emerged under this sub-category was the distractions from using mobile devices in informal settings. Ms. Philips and Ms. Paterson noted that when using mobile devices, students focused on how mobile devices worked (e.g., finding the label), instead of focusing on collecting data to answer the driving question. During the field trip, Ms. Paterson observed that sometimes students were focusing on mobile devices more than data collection process: "You know like using a cell phone until you kind of isolate yourself from everything else."

Individual Notes

Ms. Paterson individually reported another challenge in relation to the data collection: "… maybe the videos were too, maybe the videos actually capturing, you know, a little bit of video, you might lose some of the whole experience by capturing just a little tiny bit, because it might limit how much they actually captured, or a lot of that I think would be just experience using them." Recording the data helps students to get some pieces of the museum back into the classroom, but at the same time they can miss some of the opportunities provided in the museum. For instance, the science center with four different levels provides many opportunities for learning. Once students believe that they have answered the sub-questions, they can stop looking for more information. On the other hand, Ms. Miller underlined that when introducing a new technology, it is vital to focus on different ability levels for assisting the needs of every student.

Museum Educators' Challenges When Using Mobile Devices

Only one themed emerged under this category.

Distraction

Both museum educators mentioned that technology can become a source of distraction (see Table 6). Mr. Rice observed that when students started using mobile devices, their attention was divided between the mobile device and the objects: "In a science center, I think you still have the potential for distraction in that they're looking at their device, and therefore they're maybe not looking at the exhibit or interacting with it as much as they could."

Use of Driving Question/Challenge to Help/Hinder the Connection Between Classrooms and Museums

To investigate the role of driving question/ challenge, we identified the challenges and affordances that educators faced when designing and using the driving question/challenge.

Affordances of the Driving Question for Teachers

Two themes emerged when teachers discussed the affordances of using driving question/ challenge (see Table 7).

Affordances	Mentioned by
Themes for teachers	
Guiding the field trip experience	All teachers
Supporting teachers and students to focus on purpose	Ms. Miller and Ms. Paterson
Themes for museum educators	
Helping to create the connection between the classroom and the museum	Both museum educators
Individual notes	
Making students focused	Ms. Baker
Advanced planning (Creating DQ)	Mr. Rice

Table 7 Affordances of Using Driving Question/ Challenge

Guiding Field Trip Experience and Focusing on Purpose

The first theme was about the value of using driving question/challenge. All of the teachers acknowledged that the DQ guided the field trip experience. As a second theme two teachers underlined that the DQ supported teachers and students to focus on purpose. Ms. Miller expressed that having DQ is necessary because the DQ makes teachers and students focus on the purpose. Ms. Paterson stated that using driving questions lead students and teachers persistently to focus on the goal and to engage them in activities: "I always like having a driving question because it keeps me focused and it's something I can come back and focus the kids on."

Affordances of the Driving Question for Museum Educators

There is only one theme emerged under this category.

Connecting Classrooms and Museums

Both museum educators acknowledged that the driving question (DQ) helped to create the connection between the classroom and the museum (see Table 7). Students explored the driving question before the field trip, connected data to answer the DQ during the field trip, and focused on answering it when they get back to the classroom. Mr Rice described how the driving challenge used in the Science Center was designed to create a connection with classroom practices: "They (students) are learning about electricity and where electricity comes from and how it's made in the classroom, and then they come to the science center and they see how they interact with the exhibits and they try to apply what they learned in the classroom to the museum experience, and answer the driving question." Ms. Baker also underlined that driving questions pushed students to explore the content, and in this process it was important that teachers were on the same page: "That would (use of DQ) provide motivation to learn the content we wanted them to learn and the teacher the team felt that was important…I do think it helps keep the focus between content between the two context (classrooms and museums)."

Individual Notes

Individually, Ms. Baker highlighted that the DQ makes students focus. On the other hand, Mr. Rice focused on the importance of advanced planning for creating a successful field trip experience: "It was my observation that the students got more out of the experience … because really the preparation was key to that." Mr. Rice also stressed that it is hard for teachers to know what a museum offers when designing their driving question: "Any teacher in a classroom needs to think about what kinds of questions they want to ask, so this isn't any different in that respect other than they, the teacher, might not have the advanced knowledge of the science center, so that they can develop a good driving question." In this study, communication between museum educators and teachers before the field trip supported advanced preparation, which was supported by the development of a driving question collaboratively. For instance, Mr. Rice and Ms. Paterson met several times before the field trip to discuss what they could achieve during the field trip. And Mr. Rice visited Ms. Paterson's classroom after the field trip to see how students made sense of the museum data.

Challenges of the Driving Question for Teachers

Themes under this sub-category focus on designing and making use of the driving question/ challenge (see Table 8).

