Design and Implementation of Data Collection in a Large-Scale, Multi-Year Pre-College Engineering Study: A Retrospective

Dr. Ibrahim H. Yeter, Purdue University, West Lafayette

Ibrahim H. Yeter is a Postdoctoral Researcher in his second year in the INSPIRE-Research Institute for Pre-College Engineering in the School of Engineering Education at Purdue University. He completed his PhD degree majoring in Curriculum and Instruction with an emphasis in Engineering Education and minoring in Educational Psychology as well as an MS degree in Petroleum Engineering at Texas Tech University. He also obtained an MEd degree from Clemson University. His research interests focus on teacher education and students learning issues within Engineering Education/Pedagogy and Computational Thinking/Pedagogy field of studies. He received national and international recognitions including an Early Career Researcher award from European Science Education Research Association (ESERA) and a Jhumki Basu Scholar award from National Association for Research in Science Teaching (NARST). In addition, he is one of two scholarship recipients awarded by NARST to attend the ESERA summer research program in České Budějovice, Czech Republic in 2016. He can be reached at iyeter@purdue.edu.

Dr. Anastasia Marie Rynearson, Campbell University

Anastasia Rynearson is an Assistant Professor at Campbell University. She received a PhD from Purdue University in Engineering Education and a B.S. and M.Eng. in Mechanical Engineering at the Rochester Institute of Technology. Her teaching experience includes outreach activities at various age levels as well as a position as Assistant Professor in the Mechanical Engineering Department at Kanazawa Technical College and Future Faculty Fellow teaching First-Year Engineering at Purdue University. She focused on integrated STEM curriculum development as part of an NSF STEM+C grant as a Postdoctoral Research Assistant through INSPIRE in the School of Engineering Education at Purdue University Her current research interests focus on early P-12 engineering education and identity development.

Ms. Hoda Ehsan, Purdue University, West Lafayette

Hoda is a Ph.D. student in the School of Engineering Education, Purdue. She received her B.S. in mechanical engineering in Iran, and obtained her M.S. in Childhood Education and New York teaching certification from City College of New York (CUNY-CCNY). She is now a graduate research assistant on STEM+C project. Her research interests include designing informal setting for engineering learning, and promoting engineering thinking in differently abled students in informal and formal settings.

Dr. Abeera P. Rehmat, Purdue University, West Lafayette

A Post-doctoral Research Associate at Purdue University.

Dr. Annwesa Dasgupta, Indiana University-Purdue University, Indianapolis

Dr. Annwesa Dasgupta is a postdoctoral researcher with the STEM Education Innovation and Research Institute. Her primary role at SEIRI is to facilitate the SEIRI seed grant program (SSG) that serves as a grant competition for innovative pedagogical implementations by STEM faculty at IUPUI. Her research interests include biology education as well as integrated STEM research. In addition to overseeing the SSG program, she closely works with faculty on research-based implementation of CUREs (course based undergraduate research) as a model in the biology department. Dasgupta received her PhD in biology education research from Purdue University. Her dissertation was centered on the design of assessments that explore student difficulties in thinking about biology experiments. Previously, Dr. Dasgupta was a postdoctoral researchers at the School of Engineering Education at Purdue University where she worked on the STEM+C project, focused on enhancing STEM engagement and computational thinking (STEM+C) for K-2 grade students by developing connections across formal and informal learning environments.

Ms. Barbara Fagundes, Purdue University, West Lafayette

Barbara Fagundes is a first-year Ph.D. student in the Engineering Education Department at Purdue University. Her doctoral research interests involve representation of women in the STEM field, k-12 engineering education, and computational thinking.

Dr. Muhsin Menekse, Purdue University, West Lafayette

Muhsin Menekse is an assistant professor at Purdue University with a joint appointment in the School of Engineering Education and the Department of Curriculum & Instruction. Dr. Menekse's primary research focus is on students' learning of complex tasks and concepts in STEM domains. Specifically, he investigates how classroom activities and learning environments affect engagement and learning in engineering and science domains. His second research focus in on exploring verbal interactions in small groups and student teams. And his third research focus is on metacognition and its implications for learning. Much of this research focuses on learning processes in classroom settings. Dr. Menekse is the recipient of the 2014 William Elgin Wickenden Award by the American Society for Engineering Education. His research has been generously funded by grants from the Institute of Education Sciences (IES), Purdue Research Foundation (PRF), and National Science Foundation (NSF).

Dr. Monica E. Cardella, Purdue University, West Lafayette

Monica E. Cardella is the Director of the INSPIRE Research Institute for Pre-College Engineering and is an Associate Professor of Engineering Education at Purdue University.

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Abstract

The data collection procedure and process is one of the most critical components in a research study that affects the findings. Problems in data collection may directly influence the findings, and consequently, may lead to questionable inferences. Despite the challenges in data collection, this study provides insights for STEM education researchers and practitioners on effective data collection, in order to ensure that the data is useful for answering questions posed by research. Our engineering education research study was a part of a three-year, NSF funded project implemented in the Midwest region of the US. The project has engaged more than 60 teachers from 15 different public elementary schools and one private elementary school from five different school districts, as well as homeschool educators. More than 1,000 students, ages kindergarten to second grade, have been involved. Through this project, children engaged in integrated STEM + literacy +computational thinking activities in formal, informal, and homeschool settings. For this multi-faceted project, data collection was complex. The primary data collected for this project was video-recordings of K-2nd grade-aged children as they engaged in curriculum activities in both classroom and homeschool settings, as well as in activities designed for and set in a science center setting. Video recordings allow us to examine the ways that the children engage in engineering design and computational thinking, as well as in mathematics, science, and literacy. Video recordings also allow us to examine the interactions between children, as well as interactions between children and teachers/parents. Additional data included: copies of student work (e.g. worksheets, engineering design prototypes); field notes collected during classroom observation and science center visits; post-implementation interviews with teachers and parents; and surveys. In addition, a new approach, referred to as the *1+2 technique*, in video data collection was developed to record the targeted data. Overall, the main aim of this paper is to provide critical insights for researchers who anticipate implementing more successful, purposeful and effective data collection in elementary schools, specifically in K-2 grade levels. We also anticipate that this paper will help practitioners and professional developers consider how they might collect video recordings: whether for allowing practitioners to reflect on their teaching practices; allowing teachers to share with families the in-class activities that children engage in; or assisting professional developers in developing video-based training materials.

