



The Video Case Diagnosis Task: Assessing Pre-Service Teachers' Knowledge of Engineering Design Practices (work in progress)

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Conducting engineering design challenges in K-12 classrooms is not new, but the National Research Council's recent *Framework for K-12 Science Education* (2012) and the *Next Generation Science Standards (NGSS)* (National Research Council, 2013) derived from the *Framework* bring new urgency and importance to the task of exposing K-12 students to the practices and big ideas of engineering. The *Framework* indicates that all children should develop competencies in engineering design, and the *NGSS* explicitly includes a "conceptual shift" toward "the integration of engineering and technology into the structure of science education" (Achieve, Inc., 2013). This shift requires not only the adjustment of K-12 science curriculum and pedagogy, but also a transformation in the preparation of new K-12 teachers so that they possess the knowledge and skills necessary to include the discipline of engineering in their classrooms. This is especially important at the elementary school level, where teacher candidates tend to have limited academic preparation in science and little formal exposure to engineering.

The teacher education community is limited in its understanding of how novice teachers of elementary students learn to teach *science*. Because engineering has previously not been a common component of elementary school science education, even less is known about how novice elementary teachers learn to teach engineering. Research is needed to inform a new model for preparing pre-service elementary teachers to teach engineering.

In this research study in progress, we are developing and investigating an innovative model that introduces novice elementary teachers to "community-based engineering design" as a strategy for teaching and learning in urban schools. Community-based engineering experiences for urban schools involve the finding and solving of technological problems in students' local environment, such as their neighborhoods, community centers, or schools. For example, elementary students might notice a nearby vacant lot and design and build tools and techniques to prepare its soil for urban gardening. Or they might identify limitations of their local playground and design and build prototype play equipment that would better meet the needs of children in their neighborhood. Or perhaps the local Boys and Girls' Club needs to update its game room, and elementary students design and build prototype arcade games. Each of these engineering experiences would respond to a problem in the local community and engage students in framing a problem, planning a solution, and prototyping and testing artifacts. Each community-based engineering experience could also connect to a unit in the school science curriculum, reinforce disciplinary core ideas from the *NGSS*, and engage students in key science and engineering practices.

To investigate the community-based engineering approach to preparing new elementary teachers to teach engineering, we are asking three key research questions. During community-based engineering experiences, what is the evolution of novice urban elementary teachers':

1. Understanding of engineering practices?
2. Abilities of engineering design?
3. Abilities to identify and respond productively to *students'* engineering ideas and practices?

To answer the research questions, we are employing a mixed methods study design. Data sources include video recording of the novice teachers during community-based engineering tasks, the Creative Engineering Design Assessment (Charyton et al, 2011), a Curriculum Critique and Revision task (adapted from Forbes, 2011), and a new Video Case Diagnosis (VCD) task developed specifically for this research study.

In this paper we focus on research question #1 and the Video Case Diagnosis task, a new research instrument intended to be a key contribution of this research project.

Background

The development of a Video Case Diagnosis task for measuring teachers' engineering pedagogical content knowledge builds upon previous research that uses video cases of student work in science and mathematics (Hammer & van Zee, 2006; Norton, McCloskey, & Hudson, 2011; Santagata, Zannoni, & Stigler, 2007; Weilan, Rogers, Akerson, & Pongsanon, 2010). It also adds to prior work that has investigated teachers' preparation for teaching engineering (Hsu et al., 2010; Hynes, 2009) and changes in their engineering teaching abilities and attitudes after professional development experiences (Capobianco et al., 2011; Nadelson et al., 2012; Hsu et al., 2013; Hynes, 2009; Yoon et al., 2012).

Methods

Participants in the study are graduate students in their final year of an elementary teacher preparation program. During their science teaching methods course, they solve a sample community-based engineering problem developed by the course instructor. They also design a community-based engineering mini-lesson to implement in their elementary school practicum setting. At the beginning and end of their methods course, they complete the Video Case Diagnosis (VCD) task as a pre/post test of their understanding of engineering practices and their abilities to identify and respond productively to students' engineering ideas and practices.

In this paper we report on pilot-testing of two versions of the VCD. In pilot-testing, Version 1 was completed by 32 pre-service teachers during Week 1 of their elementary science methods course. Version 2 was completed by 29 of those teachers during Week 14 of the course.

