Conducting Discipline-Based Educational Research Outside of the Classroom

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Abstract

This "tricks of the trade" paper seeks to support new researchers interested in conducting discipline-based educational research outside of the classroom setting. Based on national calls, we need to increase science literacy and expanding our efforts to informal science, technology, engineering, and math (STEM) learning will support these calls to action. Traditionally, discipline-based educational research in STEM has been conducted in typical classroom environments. This can include classrooms from preschool through higher education. However, there is an ever-widening set of opportunities afforded to people to learn about STEM careers and STEM topics outside of the classroom. To better understand the impacts of informal education experiences, it is important to research outside of the classroom. While research into these experiences is expanding, conducting research outside of the classroom setting presents its own unique set of challenges. The authors on this paper have all conducted STEM research and assessment in a variety of informal learning settings including youth organizations, science resource centers, community outreach programs, and museums across different age groups. In this paper, we discuss some of the challenges present in informal learning settings along with tips for how to plan for and overcome issues that will inevitably arise. We also highlight the unique benefits of working outside of a traditional classroom. By sharing our "tricks of the trade," we hope to empower developing researchers to explore the impacts of informal learning in STEM.

Introduction

In response to numerous calls for improved STEM preparation at all levels in the United States (e.g., [1]–[3]), there has been a renewed focus on STEM education, particularly at the primary and secondary education levels. This includes in-school opportunities, such as the introduction of the Next Generation Science Standards (NGSS) [4], which seek to integrate engineering and technology into science curricula at all levels, along with a range of informal STEM experiences [5]. With this interest has come an increased research focus in the same area. For example, in a literature review centered on pre-college engineering education research from 2000-2015, Hynes et al. [6] found a marked increase in publications in 2011 compared to the previous years. These studies provided important insight into the impacts of pre-college engineering education. For example, several studies indicated that exposure to pre-college engineering education supports the development of an engineering identity (e.g., [7], [8]). This expanded research interest provides important ideas about supporting the development of future STEM professionals and STEM-literate citizens.

While these studies have provided valuable insight into pre-college students' experience with STEM education, the studies focus disproportionately on experiences that occur within

classrooms. For example, Hynes et al. [6] found that approximately 75% of studies in pre-college engineering education research occurred in classroom settings, with the remaining 25% occurring in informal settings. However, this focus on classroom experiences is in direct contrast to where pre-college students spend their waking hours, with approximately 80% of a student's waking hours being spent outside of the classroom [9].

Outside of the classroom, many pre-college students have an ever-growing list of opportunities to gain STEM experience in their communities. The National Research Council (NRC) [5] classifies these opportunities into four categories that make up a "STEM ecosystem", including *designed settings, naturalistic settings, people and networks of people,* and *everyday encounters.* Designed settings include opportunities like after-school programs (e.g., [10]), clubs such as Black Girls Code [11], museums (e.g., [12]), and youth programs like the Girl Scouts [13], Boy Scouts [14] and 4H [15]. Naturalistic settings include opportunities like those in parks (e.g., [16]). People and networks of people include STEM professionals, educators, and other community members which may serve as role models or other inspiration for students (e.g., [17], [18]). Finally, everyday encounters are opportunities for students to engage in STEM in their everyday lives, which may include experiences online through platforms like code.org [19], videos on television or other streaming services (e.g., [20]), books (e.g., [21]) , at-home kits (e.g., [22]), toys (e.g., [23]), conversations with family, and many more opportunities. While students can, and are, being exposed to STEM outside of the classroom, comparatively little research has been conducted outside of the classroom, especially in engineering.

Understanding students' experiences in and out of the classroom can help us better prepare students to be future STEM professionals and STEM-literate members of society; however, conducting research outside of the classroom presents a range of challenges to researchers who wish to undertake these studies. Some of these challenges are logistical. For example, the duration and depth of participation in these informal experiences differs significantly both from experience to experience and participant to participant [5]. Other challenges are more theoretical in nature. For example, many informal experiences have poorly defined, difficult to assess, or non-existent learning outcomes [5]. These and other challenges can make conducting research in informal learning settings an overwhelming task.