Introduction

Purpose of the Paper

This paper describes the evolution of data collection in a large-scale study focusing on elementary school students in a variety of settings. The organization of this paper is therefore not in a traditional format. The focus of this paper is on the data collection and management strategies to provide effective and targeted data collection, rather than the project outcomes. In addition, we provide reflections from the data collectors to share their experiences during the data collection and management. This paper is intended to provide an outline for prospective investigators, data collectors, evaluators, and data managers to use in their own projects.

Difficulties in Large-Scale Data Collection

Any large project that requires data collection from multiple environments has challenges in organizing the data collectors and collected data. This is particularly true when working in classroom settings. Large-scale data collection across multiple schools and classrooms in P-12 settings has its own unique set of challenges. To begin with, identifying potential schools and teachers as adopters can be difficult (Back et al., 2015). Schools have schedules and professional development commitments; planning for simultaneous implementation for multiple schools needs to be carried out months in advance (Nadelson et al., 2013). Letters of commitment are often needed from any potential collaborating institutions. P-12 schools may require only a letter of collaboration from the principal, or an in-depth vetting process involving specific research consultants, the superintendent, or even the entire school board for full approval. Federal regulations, including the Family Educational Rights and Privacy Act (FERPA), and oversight organizations like an institutional review board (IRB), regulate and oversee the kinds of data that may be collected and methods that may be used to collect these data.

Schools often permit collection of any sensitive data only if de-identified such that it cannot be linked back to a particular student. The difficulty level of the data collection can vary and depends on the project setting, length, and attributes of the targeted sample. One feasible approach is to collect data using large student groups and then repeat the sampling with targeted student groups after initial analysis, instead of beginning with a small initial targeted sample at the outset (Ryan & Bernard, 2010; von Maurice, Zinn, & Wolter, 2017). Once data collection sites and populations are identified and all proper steps have been taken, there are additional considerations such as the logistics of the data collection itself, de-identification of data, organization, and storage of data, analysis of data, and dissemination of data. There is also a need for an adequate supply of data collection equipment like cameras, audio recorders, and a secure storage server. Additionally, due to the varying schedules of data collection personnel, it can be difficult to arrange the collection of observational data across schools. These individuals must be adequately trained to ensure high levels of consistency in data collection across multiple sites, particularly in a large-scale project.

Integrated STEM Curriculum

Integrated science, technology, engineering, and mathematics (STEM) education is seen to be vital for our future due to the interdisciplinary experiences that it can provide students in P-12 education settings. Integrated STEM experiences can equip students with essential skills and knowledge necessary for the global economy (Becker & Park, 2011). Moreover, content and context integration methods in education can support students in recognizing how the STEM disciplines are interwoven (e.g., Roehrig, Moore, Wang & Park, 2012) and incite innovative ways to teach and develop students' understanding in STEM fields (Roberts, 2013; Yasar et al., 2016).

In our project, the integrated STEM curriculum was developed for kindergarten, first, and second grades, and it emphasized engineering design and literacy as the means to facilitate the integration of STEM disciplines. In this curriculum, picture books are coupled with a design challenge that engages students in authentic activities designed to foster their understanding of science and mathematics. The development of three integrated STEM modules was informed by STEM integration research, which defines STEM as the purposeful merging of science, technology, engineering, and mathematics applied to solve real-world problems (Breiner, Harkness, Johnson, & Koehler, 2012). In this curriculum, STEM and non-STEM disciplines are merged to promote teaching and learning as a holistic body and to foster STEM literacy (Breiner et al, 2012; Roehrig et al., 2012). The three modules were designed based on the Framework for Quality K-12 Engineering Education (Moore et al., 2014), which recommends developing integrated STEM curricula that include an engaging context, involvement in an engineering design task that allows students to learn from failure and redesign, alignment to appropriate standards, use of student-centered pedagogies, and promotion of teamwork and communication skills (Moore et al., 2014).

Project Description

Our project focuses on the implementation of engineering practices and the characterization of computational thinking (CT) for children in grades K-2. The competencies we investigated are described in more detail in other papers (e.g. Hynes et al., 2019; 2016): *Abstraction, Algorithms and Procedures, Automation, Data Collection, Data Analysis, Data Representation, Debugging/Troubleshooting, Pattern Recognition, Problem Decomposition, Parallelization,* and *Simulations*. The project includes learning in both formal school (e.g. public and private schools) and out-of-school (e.g. science center) settings as well as homeschool settings, which share characteristics of both formal school and out-of-school settings. By characterizing CT in contexts accessible to children, we considered rich learning opportunities for children across various settings, including home, museums, and schools. Therefore, CT has been integrated in an existing K-2 STEM and Literacy curriculum. Through this project, we have partnered with five different school districts as well as homeschool settings in suburban and rural areas in a Midwestern state, and have offered professional development opportunities to prepare teachers to implement the developed curriculum in their classrooms.

Moreover, existing studies (e.g. Bell, Lewenstein, & Shouse, 2009) suggest that children only spend about 18% of their waking hours in formal school environments. Thus, this project intends to promote learning by capitalizing on the time spent in out-of-school settings and making connections across in-school and out-of-school environments. As part of this project, an engineering and CT exhibit was designed and installed at a local science center. In addition, we have created a wide range of activities for out-of-school settings to promote CT and engineering among children in the kindergarten to second grade age band. Moreover, a selection of apps, books, and toys have been evaluated for their potential to promote engineering, design, and CT thinking in children. In line with our goals, we have investigated computational thinking in children during in-class activities (e.g. Dasgupta, Rynearson, Purzer, Ehsan, & Cardella, 2017), during their visits to the local science center with their families (e.g. Ehsan, Rehmat, Osman, Yeter, & Cardella, 2019; Ehsan, Dandridge, Yeter, & Cardella, 2018), and during the implementation of the curriculum in homeschool settings (e.g. Dandridge et al., 2019). In all these studies, we have observed evidence of children engaging in both engineering and CT practices.

