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A methodological approach for researching online teacher professional development

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A methodological approach for researching online K-12 teacher professional development in engineering

Abstract

This paper describes a method to study engineering teaching and learning in an online in-service teacher professional development setting. We first describe the theoretical considerations we bring to research. Then, we describe *interactional ethnography*, including the types of questions that can be asked and the methodological approaches that have been taken previously. We argue that since this approach has been demonstrated to be appropriate for the study of student and teacher learning, it is also appropriate for synchronous online learning environments. We demonstrate the application using the example of a series of workshops for elementary school teachers learning about engineering content, pedagogy, and practices. We also describe the affordances of online digital tools in the facilitation of these experiences and in data collection, and we make suggestions for other uses of this approach.

Rationale

Recent STEM education reforms have emphasized the importance of engaging students in the *practices* [1-2]; and *habits of mind* [3-5] of engineers in K-12 settings. In response to engineering standards at both the national and state levels [1,2,5], curricula have been developed to help teachers overcome their lack of experience with engineering. However, two important aspects of teaching and learning engineering have been understudied: 1) the ways in which teachers learn about engineering, and 2) how they transfer that learning to the classroom to support their students as engineers.

Using empirical studies of engineering across disciplines, Cunningham and Kelly [5] identified sixteen epistemic practices of engineers that are important to consider for K-12 classroom engineering projects in addition to the science and engineering practices identified in the Next Generation Science Standards (NGSS), and the epistemic practices have been incorporated as habits of mind of engineers for practitioners [7]. These practices, based on disciplinary work, are the ways social groups propose, communicate, justify, assess, and legitimize knowledge claims [8,9]. It is the participation in these practices that give us insight into how students (and teachers) learn about engineering.

Teacher workshop settings, like K-12 classrooms, are a complex cultural setting. From a pragmatic perspective, the engineering activities in these workshops are navigated by teachers in small groups that collectively use epistemological judgments [10]. While it is almost certain they will learn through participation in any workshop activity, they will not always learn what the facilitators intend, so the interesting problems to research are the directions that learning takes [10]. Since a significant portion of the teacher workforce was prepared prior to recommendations of NGSS, many teachers need professional development experiences in the areas of engineering and in practices-based teaching. They also need to experience engineering curricula from a student's perspective and to consider how they can use it in their own contexts [7].

Sustained professional development is most effective for fostering teacher learning and changes in teacher practice [11-13]. According to Loucks-Horsley [11], effective PD is 1) designed to address student learning goals and needs; 2) driven by a well-defined image of effective classroom learning and teaching; 3) designed to provide opportunities for teachers to build their content and pedagogical content knowledge; 4) supportive of teachers development of professional expertise, 5) linked to other parts of the educational system; and, 6) continuously evaluated and improved. These factors require long-term engagement with the participating teachers, and a blended approach of face-to-face and online learning [14].

Specific to K-12 engineering PD, there is not a clear description of the knowledge and skills needed for teaching engineering, in part due to the ways that states certify teachers—the majority of engineering teachers are trained as science or technology educators and few have engineering experience [3]. With only standards as reference, teachers are expected to learn engineering on their own and enact this learning with students. Neither national STEM education reforms in science [1], computer science [15], or math [16], nor those from the state-level [17]. will improve the education system alone, so high-quality engineering PD experiences are essential for improving K-12 STEM education [18].

Theoretical Framework

We approach teacher learning through a sociocultural lens. It is guided by empirical studies of professional engineers and views the materials used in learning as a part of the discourse that is important to consider. We also view teacher learning through the lens of professional vision, where they develop their ability to teach through interactions with instructors and as they get practice in the classroom.

Studies looking closely at the professional practice of engineers (i.e. "engineering studies") give us insight into the ways in which engineers create knowledge. These "epistemic practices" are constructed socially, are situated in activity, rely on prior discourse and/or artifacts, and matter to what counts as knowledge [9]. People doing engineering work behave within the social structure to do their best understanding of high-quality work [19]. Their interactions are essential to understanding how they accomplish their goals [20], and the solutions they develop are tied directly to the beliefs and assumptions they hold [21].