In this "tricks of the trade" paper, we seek to provide recommendations to support new researchers who are embarking on research outside of the classroom. We draw on lessons learned by three researchers who have experience in conducting discipline-based research in a range of informal settings. We hope our recommendations encourage others to conduct research outside the classroom to further contribute to the informal STEM learning body of knowledge.

Contexts

Each author has conducted research in a different informal STEM context, two of which (Contexts 1 and 2) were for dissertation research and one (Context 3) is an on-going engineering outreach program. A description of each context is provided below to help frame this paper and the recommendations.

Context One: A short-term engineering program in a youth organization
The first context was a dissertation research study conducted by Dr. Clark with local Girl Scout troops. This study focused on the impact of the completion of an engineering badge [24] on the participants' views of engineering and of themselves as future engineers. Dr. Clark led the badge activities to create a common experience across the participants. Originally, this study was planned to occur in person; however, due to the emergence of the COVID-19 pandemic, the study activities were moved into online and hybrid formats.

This study was framed using Possible Selves theory [25], and data was collected using pre- and post-interviews. Additionally, participants were asked to complete the Draw-an-Engineer Test (DAET) [26] prior to their first interview, followed by a variation on the DAET prior to their post-interview where participants were asked to envision themselves as an engineer. The DAET drawings were used as a focal object in both the pre- and post-interviews. The interviews were analyzed using interpretative phenomenological analysis [27] in order to investigate the meaning that the participants made of the experience. Additionally, observations of the badge activities were conducted but were of very difficult and, ultimately, limited use due to the delivery modality shift.

Context Two: A study of museum professionals
The second context was a dissertation research study conducted by Dr. Burns about informal science institutions (ISIs). ISIs are designed learning environments which give participants choice in how they interact with the content, exhibit, or exhibition [28]. ISIs include museums, science centers, aquariums, zoos, and environmental centers, as well as the segments housed within them. These smaller parts could include exhibits, exhibitions, demonstrations, and short-term programs [28], [29]. The research interviewed professionals from many different types of ISIs located in different parts of the United States and Canada. The professionals represented 15 institutions, including science museums, science centers, zoos, aquariums, children's museums, and a research and evaluation company. A three round Delphi study was completed for this research project. Round 1 consisted of semi-structured interviews, followed by two subsequent rounds of Likert-response surveys.

Context Three: Ongoing outreach and engagement with community members

This third context, in which work was conducted by Dr. Kajfez, is ongoing workshops with local families through a local children's hospital. Much of the research in this context focused on the engineering student volunteers' experiences as they participated in the workshops in their courses [30] and with the public. However, some assessment studies were conducted with parents of children with disabilities who attended the sessions, which is the focus for this paper. Workshops not associated with a class included 5-10 families who have children with disabilities and approximately 10 engineering student volunteers. The workshops were facilitated by Dr. Kajfez, her colleague, and their students. Most of the workshops took place at a hospital facility.

Related to data collection, most data were collected through simple surveys. Surveys were distributed via pencil and paper at the event to ensure they were easy and quick to fill out. The questions asked parent participants to identify the best parts of the workshop and areas for improvement. The data from these surveys were used to improve the workshops over time ensuring they met the needs of the families involved.

Methods

For this paper, we chose an autoethnographic approach. Autoethnographies allow for the first-hand examination of researchers' experiences [31]. Others in engineering education have used similar approaches to share experiences as graduate students (e.g., [32]), instructors (e.g., [33]) and early career faculty (e.g., [34]). As researchers in these informal learning spaces, we were fascinated by the past work of others and interested in understanding the similarities and differences between our lived experiences in informal STEM learning spaces. Our goal was to generate recommendations for others interested in working in this domain by sharing our experiences. Through this autoethnographic approach, we were able to share our lived experiences while systematically analyzing them.

To examine our experiences, we collectively developed a set of reflection questions, listed below. We then each answered them independently about our work in our specific informal learning context. We each reflected on the following prompts:
- Describe the setting in which you have conducted research and assessments in informal STEM settings.
- What questions were you investigating, and what methods were used?
- What population(s) were you focused on?
- How did you recruit participants? What went well? What were the challenges?
- How did you collect data? What went well? What were the challenges?
- What unexpected challenges arose during this research and/or assessment?
- What were you worried about that went well? What preparations did you take to help ensure it went well?