The project involved various researchers including faculty members, postdoctoral scholars, staff professionals, and graduate and undergraduate students. Throughout the four years of the project, more than 60 kindergarten, first, and second grade in-service teachers participated in the study. The participating teachers were from 15 different public elementary schools and one private elementary school within five different school districts. Four homeschool educators were also included. More than 1,000 kindergarten to second grade students have been involved in the project.

Data Collection, Sources, and Management

Initial and Ethical Considerations

The process for collecting and using data in P-12 school settings is significantly different than other fields, such as social networks or e-commerce (Carmel, 2016). Those who have access to the data need to have clear boundaries and parameters on what to access and which information can be made available in which levels of the data (Carmel, 2016). Therefore, ethical consideration is vital when conducting research. In this context, ethics are the norms of conduct that must be followed when conducting research as they aid in distinguishing between acceptable and unacceptable behaviors (Resnik, 2011). The inclusion of ethical consideration in research is a safeguard against the fabrication of data and cultivates trustworthy collaboration. In addition, ethical considerations are a means to protect confidentiality and many other issues. Given the importance of ethical considerations in research, guidelines have been adopted by the Institutional Review Board (IRB). An Institutional Review Board is a panel of experienced individuals who help to ensure the safety of human subjects in research, and who assist in making sure that human rights are not violated. The guidelines address issues such as honesty, confidentiality, respect for intellectual property, and non-discrimination, among others. The review panels ensure that the researchers follow these guidelines for the integrity of the project.

Specifically, for projects in P-12 settings, applications with an IRB must be made early to ensure proper project planning. Collecting multiple types of data generally requires a full review which can take weeks or even months depending on the institution. These applications require all data collection instruments, consent and assent forms, post-implementation interview protocols, and sometimes even components of the curriculum that will be studied. School boards will sometimes want to review these documents themselves and will want to see the approval from the IRB before they will allow research to take place in their classrooms.

For all studies, parental consent forms, along with an initial explanation of the study, must be developed to explain the study and to ensure parents are informed of any research activities that might take place with their children. They must be informed of what will happen if their children take part in the study and what changes, if any, will happen if they choose for their child to opt out. In addition, although young students are unable to sign consent forms, they must also agree to be involved in the research project. A script to ensure student assent, and to allow students to opt out, must be developed so that it can be read to students prior to data collection activities.

Researchers must also carefully consider how to alter their project to ensure that students who have opted out are not involved in the data collection, but are not deprived of educational opportunities or put into situations where they might feel left out. For example, when taking videos or pictures of student work in this study, students who were not part of the data collection process could take part, but either the “record’ button was not pressed or these data were immediately deleted.

Recruiting and Training Data Collectors

In order to collect the targeted data effectively, first, we recruited potential data collectors, including faculty members related to the project, postdoctoral researchers, graduate students both related to the project and from other areas and undergraduate students. Those who accepted went through multiple continuous training sessions throughout the project implementation. The first training session focused on how to collect the targeted data effectively, took almost an hour, and was conducted once at the beginning of each year of the project implementation. When necessary, a make-up session was provided by the data manager for those unable to attend the first training. Within the first session, all of the aspects of the data collection techniques (e.g. video recording), strategies (e.g. selecting the best location for recording equipment), and appropriate manners and cautions (e.g. not blocking the classroom exit in case of emergency, not acting in/replacing the teacher’s role, etc.) were discussed. Follow-up training sessions occurred in a number of ways. Specific discussions related to data collection and small “refresher” training sessions were embedded in the weekly project meetings. Questions from data collectors were answered as they came up and common problems seen in the data collection process were also regularly addressed.

In the second year of data collection, the data manager conducted a follow-up training session of approximately one hour. In this follow-up training session, the data manager facilitated a platform for data collector personnel to reflect on their experiences. The data manager also provided their observations, including best practices and common mistakes. For example, a common problem was syncing the audio receiver with its transmitter so that the system could pick up the conversations and interactions happening in the classrooms. Few problems were seen in collecting video data, however, in several cases, the audio recording data were not effectively collected. Another issue in audio recording was that, even though in some cases the audio and video appeared to be properly synchronized, a “glitch” occurred during the data collection causing data to be lost. It was often hard to detect the glitch in advance; therefore, it was suggested to replace the batteries and use the headset hooked up with the transmitter for each observation session. In addition, during the follow-up training session, the data collection team engaged in brainstorming to exchange the best practices. As we moved in the data collection process, we then used both phone or email as a way to communicate for instant troubleshooting or communications as a part of the ongoing training and data collection support. At the end of the data collection, we evaluated what worked well and did not so that we could take the notes for upcoming projects and data collection. While data collection for every project is unique, initial training and continuous retraining and evaluation of techniques provide many benefits and can be applicable to any project.

The training sessions were provided by experienced data managers who had a range of prior expertise in collecting and securing multi-faceted data from various STEM-related projects. The sessions included theoretical perspectives (e.g. Hawthorne effect), demonstrations, practice, feedback, instant troubleshooting, and knowledge on classroom application. The main purpose of these sessions was to provide data collection personnel with sufficient knowledge and background about the data collection process and project. In addition, the data collectors were encouraged to focus on an understanding of how and why the data were collected. Reinforcing this habit of mind was believed to encourage them to stay focused on collecting the targeted data.

In addition to training the data collection personnel on how to use the equipment and engage in a classroom as a silent observer, the data collection team needed to be prepared to enter each school building. In the case of this project, that meant requiring all data collectors to complete background checks to have on file for each school they would be collecting data in. Project organizers needed to be aware of which data collectors were eligible to collect data at which sites in order to schedule and reschedule data collection as needed. Most school districts will have information about how to be cleared to participate in the classroom; typically, this will be in a "volunteer" section of the school's website or can be found by calling the front office. Worth noting is that school entrance policies and procedures vary between districts and schools and are, at times, changed between school years. The project organizer also secured maps of classroom buildings and building entrance procedures for data collectors' use. Data collectors were encouraged to park where directed (typically visitor parking), bring a government-issued photo ID, and arrive at least 10 to 15 minutes early to ensure they had time to fulfill the entrance procedures and set up the recording equipment in the classroom.