Consistent with our overall sociocultural understanding of classroom work is sociomaterialism, in which the artifacts used are equally important to consider with the social aspects of talk and action [22]. In other words, the people and the materials are both significant and should be studied together [23]. Classroom engineering should also be viewed using the concept of sociomaterial bricolage [20] because participants are constrained by the availability of materials, and as bricoleurs, must make do with what they have [24].

Teachers develop their professional vision over time. Goodwin [25] describes how members of a profession learn discursive practices by observing phenomenon in a specific context, then mark or highlight the specific aspects that are salient, and finally by producing representations of these practices. This expertise and pattern recognition enables them to diagnose problems and identify opportunities [26]. In learning to teach, teachers must first notice *what* is important in a teaching situation [27,28] and understand *why* it is important [29]. Particularly as these teachers learn new content and practices, they learn to identify these interactions in complex classroom environments as they interact with their instructors and as they gain experience teaching it [30].

We use this theoretical framework to guide our research questions, methods, and analytical decisions. Classroom engineering is typically done in small groups and involves collaboration, negotiation, and problem solving, so interactional ethnography [30,31] will be used as a primary approach to investigate those research questions.

Interactional Ethnography

Borrowing from sociolinquistics, cultural anthropology, ethnomethodology, and critical discourse analysis, *interactional ethnography* (IE) is an approach to study cultures-in-the-making and consider the discourse, actions, and uses of texts, signs, and symbols in the co-construction of reality within social groups [30]. Analysis of these aspects of learning activities is relevant due to the importance of the use of language in these settings [33]. This approach is important for at least two significant reasons. First, it is useful in addressing research interests that must be situated within social practice but can be systematic enough to address concerns of validity and trustworthiness [34]. Second, it is also appropriate for investigating talk and action demonstrating the roles and responsibilities that are locally defined and enacted by the participants that would be difficult to consider through experiments, pre-/post-assessments, or other techniques used in the field [31].

One of the primary data sources of research on science and engineering activity is video data. This can be difficult to convey trustworthiness to the reader, so researchers must be transparent in their epistemological decisions about the systematic investigation of the interactions involved in the setting [35]. IE typically starts with a period of observation that assesses the culture of the classroom to better understand the baselines for talk and action [36]. It is through this understanding of cultural norms in which the analyst can contextualize the events that make up the overall activity, similar to Polkinhorne's hermeneutic circle [36].

Depending on the research interests, it is often appropriate to also consider written texts (i.e., engineering journals) and artifacts (i.e., the developed technology) as data. Johnson [37] found that video and journal data support each other in analysis. Insightful discourse occurs within the group may not appear in the journal and some outcomes are so obvious they do not warrant a discussion but appear in the journal based on the prompts. Kelly and Green [30] describe this methodology in greater depth with illustrative examples. They show this approach to research to be useful in many ways, including to investigate gender positioning in science among kindergarten students [38], preservice teachers learning about ambitious teaching practices [39, 40], the language usage of a science teacher in a bilingual class [41], and elementary students engaged in engineering design projects [31,42].

Due to COVID-19, many educational offerings had to change from in-person to online. To continue our research progress, we adapted an existing methodology to investigate teacher learning. We will use this example to describe the application of IE to this setting and will highlight the affordances of this method as well as a description of the kinds of analyses that are currently underway with the data we collected.

Context

The first part of the study we describe here seeks to understand how rural elementary school teachers learn about and engage in the epistemic practices of engineering [5] and how they apply local knowledge from their area to help students connect engineering as a school project to engineering in their lives. Rural schools are home to many students from low socioeconomic backgrounds and a high percentage of the students are potential first-generation college attendees. These populations are underserved in engineering. The study will then research the ways in which a subset of the workshop teachers teaches engineering in their classrooms, using the workshop as a basis of comparison. We plan to use the knowledge we gain through this research to make recommendations for teacher educators about the needs of these teachers and how to best support their use of engineering design projects in their classes.