The Video Case Diagnosis (VCD) task is a novel video-case-based assessment of novice teachers' abilities to identify and respond to students' emerging science and engineering ideas and practices. The novice teachers watch a brief (4 to 6 minute) video of a pair of elementary students attempting to solve an engineering design problem. Then the VCD paper-and-pencil response sheet asks the teachers to list (1) the ideas that the students in the video express about science phenomena, (2) the science "practices, processes, or skills" exhibited by the students, and (3) the engineering "practices, processes, or skills" exhibited by the students. The prompt includes the phrase "practices, processes, or skills" because pre-service teachers may not be familiar with the term "practices" when used to describe a set of behaviors for engaging in scientific or engineering endeavors. They may be more familiar with the terms "processes" or "skills." For each of these three prompts, the VCD also asks for evidence from the video that each idea or practice (or process or skill) was exhibited. Finally, the VCD asks the teachers to list

three suggestions (i.e., a “menu of possibilities” [Hammer & Van Zee, 2006]) for how the teacher could respond to help the students further develop their ideas and practices. Each administration of the VCD takes 30 minutes, including watching the video.

In Version 1 of the VCD, the six-minute video clip shows two fourth grade boys working on the engineering problem of lifting a heavy vessel out of the ocean. The video comes from a literature-based engineering unit taking place in these students’ classroom. They had determined that the characters in a story (*James and the Giant Peach* by Roald Dahl) could use engineering to solve their problem of being stranded at sea in a giant peach. The two students were planning their solution to this problem. Their teacher had asked them to construct a prototype of a device that would solve the problem for the characters. The video clip begins as one of the boys re-states to the other the problem that they are trying to solve. Then the students take turns explaining their ideas for a “peach lifter” that uses a lever arm to swing the peach out of the water. Each boy, in an effort to distinguish his idea from his partner’s, makes a sketch of his idea. Frustrated with what he perceives as his partner’s lack of understanding, one boy finds a water bottle with a hole on the top to use as a model fulcrum, and he adds a pencil as a lever arm and eraser as a model “peach.” The two boys both interact with these physical materials to test out their ideas about how the lever will work. The video ends as the boys begin to discuss the materials they will need to construct a prototype lifter. As described above, the teachers complete the VCD task by watching this video and then responding to four prompts on a paper-and-pencil response sheet. They are provided with a transcript of the video and are allowed to refer to it as often as they want.

Version 2 of the VCD uses the same response sheet, but the video clip shows different students working on a different engineering problem. However, the Version 2 video is similar to the Version 1 video in that it also features a pair of boys who are in the planning stages of their engineering activity and who engage in talking, drawing, and discussing real physical materials. The Version 2 video clip is also six minutes long. In it, two third-grade boys are working on the challenge of building a musical instrument that can play at least three different notes. As it begins, one boy is telling the other that their instrument will include a guitar and a maraca and will make its sounds when shaken. The other boy asks him how they will make the guitar part, and then they walk over to ask their teacher whether certain materials are allowable. They hear the teacher asking other students how they are going to make three pitches, and without talking to the teacher the two boys return to their desks, adjust their plans, and make a drawing to show what they intend to build.

In this paper we report on our analysis of teachers’ responses on the two pilot versions of the VCD to the prompt, “What practices, processes, or skills of engineering did the students exhibit?” This analysis explored research question #1, which asks about pre-service teachers’ understanding of engineering practices. With this research question, we are not looking for pre-service teachers to recall a memorized list of engineering design process steps. We view engineering practices not as a pre-determined sequence of steps, but as a range of activities used to engage in the discipline of engineering (NRC, 2012).

To characterize the teachers’ responses to the prompt about students’ engineering practices, we followed a qualitative data analysis approach based in grounded theory (Charmaz, 1995) and

consistent with the constant comparative method (Glaser & Strauss, 1967). The coding process was conducted by two researchers: an elementary teacher educator who was previously a mechanical and aerospace engineer, and a science and engineering education researcher. We iteratively generated and defined coding categories until no new codes were needed to categorize all of the responses listed by teachers. In the Findings section we describe all categories of “engineering practices, processes, or skills” proposed by the pre-service teachers.

Preliminary Findings

In the pilot-testing of two versions of the VCD, there was a wide range in what the participating elementary pre-service teachers described as “engineering practices, processes, or skills.” Table 1 reports all coding categories and the responses within them.