Finally, data collection personnel needed to be trained on the ethical and legal considerations regarding the research being undertaken. They would need to arrive early enough on the first day to collect the consent forms, discuss which students did not have consent with the teacher, and collaborate with the teacher on a plan for what to do about students with no consent form. The data collector would need to read the assent script and get verbal assent from students with parental consent. For students without both parental consent and student assent, the researcher and teacher would work together to ensure that no educational opportunities were lost while also trying to streamline data collection. In the first year of general data collection, this often meant that certain students were grouped together and asked to remain in a specified area of the group when all-class activities were going on. In the second year, specific case studies were the focus and so it was important to ensure that any group that was chosen for a case study had only students with both parental consent and student assent.

Data Sources

Within this project, we collected four types of data; (1) video and audio recordings, (2) observational field notes, (3) digital scans and photographs of student artifacts (i.e. completed worksheets, prototypes), and finally (4) audio-recordings of teacher post-implementation interviews (see Appendix A). It is important to note that school-based data were collected from students who agreed to participate via an assent process and whose parents gave us permission via a signed consent form in accordance with our IRB protocol. Similarly, our science center participants provided consent (via signed consent forms for parents) and assent (signed forms for children eight or older and verbal assent for younger children) before participating in any study procedures.

The data collection process was guided by two checklists, beginning and ending, to ensure the proposed data were collected effectively and the tools for the data were ready and returned to the data management station back at the university. Examples of beginning and ending data collection checklists are provided in detail in Appendix B; as with all aspects of this project, as the project evolved, so too did the checklists. Different equipment was used in different stages of the project. Note that the example checklists are for the final phase of the study focusing on specific case studies rather than general data collection.

1. Video & Audio Recordings

Video and audio recording has been used across various platforms to collect data, including in P-12 educational settings. If implemented effectively and purposefully, both video and audio recording may provide rich evidence that can assist researchers in understanding and investigating the educational phenomenon. Throughout the project, we collected data from *public*, *private* and *home schools* as well as *science center* settings.

a. Public and Private School Settings

In order to capture the whole classroom dynamics and actions made by teacher and students (for instance, an interaction between students and teacher, students' behaviors, collaborations, social interactions among their peers) videotaping with a high-quality audio recording method is an effective and acceptable technique to collect the targeted data. In the first year, a single camera was often used to record the whole classroom for class-wide activities and to zoom in on a single randomly-chosen group (with complete consent/assent). A second camera or iPad was sometimes used to gather additional data, including videos or images of additional student groups for a wider variety of data. In order to facilitate successful data collection in the second year, we implemented a strategy, referred to as the *1+2 technique*, that videotaped the case studies (a group of the same students throughout the project) and the whole classroom simultaneously (see Figure 1). In this case, "1" stands for the main camera that captured the whole interactions and behaviors happen in a classroom by teacher and students. "2" stands for two sets of cameras that captured selected students' actions for the case studies.

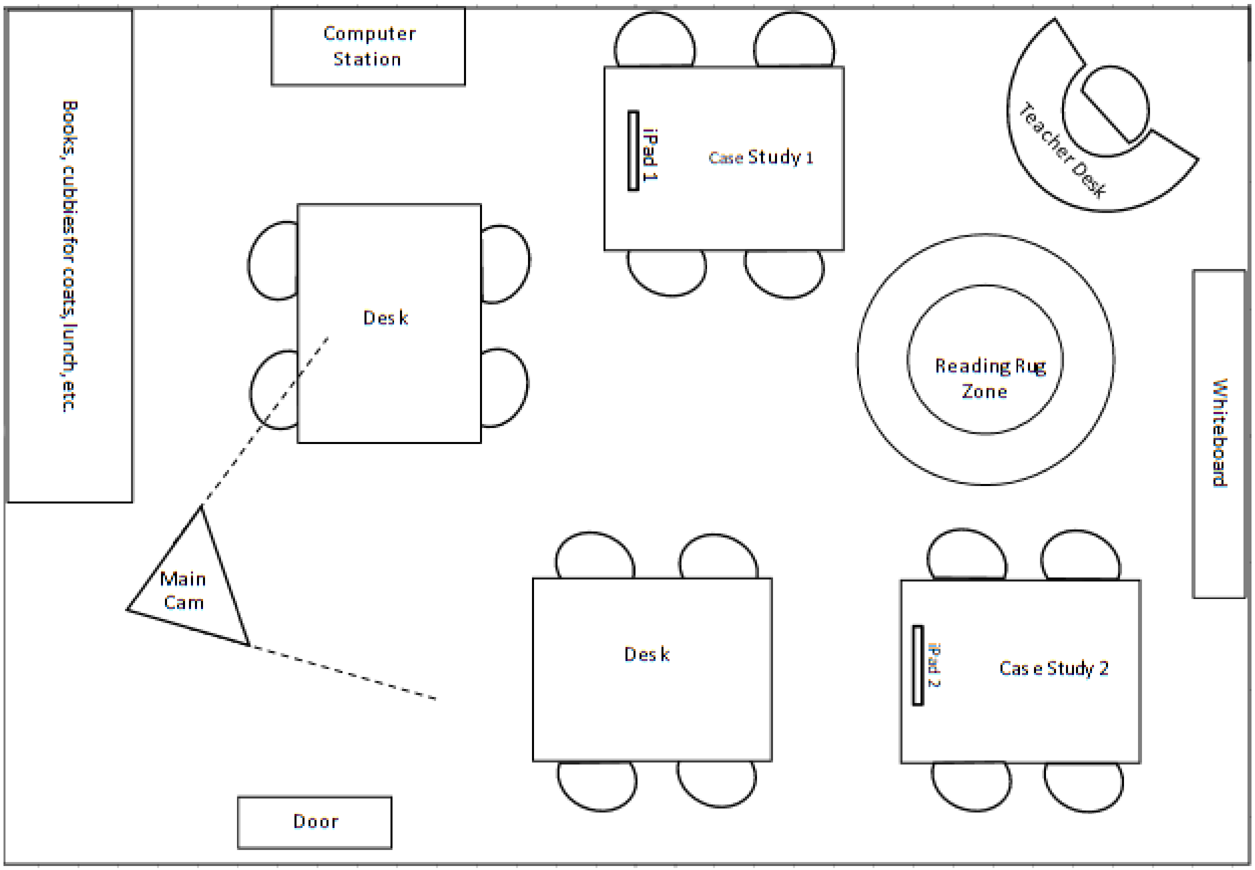

Figure 1. A representation of 1+2 technique for video data collection

b. Science Center Setting

For collecting data at the science center, we utilized two sets of video cameras that included wireless microphones for picking up the audios. Prior to conducting any research, we experimented with various recording positions to see what location would be the most effective to capture families' interactions with the exhibits. After finding the right vantage point, we located the cameras there and attached two microphones to family members. One microphone was attached to the target child, and depending on the structure of the family, we asked either one parent or a second child to carry the microphone. We also used an iPad Pro to take field notes and capture audio for the interviews. In addition, for the engineering design exhibit in which families were building a playground, we took pictures of the final designs as supplementary documentation.