Originally planned as a two-day in-person workshop, the resulting workshop was a four-part series of half-day, synchronous meetings with eight rural teachers from three schools in rural areas in the Mid-Atlantic region. All eight participating teachers had attended the same school in which they teach, have greater than five years of classroom experience, teach about the environment and ecology in their science curriculum, and have never learned about or taught engineering before. They were recruited for the reasons mentioned and because their superintendents were supportive of their teachers learning about and teaching engineering. The teachers were situated in 4 pairs of teachers who teach in the same grade at the same school. During the workshop, each pair was physically located within their schools in private conference rooms wearing masks and the workshop was facilitated by the instructors via Zoom. Materials needed to participate in the hands-on designs were packaged into kits and delivered to each school. The overall objectives were to introduce teachers to engineering and engineering practices through participation in design and reflection activities as a "student" engaged in engineering as well as time as a teacher to reflect on teaching the activities with their students.

Day 1 introduced teachers to the concept that a technology can be an object, system, or process that solves a problem or makes life easier and that engineers design or improve technologies. Then, teachers participated in the activity called "Perspiring Penguins" [43]. In it, teachers designed a habitat using materials given to them for a penguin (ice cube) to survive in a Phoenix Zoo (heat box), attempting to minimize both cost and the percentage of mass loss during the five-minute exposure. We reflected on the ways they engineered by identifying the NGSS [2] and epistemic practices of engineering [5] used, and discussed ways to assess students' engagement in the practices using a continuum based on the NGSS practices [44] adapted to engineering. The teachers also watched video of teachers and students engineering in the classroom and identified practices they observed.

On Day 2, teachers identified several examples of engineering they encounter in their lives. Photos provided by the participants led to discussions about why it was an example of technology and how effective it might be to use as examples with their students [45]. Then, using the engineering design project from Day 1 as well as classroom video, teachers identified and discussed the different types of failure and their consequences [37]. They also used an analytic rubric [31] to quantitatively assess improvement and reflected on the needs to use this approach in the classroom.

During days 3 and 4, teachers piloted a new curricular unit, "The Problem with Plastics," as students and reflected on each of the eight lessons as teachers, including which of the 16 epistemic practices [5] were prominent. Significant time was included to discuss logistics of working through the lessons with students and to answer any questions they have before implementing the unit in their classes. Table 1 summarizes the workshop agendas.

Table 1-Workshop series goals and activities

Day	Learning Goals	Activities
1	Describe features of technologies Engage in an engineering project Reflect on engineering practices they used Observe and reflect on students and teachers engaged in engineering practices	"Tech in a bag" "Perspiring penguins" Engineering practice rubric, epistemic practices of engineering Classroom video
2	Identify and reflect on examples of engineering in their area Consider the role of failure and improvement in engineering Describe the role of teacher feedback in classroom engineering	Photodocumentation Classroom video Classroom video
3	Experience first half of environmental engineering unit as a "student" Reflect on first half of environmental engineering unit as a teacher Make connections between the unit and local ecosystems, trash/recycling, and pollution	"The Problem with Plastics" Unit
4	Experience second half of environmental engineering unit as a "student" Reflect on second half of environmental engineering unit as a teacher Make connections between the unit and local ecosystems, trash/recycling, and pollution	"The Problem with Plastics" Unit

Facilitation and Data Collection

This section will briefly describe the digital tools we used to facilitate the workshops as well as ways they facilitated data collection.

Google Classroom

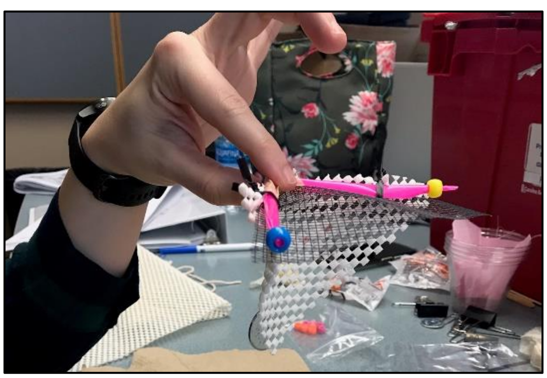
Electronic copies of all workshop materials including handouts, presentation slides, agendas, and evaluations were all shared through Google Classroom, to which each teacher was invited. Surveys were submitted anonymously to increase accuracy.

Photo, video, and document submissions

Prior to the first and second meetings, we asked teachers to submit 3-4 photos of examples of science or engineering in their lives, following the protocol of Avery and Kasam [45]. These photos were used as topics for discussion about why the example counts as engineering and why it is a relevant example in the teachers' school district. Figure 1 shows two examples of technologies identified by teachers: a paper mill that employs several of the rural students' parents and a dam that serves as a local park, fishing hole, and recreational area.