- What else would you like to share about your experience working in this informal STEM setting?

Once we each wrote a reflection, we read each other's reflections separately, noting similarities and unique findings. We then met and collaboratively discussed and developed themes and recommendations through a synthesis of our experiences.

Themes & Recommendations

Three themes emerged from our analysis: *leveraging your networks*, *anticipating recruitment challenges*, and *the need for flexibility*. Each of these themes, plus specific recommendations are discussed below with specific insights provided related to informal learning.

Theme 1: Leveraging Your Networks
When first reviewing our reflections, we noted the unique networks we each had to access in order to conduct our work. Dr. Clark was able to access the Girl Scout network through her previous involvement in the organization; however, she did have to receive approvals from leaders in the organization who she did not know personally. While Dr. Burns was not directly involved in the museum setting, she knew many individuals who were through collaborations on other projects and was able to leverage their connections to find research participants. Similarly, Dr. Kajfez relied heavily on her contacts at the children's hospital to reach families. For each informal learning setting, it was important to identify the network and then find a way to access it, which in every case required discussions and connections with multiple people to reach the participants of interest.

We also noticed a theme around the who stakeholders and participants are in this research. While Dr. Clark's research focused on middle school Girl Scout participants, Dr. Burns and Dr. Kajfez did not research the children directly involved, even though in both cases they were clearly stakeholders in these informal STEM learning efforts. We wanted to highlight this because it is possible to do work in the informal learning space and conduct research on one of the many groups involved in contributing to the body of knowledge in unique ways. Informal learning research does not have to only mean research with children.

Related to the network theme, we recommend that researchers identify the network their population of interest is a part of and then consider the many ways in which one might access the network as a whole. Through those access points, various groups (e.g., children participants, parents, designers, etc.) can be accessed for study recruitment. They do not have to be accessed directly by the researcher. This network consideration is especially important in informal learning because the networks which can be accessed expand well beyond those of the traditional classroom. While traditional classroom work might consider teachers, students, and administrators, outside of the classroom, parents, friends, religious networks, etc. become

possibilities for connections. Researchers should use their contacts within those networks to discover how to quickly establish trust and rapport with potential participants. The network access points often have key insights to make study recruitment a success.

Additionally, by leveraging your network, you may be able to determine how to quickly establish rapport and trust with your participants. In formal settings, we have often had an administrator or instructor introduce the research project or help with recruitment in other ways. However, you often do not have that luxury in informal spaces, as there is often a less defined hierarchy, so you must quickly establish trust and rapport with your potential participants. For example, at the advice of Girl Scout council staff, Dr. Clark spent the beginning part of her research "pitch" to troop leaders and parents sharing her long-standing involvement with the Girl Scouts. This helped troop leaders and parents feel more comfortable allowing their children to take part in the study.

Theme 2: Anticipating Recruitment Challenges
The COVID-19 pandemic contributed to complicated recruitment challenges, including participant retention. When the Girl Scout and ISI studies were being completed, virtual data collection, including virtual interviews, became necessary. Schools and jobs were forced to change to virtual settings as well. Using the network recommendations listed above, we were surprised at the positive response to recruitment. The Girl Scout study had many more troops express interest than expected, and a lot of parents who were willing to allow their child to participate. However, the process of getting participants registered was very complicated, creating the biggest hurdle. Similarly, the COVID-19 pandemic had closed many ISIs. However, as mentioned earlier, the new comfort levels with meeting virtually allowed participants from all over the United States and a participant from Canada to take part in the ISI related study, almost like we were meeting face to face. It felt personable.

In contrast with studies in formal learning settings, participants in informal settings are significantly more transient. While a classroom of students may be substantively the same each time they meet, even with a defined group like a Girl Scout troop, the participants in informal settings tend to fluctuate from meeting to meeting, which is amplified in spaces such as museums or outreach programs. Depending on the study design, this may mean that a researcher in informal spaces must plan for additional time to meet participant recruitment goals by either coming back to a given group or by adding additional settings to the study. For example, while her initial recruitment plan was successful, Dr. Clark was concerned that parents would not be willing to let their child participate in her study. Therefore, she included nearly twice the needed recruitment timeline in her project plan to allow for additional recruitment activities in the case where she would need to reach out to other troops and service units.