c. Homeschool Setting

For the homeschool video and audio data collection, we provided data collection tools (e.g. iPads, video camera) to the homeschooling teachers to collect the targeted data in their own home settings. The data manager provided data collection training to each homeschooling teacher on how to collect data on the teaching environment, develop case studies (in this context, homeschooling students), and properly obtain images of the students' prototypes and artifacts.

Instead of the *1+2 technique*, homeschooling teachers used one camera or iPad to capture the entire educational setting. After they completed the project, we transferred the data to the secure institutional storage.

2. Observational Field Notes

Field notes were initially taken with the *LiveScribe* pen and notebook system. As part of the field notes, specific information was required in two general categories: context and data. To record the context, the date, observer, specific equipment used, the lesson taught that day, and the classroom information were recorded to match with other data collected on that date, put in order with the surrounding lessons, and compare to other similar lessons. The data itself included specific notes about what was happening in the classroom, times that specific events occurred, and initial codes as appropriate. Initial codes were developed so that if the observer noted something that would be of particular interest, for example, students engaging in computational thinking, they could make a note of that to make it easier for future data analysis. General directions for taking field notes included "Focus on student actions. Write down a new time whenever you change codes or classroom activity changes. Be as specific as possible including student demographics, actions, and who they are interacting with." An image of the initial field note template is provided in Figure 2. As the qualities of interest may vary substantially between different data collection events (and in this case did so between the first and second year of data collection) direction for field notes and guidance on which events to take note of can vary substantially.

Date: Lesson: Observer:

Time	Notes	Code(s)

Camera(s) & Audio Recorder(s): School/Grade/Teacher:

Figure 2. Field note template for LiveScribe equipment

For the case study phase, field notes were collected using an Apple Pencil and iPad Pro through the *Notability* application. Key information about how to collect field notes more effectively for the project was divided into six main categories:

- *Case Study (CS) Attendance.* For the CS Attendance column, write each student's initials to clarify who is in the classroom.
- *Teacher ID.* For the Teacher ID column, please do not use the teacher's name. Rather, please use their specific ID given in advance. You will be given the Teacher ID in advance via email.
- *Date.* For the Date column, please write the teaching date formatted as Month Day, Year. For example, *February 8, 2018.*

- *Lesson.* For the Lesson column, please write the specific lesson that the teacher teaches.
- *Time.* For the Time column, note each time the lesson begins or ends, any time the classroom activity changes, and every time you write a new note.
- *Field Notes.* For the Field Notes column, take specific notes focusing on what the students are doing.

The body of each page of the notebook had two headings: time and field notes. The first entry was the time that the lesson started and the last entry was the time that the lesson ended. Times were recorded alongside each additional note. Additionally, if breaks were taken for any reason, data collection personnel were to note the time the break began and the time the break ended. An image of the field note template is provided in Figure 3 below.

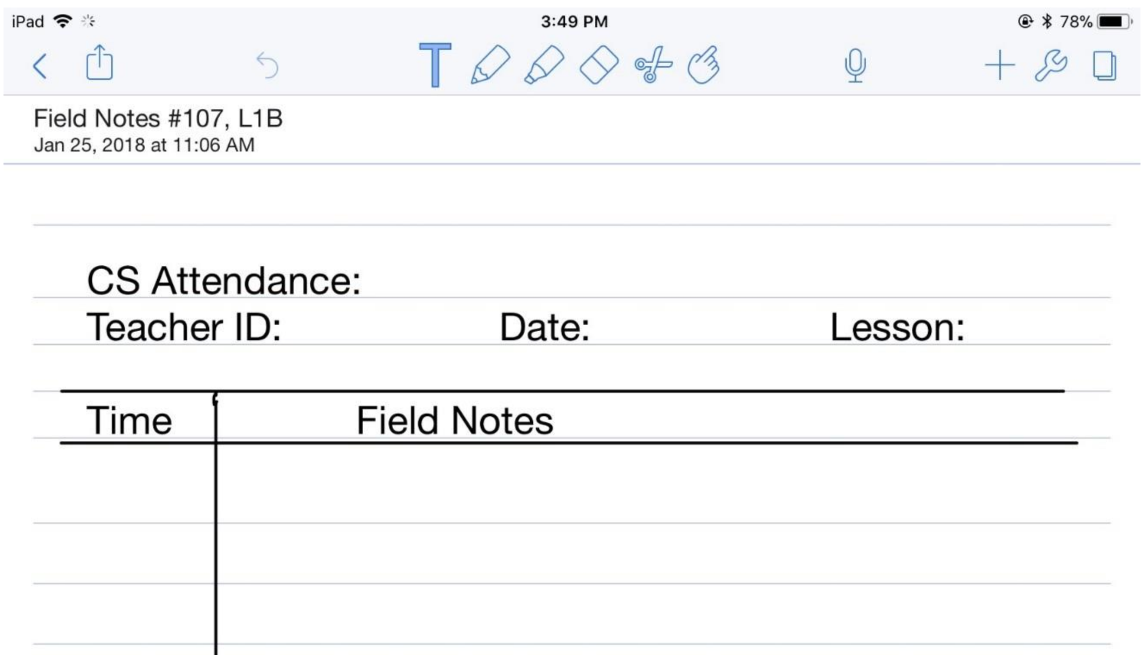

Figure 3. Field note template in Notability application

3. Worksheets: Digital Scans and Photographs of Student Artifacts

Student worksheets were collected and returned to classrooms or secured after scanning and de-identification. We collected worksheets from all students, but we did not scan those from students who did not assent or whose parents did not sign the consent forms. In addition, student activities and prototypes that did not incorporate worksheets (e.g. tangrams) were captured by using a digital camera or iPad device. Specifically, we took the pictures of prototypes after they had been built and before they were tested, if possible, preferably outside of curriculum implementation class time so that we could take complete field notes during class time and more easily position to photograph prototypes. Wherever possible, student work was connected through student identification numbers that would allow for review of a student's work across the semester, without personally identifying which student the work came from.