Figure 1- Paper mill and dam used by teachers as an example of technology

Teachers also submitted photos and videos of their floating water filters and penguin habitats for others in the class to see. These submissions are also being used as data sources. Figure 2 shows the photo of a prototype and a screenshot of a video submitted to demonstrate the performance of



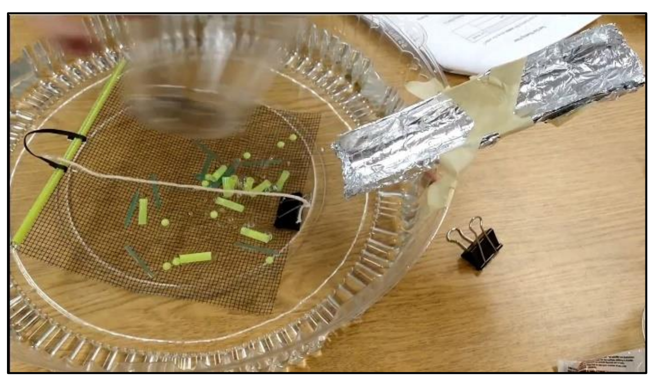


Figure 2 - A photo of a floating filter and a screenshot of a video of the filter test

their technology. These were submitted as "assignments" through Google Classroom. Additionally, we collected documents, such as engineering journals for both the penguin habitat design and the "Problem with Plastics" unit, completed by the teachers during the activities.

Teacher reflections

In addition, the use of Google Slides and giving everyone editing privileges enabled us to collect reflective comments in real time. Figure 3 shows the prompts provided in the Google Slides and a response entered into the slide by teacher group 2. At several times throughout the

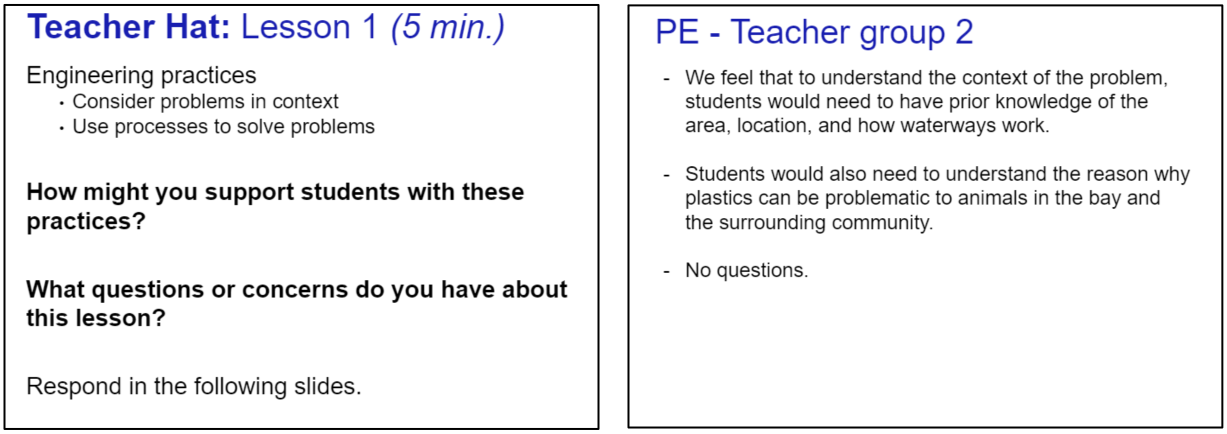


Figure 3 - Example Google Slides of prompts provided by the facilitators and teacher responses.

the series, we had teachers reflect on prompts (Figure 3). A blank slide for each group was included in the slide deck for teachers to respond to these prompts, allowing for formative assessment in addition to data collection. They also reflected on the epistemic practices of engineering [5] they viewed as most prominent in the lesson. These reflections served as the basis for discussions based on the needs and readiness of the teachers. This approach allowed us to collect feedback from each group for each reflection. This is typically not a possibility in brick-and-mortar workshops due to time constraints.