Table 1. Pre-service teacher responses to a prompt asking what “engineering practices, processes, or skills” were exhibited in a student video

Category	Example VCD response	Version 1 frequency ^a	Version 2 frequency ^b
<i>Practices/processes</i>			
Problem identification	“Formulate a need: to make an instrument”	0	6
Brainstorming	“Brainstorming about a solution to the problem”	0	2
Conceptual planning	“Creating a plan”	7	11
Planning with materials	“Develop a materials list”	5	4
Drawing	“Use of diagrams to represent information”	8	4
Modeling	“Developing a model”	0	7
Construction	“Actually building a musical instrument”	12	6
Testing	“Experimenting”	5	5
Iteration	“Back to the drawing board when an idea is flawed”	1	8
Oral communication	“Speaking”	2	0
Argumentation	“Giving a claim and evidence”	0	4
Collaboration	“Use of a team”	1	1
<i>Concepts/technical vocabulary</i>			
	“Lever” (Version 1)	12	1
	“Thin vs. thick” (Version 2)		

^a Version 1 was completed by 32 pre-service teachers. Across all participants, 53 activities or concepts were listed as “engineering practices, processes, or skills.”

^b Version 2 was completed by 29 pre-service teachers. Across all participants, 59 activities or concepts were listed as “engineering practices, processes, or skills.”

Table 1 reveals that on Version 1 of the VCD, which was given as a pre-test, the teachers misconstrued the technical vocabulary (e.g., “lever,” “weight”) used by the students as engineering practices or processes. When they did identify actual practices or processes, they focused on the students’ engagement in drawing and physical construction. They did not frequently attend to other important engineering practices such as problem identification,

generation of multiple solutions, or iteration. On Version 2 of the VCD, which was given 13 weeks later as a post-test, the teachers more often identified engineering practices that are consistent with those described in the *Next Generation Science Standards* and other seminal documents on engineering. Only on Version 2 did the teachers notice the students identifying the problem, brainstorming, modeling, and engaging in argumentation. It is important to note that at this stage of pilot-testing, we do not have evidence to indicate whether the pre/post differences were due to change in teacher understanding or to differences between the two versions of the task. The videos for the two versions were chosen intentionally to show the same range of engineering practices, but a next step is to validate this equivalency of the two versions.

Next Steps and Conclusion

The next phase of this work-in-progress is to develop a formal scoring rubric for both versions of the Video Case Diagnosis and then analyze the pilot data according to the rubrics in order to establish inter-rater and test-retest reliability. The approach to developing rubrics and scoring the pre-service teachers' video case analyses will be adapted from Norton et al. (2011), Santagata et al. (2007), and Sherin and van Es (2009). The following steps will be followed:

1. The video cases will be viewed by two groups of experts: expert elementary science educators and expert science education researchers who specialize in attention to student thinking.
2. The expert viewers will be asked to identify video components along three dimensions: (1) students' science and engineering *ideas* (what is it that students think about the science phenomena or engineering solution in the video?), (2) students' science and engineering *practices* (which of the eight practices in the *NGSS and Framework for K-12 Science Education* are exhibited?), and (3) productive *teacher responses* to student ideas and practices.
3. The research team will review the experts' video analyses and will note which student ideas, student practices, and teacher responses were described by a *majority* of the expert video viewers. These ideas, practices, and responses will comprise the "exemplar" answer.
4. Pre-service teachers' analyses of the video cases will then be scored against the exemplar answer. Each pre-service teacher video case analysis will be scored as "high" (2 points), "medium" (1 point), or "low" (0 points) in its alignment with the exemplar answer in the three main dimensions of student ideas, student practices, and teacher responses. A rubric will be developed to indicate what constitutes "high," "medium," and "low" alignment in each dimension for each video case. To establish inter-rater reliability, two researchers will independently score all of the pilot VCD responses. If their agreement is less than 80%, discrepancies will be discussed and the scoring rubric will be revised. The two researchers will then independently score all responses again. This process will be repeated until their scores agree more than 80% of the time. Test-retest reliability will be determined by administering both versions of the VCD to approximately 20 pre-service teachers who are not involved in the project. Reliability will be achieved when there is greater than 80% agreement, on average, in the performance of individual teachers across the two versions.

The completed Video Case Diagnosis task will be a key component of our research on the use of “community-based engineering design” as a strategy for introducing novice elementary teachers to teaching engineering in urban schools. The research project as a whole responds to the need for research on how new teachers, especially in tightly constrained urban elementary schools, learn to do and teach engineering, how they incorporate engineering into their first years of teaching, and how exposure to engineering interacts with their understandings of science inquiry.

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