Student artifacts, including written work and images of prototypes, were also collected from homeschool students. At the end of the implementation, the written work, prototypes, and/or images of prototypes were provided to the research team by the homeschool teachers.

4. Teacher Interviews

There were more than 60 kindergarten, first, and second grade teachers from public elementary schools and one from a private elementary school. A detailed post-implementation interview protocol was developed by the research team and used to debrief each teacher to collect the data regarding their experiences with implementing the project. The protocol had a semi-structured interview approach and is provided in Appendix A. In the first year, focus group interviews with all of the teachers by grade level in each school were conducted to gain a broad view of how the lessons were received, how teachers felt their students reacted to the lessons, and what, if any, changes were made. The focus group format was used to get a wider range of answers where one teacher might be reminded of something after listening to another teacher. In the second year, individual debriefs were conducted in order to gain a more in-depth understanding of the individual teacher's experiences with the curriculum and their perceptions of student learning and engagement.

Data Management

Another critical component of a large-scale project is to manage the collected data for future analysis while complying with all regulations for the safety and security of the data and the anonymity of participants. For our project, the data management included collecting, transferring, de-identifying, storing, and securing data to ensure its reliability and readiness of the data for the researchers. In the course of data collection, we amassed over three terabytes (3 TB) of data including classroom video and audio recordings, observational field notes, digital scans and photographs of student artifacts (i.e. completed worksheets and prototypes), and audio and video recordings of teacher debriefs. To ensure continuous accessibility and security for such a massive quantity of data, we utilized storage in a highly secured research repository provided by the home institution. In a more general context, the choice of data storage location should be made early and the chosen option should be large enough to include all data. Access to the data is another consideration; not all who have been involved in the project will continue to be involved indefinitely. It might be useful for all undergraduate data collectors to have access so that they may store data, but these accesses must be reviewed periodically (e.g. every semester). For this project, access required an approval from the project Principal Investigator. Access to the data was highly restricted and required a unique and individual credential (e.g. institution ID).

De-Identification Process

As soon as the data were collected, scans and images were reviewed and transferred by the data manager to ensure there were no identifiable student features (e.g. names on work, faces, etc.). Any identifiable features were blurred or cropped. Identification on the data, like students' worksheets and artifacts, were removed and replaced with a numerical de-identification code to allow for tracking the same student's works across the curriculum while maintaining anonymity.

In the course of labeling the data, we considered a few aspects in order to optimize the identification system to protect individuals' information while allowing researchers to compare data across lessons and even years for some students. Each new participant was given an individual ID that was tracked across the project and the ID system was created before data collection began and evaluated and revised as necessary throughout the project. For more information, see Appendix C.

Growth through Practice

The data collectors and other project personnel involved in this paper were asked to respond to some prompts to discuss their evolution through this project. Excerpts from their responses are shown below each guiding question.

1. How did your approach and/or practices towards the data collection change over time?

Four of the authors described becoming more confident throughout the data collection process.

- Over time, I become more confident of [in] conducting the data collection. I become more confident of [in] doing interviews with parents, and with using the equipment.
- Over time, I gained more confidence what helped me to take more confident decisions.

The other theme that emerged from the responses was precision, particularly in camera placement and use of equipment.

- My approach improved over time in different aspects, for instance, I became better in handling the equipment choosing the best angles and placing this where it won't become a physical barrier to the participants. My attention to details increased as I realized how important it is to cover all the aspects involved when conducting the study to have better outcomes.
- The entire data collection procedure to planning for the equipment and subsequent downloading of data from the videos, iPad, LiveScribe pens got more streamlined with practice over multiple data collection sessions across different schools.

Overall, with practice, data collectors and data managers became more confident in their roles, from using the equipment to speaking with participants and streamlining data collection and storage.

2. What were the challenges or obstacles you faced during the data collection and how did you overcome them?

Five of the authors noted that technology was at times the most challenging aspect of the data collection process. Researchers overcome this obstacle by checking the equipment multiple times while collecting data and, where possible, asking participants to repeat a section of their interview.

- My biggest challenges was [were] that in the middle of collecting data technology would fail.

- When technology failed, I often tried to handle the situation by checking the equipment, replacing the battery.
- I often had issues with technology failures, such as syncing problems between the audio receiver and transmitter.
- The LiveScribe pens would turn off after a bit and if you didn't realize they were off, or if you hadn't clicked the 'record' button yet, you could lose some data you thought you were collecting.

The second challenge noted by multiple authors was problems with consent. If researchers had not collected the consent forms immediately, students decided not to assent partway through the data collection, or students without parental consent joined in whatever was being recorded, that could cause problems for data collection. Constant vigilance was needed to ensure only consenting students were recorded, though at times, some data clips needed to be deleted.

- The two biggest challenges/obstacles I faced during data collection are technology failure and children without consent jumping in front of the recording unintentionally.
- Another challenge was to collect all the consent forms in a reasonable timeline to avoid data loss, for instance, having to delete crucial data, for example, happening to capture a participant before her/his consent and having to exclude her/his participation later because she/he didn't consent afterward.
- Students often moved around unexpectedly. In such circumstances, I had [a] hard time to manage the video cameras' angles for non-consenting students.

Additional problems seen included last-minute schedule changes or unexpected classroom occurrences, including reorganization for activities, needing to take a break to allow the students to expend some energy, or simply running out of time and not being able to continue a lesson due to rigid school schedules.

3. How did the data collection empower you to be an independent researcher?

Four of the authors described improved interaction with human subjects, in particular, focusing on patience and coping with participants deciding to revoke consent during the study.