Evaluations

At the conclusion of each workshop, teachers were asked to complete a workshop evaluation. These were assigned as a Google Form that were pre-scheduled to appear in the Google Classroom near the end of the session. A summary of the four workshop evaluations can be found in Table 2. The decrease in scores in day 4 seemed to result from one teacher who thinks that schools will not be able to have students work in groups within the next several years.

Table 2 - Quantitative evaluation summary of four workshops. Constructed responses were also collected but not included in this report

1 - The goals and objectives were clearly specified at the beginning of the workshop.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.75	**0.43**		**4.80**	**0.40**		**5.00**	**0.00**		**4.71**	**0.45**
2- My understanding of this topic has been enhanced											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.38	**0.70**		**4.70**	**0.46**		**5.00**	**0.00**		**4.71**	**0.45**
3 - The content is relevant to the science curriculum I teach											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.38	**0.86**		**4.40**	**0.66**		**4.86**	**0.35**		**4.43**	**1.05**
4 - I will be able to apply what I learned into my classroom instruction.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.50	**0.71**		**4.60**	**0.66**		**5.00**	**0.00**		**4.57**	**0.73**
5 - The workshop activities were carefully planned, well organized, and well executed.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.75	**0.43**		**4.70**	**0.64**		**5.00**	**0.00**		**4.86**	**0.53**
6 - The instructor was knowledgeable about the content. *											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	5.00	**0.00**		**5.00**	**0.00**		**5.00**	**0.00**		**5.00**	**0**
7 - I felt comfortable asking the instructor questions.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.88	**0.33**		**4.90**	**0.30**		**5.00**	**0.00**		**4.71**	**0.70**
8 - The presenter's instructional techniques facilitated my learning.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.88	**0.33**		**4.70**	**0.64**		**4.86**	**0.35**		**4.71**	**0.45**
9 - I had sufficient time to complete all required tasks.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.63	**0.70**		**4.80**	**0.40**		**5.00**	**0.00**		**4.43**	**0.49**
10 - I had sufficient time to reflect on what I had learned.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	4.63	**0.70**		**4.80**	**0.40**		**5.00**	**0.00**		**4.86**	**0.35**
11 - The online tools and methods were conducive to my learning.											
Day1	Mean	SD	Day 2	Mean	SD	Day 3	Mean	SD	Day 4	Mean	SD
	5.00	**0.33**		**4.80**	**0.40**		**4.86**	**0.35**		**4.43**	**1.05**

Zoom

We used Zoom to communicate during the workshop visually and verbally. The teachers were in three different physical locations and the facilitators were in four. Everyone had their cameras turned on and presenters shared their screens. In whole group settings, each participant sat at his/her own computer. For small group activities, we used the breakout room feature, each with a facilitator from the research team. One camera from each group was fixed on the participants and the other camera was focused on the technology they were developing or improving. Videos in the whole group setting were saved to the cloud, while breakout room recordings had to be saved to local machines by the facilitators.

In addition to synched audio and video recordings, Zoom offers two additional features that are useful as researchers. First, all comments submitted to the group chat are saved in a text file with corresponding time stamps. We used chats to collect quick feedback to frequent or simple questions in which we wanted responses from everyone. Second, Zoom contains a feature that transcribes the utterances from the recordings word for word. These transcriptions are also time stamps and can be viewed in conjunction with the recording and the text is highlighted as the words are spoken. In our experience, the transcription is quite accurate and will save a considerable amount of time and/or money typically devoted to transcribing by hand or by hiring a transcription service. Figure 4 shows and example of the recording and transcription.