Making use of DQ

Two of the teachers (Ms. Philips and Ms. Paterson) stressed that making use of the driving question could become a challenge. Ms. Paterson noted, "… remembering to stop and make a connection to it before, and sometimes I tend to get out here and then oh, and it's like and I know where I'm going but I don't think I always make a connection in a timely manner with the kids." Teachers participating in this study had used driving questions previously. Since they were not familiar with using driving questions when organizing field trips, putting the driving question at the center of the investigation was a challenge for them.

Table 8 Challenges of Using Driving Question/ Challenge

Challenges	Mentioned by
Themes for teachers	
Making use of DQ	Ms. Philips and Ms. Paterson
The challenge of designing a good driving question	Ms. Miller and Ms. Paterson
Themes for museum educators	
The challenge of designing a good driving question	Both museum educators
Individual notes	
Building a better understanding of the topic	Ms. Paterson
Helping teachers to design DQs	Mr. Rice

Designing DQ

Two teachers (Ms. Paterson and Ms. Miller) emphasised some challenges when developing driving questions. Ms. Paterson believes that the challenge was creating a driving question that was relevant as well as answerable. Creating better driving questions had several iterations, and making it authentic required effort. She also noted that making the DQ too abstract could be the challenge; however, when using a mobile application, designing the sub-questions helped students. In addition, Ms. Miller added that the challenge was hard to accomplish at that age level: "…I think the age might have been a little bit young for the way we designed it."

Individual Notes

Under this category, Ms. Paterson also suggested another crucial point by focusing on the importance of building a better understanding of the topic before the field trip: "I think they (students) just need experience with electricity, and how electricity travels, though they should have had that experience because that was part of last year's curriculum." This might have led to an incomplete understanding of how electricity is created, as she noted: "I mean they (students) may not actually understand it all, but they did understand that you did have to have magnets and the magnets were turning in order to produce electricity."

Challenges of the Driving Question for Museum Educators

The quality of the driving question was crucial for the museum educators and only one theme emerged under this category that discusses the challenges noted when developing driving questions.

Designing DQ

Both museum educators mentioned the challenge of designing a good driving question (see Table 8). The iterations for creating an authentic driving question became a challenge, as Mr. Rice summarized: "I think developing the driving question is a challenge in its own right, making it as useful and yet understandable as possible." To elaborate on this idea, Ms. Baker noted, "I found it actually a little bit challenging. Just trying to figure out what a good driving question was and what a question was that would be something kids would really want to learn about."

When discussing the quality of the driving question, Ms. Baker compared two driving questions, and she found the driving question designed for another investigation was more engaging than the driving question used in this investigation. She summarized the main difference from the previous driving question as "It was a really driving question. It was very motivating." She would like to design a driving question that is more engaging in terms of content: "… I didn't feel it (driving question) allowed them to go very deep." For future field trips, she would like to see that the final products investigate more content by including the evolutionary relationships.

Individual Notes

Mr. Rice noted that teachers need to know the museum to make a question that can relate to the classroom and the exhibits, and teachers do not have time for designing DQs. He suggested that the museum can design a pool of DQs, and then teachers can modify them:

> A teacher isn't going to have a whole lot of time in preparation for a field trip to come up with just the perfect driving question, so I think there will probably need to be a way to simplify that. I wonder if that's something the science center could help develop, maybe with the support materials, you know, here are some driving questions for each exhibit or each content area, something like that, that teachers can at least browse through and it starts their own ideas. And then they of course then would have the opportunity to modify it in preparation for their trip and not feel like they have to come up with the perfect question from scratch.

Discussion

Well-documented problems with informal education (Orion 1993) have pushed educators to find alternative ways such as virtual field trips (Stainfield et al. 2000). Instead of finding new directions, we emphasized greater support of the collaboration between museum educators and teachers by following four crucial steps identified by Bell and colleagues (2009) to connect teachers and museum educators when designing the field trip experience: advanced preparation, students' engagement with museum exhibits, teacher and museum staff involvement, and follow-up activities. Similar to previous studies we focused on how using technology can help us in this important process (Baylor and Ritchie 2002; Russell et al. 2003; Gray et al. 2010; Delen 2014). In this section, we will discuss the findings in relation to the framework used in this study.

Advanced Preparation and Teacher and Museum Staff Involvement

When organizing field trips, museum educators highlighted the importance of balancing the goals between them and the teachers, in a process Kisiel (2010) referred to as the collaboration between museums and classrooms. This connection occurs only at the basic level by museums sharing only the structure of the field trip. When discussing previous field trip experiences, museum educators and teachers participating in this study did not mention designing the field trip collaboratively, which supports idea of the disconnectedness between stakeholders (Gupta et al. 2010; Morag and Tal 2012).