- I learned how to interact and be patient with human subjects.
- I also gained familiarity with handling IRB documents for elementary level students and the appropriate recording measures for students with and without consent in a classroom.
- I understood the importance of respecting human subjects during a study and understanding their limitations. Moreover, I became more efficient to handle unexpected situations during the process of data collection.

The researchers also learned more about the logistics of data collection, with all authors noting improvement in their understanding in some part of the project, whether in personal data collection skills or more large-scale logistical understanding of working with large-scale projects.

- I believe this experience in collecting data aggregated value to my doctoral studies and promoted my growth as an independent researcher.

- Furthermore, as this project complements my research agenda within the context of engineering and computational thinking practices on elementary level education, my direct involvement in the data collection provided me a great opportunity to learn the critical components on how to collect the data more effectively and purposefully as well as conducting similar projects in the future.

Lessons Learned

There are a large number of considerations when collecting data on a large scale, especially when working with students in elementary settings that are not controlled by the researchers. Some of these points are laid out in this paper, including ethical considerations, training, and needs of the data collection team, interacting with schools, and organizing the data. There is, of course, much more depth that can be explored in each area and specific questions that can only be answered in the context of each different data collection project. We anticipate that this paper can be useful in identifying possible concerns and provides some focus and/or vocabulary that will be useful when developing the data collection and management plans for other projects.

The biggest takeaway from this project is to plan early, plan for all foreseeable needs, and especially, plan how you will continuously evaluate and evolve your initial plans. Nearly every aspect of this project changed in the time between the grant proposal and the conclusion of the project. New equipment was introduced at several stages of the research. Different protocols and techniques were used as the research goals became more specific throughout the project. The types of data collected remained the same, but the naming convention was streamlined as the project evolved from a general exploration to targeted case studies. Personnel involved in the project changed, and the roles of personnel within the project evolved as well. Flexibility is key and is the most important part of the planning and implementing such a multi-faced, large-scale data collection project.

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References

Back, S. M., Tseng, W. C., Li, J., Wang, Y., Phan, V. T., & Yeter, I. H. (2015). Training neighborhood residents to conduct a survey. *Journal of Higher Education Outreach and Engagement*, *19*(2), 175-194.

Becker, K., & Park. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education*, *12*, 23-37.

Bell, P., Lewenstein, B., & Shouse, A. W. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Academies Press.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, M. C., (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*,*112*(1), 3-11.

Carmel, Y. H. (2016). Regulating ''big data education'' in Europe: Lessons learned from the US. *Internet Policy Review*. doi:10.14763/2016.1.402.

Dandridge, T. M., Ehsan, H., Gajdzik, E., Lowe, T., Ohland, C., Yeter, I. H., Brophy, S. & Cardella, M. E. (2019). Integrated STEM+ C learning for K-2 aged children: CT competencies as a precursor to K-2 computer science education. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 1280-1280).

Dasgupta, A., Rynearson, A. M., Purzer, S., Ehsan, H., & Cardella, M. E. (2017). Computational thinking in K-2 classrooms: Evidence from student artifacts. In *Proceedings of the American Society for Engineering Education (ASEE) Conference & Exposition*, Columbus, Ohio.

Ehsan, H., Dandridge, T. M., Yeter, I. H., & Cardella, M. E. (2018). K-2 students' computational thinking engagement in formal and informal learning settings: A case study. In *Proceedings of the American Society for Engineering Education (ASEE) Conference & Exposition,* Salt Lake City, UT.

Ehsan, H., Rehmat, A., Osman, H., Yeter, I.H., & Cardella, M. (2019). Examining the role of parents in promoting computational thinking in children: A focus on homeschool families. In *Proceeding of American Society for Engineering Education (ASEE) Conference & Exposition,* Tampa, FL.

Hynes, M. M., Moore, T. J., Cardella, M. E., Tank, K. M., Purzer, S., Menekse, M., & Brophy, S. P. (2016). Inspiring computational thinking in young children's engineering design activities. In *Proceedings of the American Society for Engineering Education (ASEE) Conference & Exposition,* New Orleans, Louisiana.

Hynes, M., Cardella, M., Moore, T., Brophy, S., Purzer, S., Tank, K., Menekse, M., Yeter, I.H., & Ehsan, H. (2019). Inspiring young children to engage in computational thinking in and out of school. In *Proceeding of American Society for Engineering Education (ASEE) Conference & Exposition.* Tampa, FL.

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 engineering education: Research and development. *Journal of Pre-College Engineering Education Research (J-PEER), 4* (2).

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *The Journal of Educational Research*, *106*(2), 157-168.

Resnik, D. B. (2011). What is ethics in research & why is it important. *National Institute of Environmental Health Sciences*, 1-10.

Roberts, A. (2013). STEM is here. Now what? *Technology & Engineering Teacher*, *73*(1), 22-27.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the E enough?: Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, 112, 31-44.

Ryan, B., & Bernard, H. R. (2010). *Analyzing qualitative data: Systematic approaches.* Thousand Oaks.

von Maurice, J., Zinn, S., & Wolter, I. (2017). Large-scale assessments: Potentials and challenges in longitudinal designs. *Psychological Test and Assessment Modeling*, *59*(1), 35.

Yasar, O., Veronesi, P., Maliekal, J., Little, L. J., Vattana, S. E., & Yeter, I. H. (2016). Computational pedagogy: Fostering a new method of teaching. *The ASEE Computers in Education (CoED) Journal*, *7*(3), 51.

Appendices

Appendix A
Teacher Post-Implementation Interview Protocol

I. Initial Reactions

- What surprised you (or your students)?
- What worked?
- What frustrated you (or your students)?

II. Engineering and Engineering Design

- Have you ever covered engineering (with your class) before this experience?
    - If yes, what did you do before? How did this (integrated STEM curriculum) compare with what you did before?
    - If no, what did you think of this experience in terms of the engineering component? (might need to probe a bit, like if she said they were engaged, can ask how did they know?)
- What do you think your students learned about engineering from the integrated STEM lessons?
    - How could you tell?
    - Is there anything they didn't seem to understand?
- Are you planning on doing any other activities related to engineering over the school year?
- How did the integrated STEM lessons support what you're already doing?
- How did the integrated STEM lessons differ from what you're already doing?