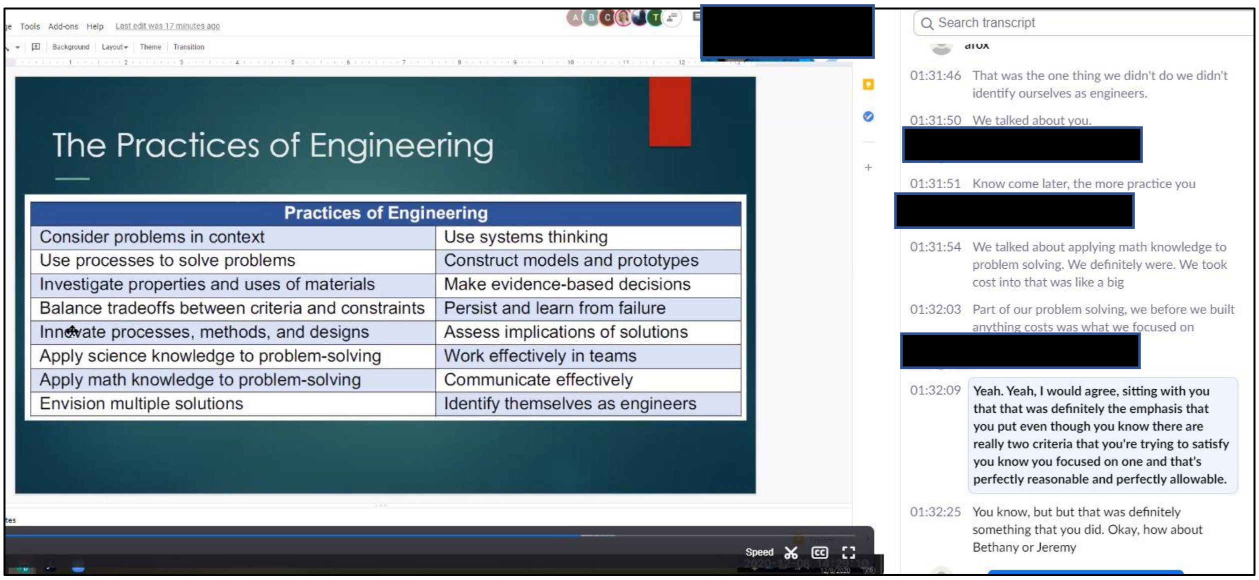


Figure 4 - A screenshot of a Zoom recording with the transcription feature on

Analyses

Using this approach to study teacher learning through an online professional development workshop allowed us to collect research data during implementation. Follow-up interviews are also planned soon. These data sources allow for the analysts to investigate several interesting questions *in situ*. This section will propose the types of questions that researchers could ask and the types of analyses they could could use to answer them. These are summarized in Table 3.

Photos

In this workshop, we were interested in how teachers connect local funds of knowledge [45] to their learning about engineering and technology. Our research question is, “How do teachers make connections between the units and their own experiences?” Basing the analysis on the methodology of Avery and Kasam [45], we organized photos submitted by teachers prior to the workshop into perceived categories. Then, we used semi-structured discussions with the teachers during the workshop to determine why they chose to take the photos, what they know about the technologies, and where they were taken. Using the teacher's responses and the photos they chose, we will use the constant comparative analysis method [47] and content analysis [48] to deduce generalities. We also have a sustained relationship with the teachers in which we can directly contact them to double-check biases that may appear in our interpretations. This approach is complementary and will help us to avoid inaccuracies in our analyses.

Journals

During the activities, teachers used engineering journals to record their ideas, data, designs, results, and interpretations. The journals will be used to help us answer research questions like, "How and to what extent did teachers use engineering practices in their design process?" There are multiple ways to analyze documents like these.

One approach is to use an analytic rubric. Johnson [31] used this approach to investigate elementary students' improvement of failed designs. Students' journals were graded using this rubric to determine if the students acknowledged the failure and if they used productive strategies on the prototype to improve the criteria they deemed most important in the next iteration. Using discourse analysis of video recordings in conjunction with the journals, he was able to determine the journals were a reasonable measurement of what occurred in the groups and demonstrated significant interrater reliability [31, 37].

Another example of analysis of engineering journals is demonstrated in Hertel,et al [49]. The authors were interested in better understanding how journals were helpful in structuring students during an engineering design challenge. They used interactional sociolinguistics to look closely at recurring group discourse patterns and ways of defining problems [33, 49] and developed *in vivo* codes to identify patterns. They found the journals were more than a tool; they were participants in the group's discourse [49].