In this study, the development of a driving question (or a driving challenge) was the key for making teachers and museum educators come together for designing the learning experience (advanced preparation, teacher and museum staff involvement). Previous studies have emphasized the role of DQ as engaging students in activities (Krajcik et al. 1994; Blumenfeld et al. 2000; Singer et al. 2000; Zhang and Quintana 2012). When planning a field trip, Morag and Tal (2012) illustrated the importance of advance preparation in the classroom, connecting museum educators and teachers, and linking a field trip to the curriculum.

Teachers and museum educators met several times to design a driving question that is connected to teachers' curricular goals. As noted by Kisiel (2010) when creating the connection between museums and classrooms, sharing concerns, suggestions, and goals are central. As noted earlier, since the Science Center did not directly address electricity, the teacher and the museum educator decided to focus on how different type of energies can be used to create electricity. In this study, the driving question/challenge connected educators to design the learning environment in advance. In addition, it guided students during data collection in the field trip and data analysis in the classroom (Vavoula et al. 2009; Cahill et al. 2011). But it is also important to note that the development of a shared driving question also raises some challenges (e.g., iterations, making the questions authentic, appropriate for grade level, engaging with content) to the quality and the development process of the driving question.

Engagement with Museum Exhibits and Follow-up Activities

Griffin and Symington (1997) found that teachers made little effort to connect the experiences across classrooms and museums. Similar to previous studies, using mobile devices helped educators bridge formal and informal settings by bringing the data back to the classroom to support students during follow-up activities (Vavoula et al. 2009; Cahill et al. 2011). Besides connecting classrooms and museums to support follow-up activities, all of the educators mentioned that the mobile application supported students to engage with the exhibits. This finding is also consistent with other studies (Hsi 2003; Klopfer et al. 2005; Vavoula et al. 2009), which have noted students' engagement when using mobile devices. Besides the benefits, the mobile application was also a source of concern. Four of the educators (both museum educators and two teachers) mentioned how the mobile devices could also serve to distract the students. Previous studies (Hsi 2003; Cabrera et al. 2005; Sung et al. 2010; Cahill et al. 2011; Gikas and Grant 2013) have also found that the use of mobile devices may decrease the level of interaction in the museum. In a previous study, Cahill and colleagues (2011) noted that "heads-down interaction with the handheld devices may be interpreted as inattentive" (p. 27) in informal settings since "the act of writing on worksheets … perceived as more acceptable by docents and museum educators" (p. 27). It is interesting to note in our study that when we look at the teachers' perspective, teachers described mobile devices as a more effective way of documentation compared to worksheets. Vavoula and colleagues (2009) reached a similar conclusion when they discussed that teachers believed students interacted with the exhibits more when using mobile devices. On the other hand, Cahill and colleagues (2011) found students had more interaction with their peers when using worksheets. Despite providing better ways of documentation, using mobile devices may reduce the social interaction.

Contributions

The use of mobile devices provides great opportunities for supporting data collection in informal settings (Krajcik and Starr 2001; Rogers et al. 2004; Fraser et al. 2005; Maldonado and Pea 2010). Using mobile devices in "designed settings" can bridge the gap between classrooms and museums (Vavoula et al. 2009; Cahill et al. 2011). Similar to previous studies (Vavoula et al. 2009; Cahill et al. 2011), the use of mobile devices as a data collection and organization tool supported two steps noted by Bell and colleagues (2009) for designing a

successful field trip experience: (1) engagement with museum exhibits, and (2) follow-up activities.

The primary goal of this study was to extend the current body of literature by connecting teachers and museum educators when developing a driving question. Previously Kisiel (2010) examined the long-term partnership between a school and an aquarium. In this study, we considered the more common single museum visit by designing the field experience collaboratively for each field trip. This supported advanced preparation, as well as teacher and museum staff involvement (Bell et al. 2009). Prior to this investigation, educators participating in this study noted a basic level of connection. Creating the initial connection by developing driving questions collaboratively also increased museum educators' engagement with the follow-up activities. One of the museum educators (Mr. Rice) visited Ms. Paterson's classroom after the field trip to find out how students connected their museum data to the design projects.

Participants in this study noted that use of mobile devices and developing driving questions collaboratively helped to connect classrooms and museums. But it is important to note that we only worked with a limited number of participants and used self-reports to understand the process. To better understand how using mobile devices and driving questions help to connect teachers and museum educators, an extension study could include more participants, and investigate students' specific work in the museum and in the classroom.

In addition, when testing the use of mobile devices there were several graduate students assisting teachers and students, which may have aninfluence on the novelty of using mobile devices. As noted by Gikas and Grant (2013), when using mobile devices students would have the following challenges in addition to the novelty "fear of the technology not working properly, small mobile device keyboards making typing difficult, and potential device distractions" (p.25). Observing teachers' and students' use of mobile devices may improve understanding of how to overcome the novelty of using new technologies.

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