III. Computational Thinking

- Have you ever covered computational thinking (with your class) before this experience?
    - If yes, what did you do before? How did this (integrated STEM curriculum) compare with what you did before?
    - If no, what did you think of this experience in terms of computational thinking?
- What do you think your students learned about computational thinking from the integrated STEM lessons?
    - How could you tell?
    - Is there anything they didn't seem to understand?
- What other activities related to computational thinking do you do over the school year?
- How did the integrated STEM lessons support what you're already doing?
- How did the integrated STEM lessons differ from what you're already doing?
- What coding activities or programs (like Angry Birds or Codeables), if any, do you use?

IV. Integration

- Overall, did the lessons integrate well into your schedule?

    - Why or why not?
- Did the integrated STEM lessons replace any literacy, mathematics, or science lessons for you?
    - Which ones?
- Are you considering using an integrated STEM curriculum next year to replace any literacy, science, or mathematics lessons?
    - Which ones?

V. Overall

- Why did you decide to implement the integrated STEM lessons in your classroom?
- Compared to typical classroom activities, how did your students react to the integrated STEM lessons?
- Did you modify the lessons to fit your students or classroom context better?
    - In what way?
    - How did the modifications help your students?
- Do you plan to teach this unit again?
- Is there any other feedback about anything you would like to share?

Appendix B
Beginning and Ending Data Collection Checklists

I. <u>Beginning Collection Checklist</u>

Before you collect data on-site, make sure you have the following equipment set in a tote bag on the countertop in the data room:

- ❑ ID/License (Government issued ID)
- ❑ Assent Script (Needed on <u>Day One</u> only)
- ❑ 2 iPads with Cases (make sure they are charged)
- ❑ 2 iOstands (go with iPads)
- ❑ 1 Digital Video Camera (e.g. Canon) set for recording the whole classroom
  - ❑ Four (4) AAA Rechargeable Batteries placed in Wireless Microphone for Receiver and Transmitter box.
  - ❑ 1 Wireless Microphone Headset
  - ❑ 1 Charging Cable
  - ❑ Additional four (4) AAA Batteries (in case the rechargeable ones do not work)
  - ❑ 2 SDHC cards, one placed in the camera and the second one in the bag.
  - ❑ An additional Camera Rechargeable Battery.
- ❑ 1 Tripod (make sure it matches with the digital video camera)
- ❑ 1 iPad Pro (make sure it is charged and includes Notability app)
- ❑ 1 Apple Pencil (make sure it is charged and synced to the iPad Pro)
- ❑ 1 iPad Air2 Charger (2 chargers if available)
- ❑ A printed copy of the curriculum sample (e.g. lessons)

In addition, if needed,

- ❑ A manila envelope (9 x 12 inches) to collect student worksheets (as needed)
- ❑ Any student work to return (if any)

II. <u>Ending Collection Checklist</u>

Before you leave the data site, make sure you have:

- ❑ ID/License (government issued ID)

…and return the followings to data manager located data room.

- ❑ Envelope containing completed <u>Student Worksheets</u> to scan (if any)
- ❑ Photographs of any created prototypes and/or artifacts by students/classroom (if taken)
- ❑ Assent Script (Needed on <u>Day-One</u> only)

- ❑ 2 iPads with Cases (make sure it is placed in charging station upon arrivals)
- ❑ 2 iOstands (go with iPads)
- ❑ 1 Digital Video Camera (e.g. Canon) set for recording the whole classroom
  - ❑ Four (4) AAA Rechargeable Batteries placed in Wireless Microphone for Receiver and Transmitter box.
  - ❑ 1 Wireless Microphone Headset
  - ❑ 1 Charging Cable
  - ❑ Additional four (4) AAA Batteries (in case the rechargeable ones do not work)
  - ❑ 2 SDHC cards, one in the camera and the second one is in the bag.
  - ❑ An additional Camera Rechargeable Battery.
- ❑ 1 Tripod (make sure it matches with the digital video camera)
- ❑ 1 iPad Pro (make sure it is charged and includes Notability app)
- ❑ 1 Apple Pencil (make sure it is charged and synced to the iPad Pro)
- ❑ 1 iPad Air2 Charger (2 chargers if borrowed)
- ❑ A printed copy of the curriculum sample (e.g. lessons)

In addition, if borrowed,

- ❑ A manila envelope (9 x 12 inches) to collect student worksheets (as needed)
- ❑ Any student work to return (if any)

Appendix C
De-Identification Process

We developed a labeling protocol that was unique for each data source (e.g., video, worksheet). We used a numerical coding system to which only the project team had access to the data. For example, for this specific label 123_Y2_2nd_L0_M1_3, “123” stands for the location and teacher ID. Since there were multiple teachers in a single school, we created a 3-digit numeric protocol. Therefore, the first “1” digit is the school identity and last digit two-digit “23” is for the teacher. Furthermore, Y2 stands for data collected in Year 2, 2nd for second-grade level, L0 for introduction lesson, and M1_3 for the main camera. “1_3” with M1_3 indicates that there were 3 videos pertaining to introduction lesson and this specific videotaped data is the first of the three videos. The following is a complete-sample provided in details for the data labeling protocol in a school setting.

School Data File Labeling Protocol

- Main Camera: 123_Y2_2nd_L0_M1_3
- Case Studies
    - Case Study#1 (Target A): 123_Y2_2nd_L0_TA1_3
    - Case Study#2 (Target B): 123_Y2_2nd_L0_TB1_3
- Field Notes
    - Field Notes (Default-Notes): 123_Y2_2nd_L0_FieldNotability1_2
    - Field Notes (PDF+Voice)
        - PDF Data: 123_Y2_2nd_L0_FieldNotes1_2
        - Voice Data: 123_Y2_2nd_L0_FieldVoice1_3
- Student Worksheet: 123_Y2_2nd_L0_SW_Name (e.g. 123_Y2_2nd_L1B_SW_Map It)
- Post-Implementation Interview: 123_Y2_2nd_Debrief
    - Debrief Notes (Default-Notes): 123_Y2_2nd_DebriefNotability1_2
    - Debrief Notes (PDF+Voice)
        - PDF Data: 123_Y2_2nd_L0_DebriefNotes1_2
        - Voice Data: 123_Y2_2nd_L0_DebriefVoice1_3