Group responses in Google Slides

In several of the teacher reflection activities within the workshop, teachers were asked to respond to prompts. In one example, the teachers were asked to respond to two questions after completing a lesson within the environmental engineering unit: 1) How might you support students with these practice, and; 2) What questions or concerns do you have about the lesson? Using Google Slides allowed each of the groups to add their responses to the slide deck used by the facilitator. One question we are interested in researching is, "What challenges do teachers see in teaching engineering for the first time?" In a workshop setting, there is rarely enough time to have in-depth discussions with all participants. This method allowed us to get responses from each of the groups. The facilitator posed questions during the workshop to probe some of the responses more deeply. This process was used after each of the nine lessons, so several open-ended responses were provided and can be analyzed to help us answer the question. Using the discourse from the group discussion and their responses, we will be able to better understand the breadth of their answers. Content analysis [51] can be used to increase the meaning of texts. Words can be aggregated into conceptual clusters or can be characterized by phrases or sections. These texts can then by more closely analyzed for their ideational, interpersonal, or textual function to better understand what the teachers mean [51].

Teacher discourse

Most of the analyses are dependent on the talk and actions of the teachers and their interactions with the other participants and the facilitators of the workshop. These interactions can be analyzed in conjunction with the data sources described above, but also alone in answering questions like, "What roles and responsibilities do the teachers assume during group work?" However, with workshops that last 16 hours and each of the small group interactions recorded separately, the word-by-word transcripts generated by Zoom would be overwhelming to analyze on their own. Event maps [31, 52, 53] are time-stamped descriptive records that supplement participant observation because multiple recordings exist for each event. They help researchers identify events and interactions for microanalysis and help to contextualize events within the broader context [33,35]. Then, the word-by-word transcripts can be used in with the video evidence of gesture and actions to generate qualitative codes. A key aspect of this analysis is comparison, but is also contextual [53], and the responsibility for describing the typicality and atypicality of the events and the full range of variation is crucial for the analyst to maintain trustworthiness [55].

The richness of these data sources allows for several analyses looking closely at the co-construction of knowledge of the participants. Although we outline several approaches that we are currently using to conduct our research, we recognize there are several methods for conducting sound qualitative research. However, we cannot overstate the importance of systematicity and the avoidance (to the extent possible) of researcher bias in making claims.

Table 3 - A summary of the data, research questions, and potential analyses using IE in online settings

Data source	Possible Research Questions	Potential Analyses
Digital photographs	How do teachers make connections between units and their own experiences?	1. Discourse analysis of discussion about photos [31] 2. Photodocumentation [45]
Engineering Journals	How and to what extent to teachers use engineering practices in their designs process?	1. Discourse analysis of journals [49] 2. Analytic rubric [31]
Responses on Google Slides	What challenges do teachers anticipate in teaching engineering for the first time?	1. Discourse analysis of discussions [31] 2. Content analysis [51]
Video/audio recordings	What roles and responsibilities do teachers assume in group work during an engineering design challenge?	1. Event maps [53] 2. Discourse analysis [31]

Conclusions and Implications

This paper describes an approach to conducting qualitative research using digital tools to conduct research during an online teacher professional development workshop about engineering. We describe the theoretical underpinnings of this methodology and use examples from our own work to describe the data sources, research questions, and analytic approaches in more concrete terms. Research in this area will likely lead to a better understanding of how these teachers learn about engineering in a setting like the one described, and will be used as a base of comparison when we analyze data collected as a subset of the teachers from rural school districts implements these engineering units in their elementary classes.

We argue that the methods described in this paper can be useful for those in engineering education regardless of whether they teach precollege teachers, because these online learning experiences have become more common due to the COVID-19 pandemic and we suspect they will be common even after restrictions are lifted. Interactional ethnography is a useful means of assessing learning of students in small group work, as is common in engineering education. Workshops like these are used in several ways to teach adults, but these digital tools also allow for researchers to look closely at learning in undergraduate, graduate, and even precollege settings.

Despite the challenges in teaching remotely, synchronous online instruction can also be more inclusive. Twenty-five percent of students in the United States attend rural schools [55]. Many of these students (and their teachers) live in remote areas, far from the types of universities that teach classes and workshops like the ones many engineering educators hold. And despite rural students consistently graduating at a higher rate and scoring higher than their urban counterparts on the reading, math, and science assessments of the National Assessment of Educational Progress assessment [56], rural student college enrollment is lower [57], causing in part, the underrepresentation of these populations in STEM fields. The combination of the increased learning opportunities provided by these remote learning contexts and research into the place-based learning may lead to improved participation in these jobs.

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