Keeping our participants engaged throughout the studies, including the multiple interviews and surveys, was a challenge. For each iteration of studies, we reached out to participants with reminders and scheduling. Providing updates to participants allowed them to understand how the studies were moving forward. It was also important we gave our participants flexibility to complete each part of data collection, without too much time in between that participants lost interest.

Related to the theme of recruitment challenges and participant retention, we recommend researchers use the networking recommendations from above. Additionally, we suggest proposing a timeline to participants at the beginning of the study to help them understand the expected time commitment. Further, we suggest providing updates throughout the study for participants to see how things are progressing.

Theme 3: Remaining Flexible
Finally, we saw evidence throughout our research contexts that flexibility was key to success in our projects. In informal education settings, flexibility can take on many appearances. Rarely, this may look like something as major as redesigning a study to new modalities and adjusting data collection methods in response to a major local or global event, such as the COVID-19 pandemic. This was the case in context one, the Girl Scout study. However, even more minor examples of flexibility can still go a long way to ensuring the success of your research project. For example, participants may not complete research tasks or respond to interview questions in the way you had intended. This has often been the case with Dr. Kajfez's work with families involved with the workshops, where the research team has needed to adjust survey questions or reinterpret them in the moment in order to allow participants to better understand the goal of the question. Similarly, when working with middle schoolers, it was often necessary to re-word interview questions or adjust for participant's forgetting to complete the DAET prior to the interview. It is critical to have alternate versions of questions or alternate explanations of research tasks prepared and to be ready to adjust as needed.

Secondly, due to the nature of informal learning, flexibility is key to getting the data needed for the study. As discussed above, many informal learning settings are incredibly transient and even those who meet repeatedly, such as a Girl Scout troop, tend to meet significantly less frequently than a classroom or other formal learning setting. Particularly in settings like museums, libraries, or other "one-off" events, it is critical to build flexibility into your recruitment and data collection plans. In Dr. Kajfez's work, the only chance that she had to interact with and gather data from the families who attend the workshops is the time that they are on-site. Therefore, the team running the workshops put plans in place to adapt to changes in facilities, participant's abilities, and more. Additionally, they have built-in flexibility in their data collection to allow for the appropriate data to be collected even when events have not occurred as planned, such as if significantly more or significantly fewer people than planned come to an event. Therefore, we

encourage researchers embarking on a study in an informal setting, particularly one where there will be a single instance to interact with participants, to spend time planning contingencies for a range of disruptions. This will allow for flexibility and, ultimately, to guarantee the gathering of data from your participants.

It is often also necessary to be flexible with your research timeline in any research project but particularly when working in informal settings. Timeline flexibility has been needed in all three research contexts. In both Dr. Clark's and Dr. Burn's work, the data collection timeline relied heavily on their participants' availability to participate in interviews and other research activities. Similarly, Dr. Kajfez's work relied on the availability of families, staff, and resources at the children's hospital. While this can certainly be the case in both formal and informal settings, in our experiences in research in informal settings, timelines tended to shift more frequently than those in formal settings due to the general informal nature of the work. It is therefore important to build in significant buffers into your research timeline to allow for delays and shifts.

Related to the flexibility theme, we recommend that researchers prepare alternate interview questions and activities to allow for participants to best take part in the study. Additionally, we suggest building a research timeline with significant buffer space to allow for the many delays which can occur in this type of research.

Conclusion & Future Work

Significantly more work is needed to better understand the impact and experiences of all stakeholders and participants in informal STEM learning experiences. A better understanding of these experiences will help support the development of a STEM-literate society and future STEM professionals, meeting the needs present in national calls. However, this type of research presents unique challenges. We hope that the recommendations developed from our collective experiences provide actionable suggestions to aid researchers new to this area. Others who have conducted research in informal spaces should share their own experiences to develop a set of evidence-based practices for effective research in these challenging domains. Research into informal spaces has the potential to bring new insight into how STEM learners and members of a STEM-literate society develop, and work in this area should be encouraged and prioritized.

Acknowledgments

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