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# Uncovering Elementary Teachers' Notions of Engineering Design Practices using Video-Captured Instruction

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**Abstract:** This article describes a 3-credit STEM education graduate course that provided knowledge and experiences to elementary school teachers for incorporating the engineering design process (EDP) into their instruction. We analyzed teachers' written reflections that gave us insights to the successes and challenges in helping teachers develop their notions and implementation of the EDP.

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## Introduction

*A Framework for K-12 Science Education* was published by the National Research Council to guide education professionals and school administrators on incorporating the engineering design process (EDP) in classrooms (NRC, 2012). According to the *Framework*, teachers are encouraged to engage students in the following engineering design practices: (a) defining problems, (b) developing and using models, (c) planning and carrying out investigations, (d) analyzing and interpreting data, (e) using mathematics and computational thinking, (f) designing solutions, (g) engaging in argument from evidence, and (h) obtaining, evaluating, and communicating information (NRC, 2012). Unfortunately, most elementary students have received little exposure to and instruction in the EDP, which may be due in part to a lack of knowledge and pedagogy of teachers in the domain (Committee on K-12 Engineering Education, 2009).

To address this challenge, we used the *Framework* and the *Engineering is Elementary* curricula (www.eie.org), to guide our teachers' knowledge development of and experiences in the EDP in a 3-credit graduate course, Introduction to STEM Education. In this article we describe the teachers' notions of the EDP based on our analyses of their reflections written after watching a video of two elementary-level engineering lessons.

## Literature Review

### Professional Development Programs for Teachers

Research studies have described the successes and challenges of teachers as they implemented the EDP in their classrooms. Capobianco and Rupp (2014) found that teachers tended to focus on the opening stages of the EDP, such as problem identification and planning, at the expense of the other components of the EDP, such as testing and redesigning the model. On the other hand, intensive professional development programs in engineering education have contributed to the growth in teachers' knowledge, efficacy and confidence in teaching STEM practices to their students. In particular, the professional development program offered by the Museum of Science in Boston's *Engineering is Elementary* group had resulted in improvements in the teachers' content knowledge of the EDP (Cunningham et al., 2007). Moreover, Macalalag and Tirthali (2010) found that an intensive summer workshop and monthly classroom support-visits have strengthened teachers' knowledge and implementation of the EDP. Other studies have demonstrated that STEM professional development programs helped teachers to bring hands-on learning into their classrooms, integrate EDP into the curriculum, and provide opportunities for peer support (Nadelson et al. 2013; Avery & Reeve 2013).

### Teacher Reflections Using Video-Captured Instruction

Video recording is one of the tools used in professional development programs to help teachers explore new teaching methods and reflect on their own knowledge and pedagogies (Friel & Carboni, 2000; Coffey, 2014). Blomberg et al. (2013) synthesized research on the use of video in teacher education to develop five heuristics describing good practices. These included the need to identify learning goals, align the instructional methods to goals, and identify the limitations of the video. Additionally, opportunities for peer discussions about video-taped lessons can change teachers' ideas about the video content and provide teachers with new perspectives (Ineson et al. 2015).

In summary, the *Framework* encourages teachers to implement the EDP in their classrooms, and several professional development programs have been successful in helping elementary teachers to do this. In our study, we collected and analyzed the teachers' written reflections after watching a lesson in which a teacher used the EDP. The following research questions guided our study: (a) What do experienced elementary teachers notice in video-captured instruction of lessons in science classrooms? (b) How does this inform our understanding of their notions of the EDP? (c) In what ways do partner conversations and class discussions influence teachers' ideas of the EDP?

## Methodology

### Research Setting, Course and Participants

Our study was conducted during a 3-credit course, *Introduction to STEM Education*, taught by the third author for 15 weeks at a small liberal arts college in the mid-Atlantic region of the United States. Throughout this graduate methods course, teachers were introduced to the science and engineering practices, crosscutting concepts, and core ideas outlined in the *Framework.* Specific course objectives included: (a) developing or adapting a unit to incorporate science inquiry and EDP practices, (b) creating assessments to analyze students' conceptual understandings and difficulties in science, (c) implementing and reflecting on instruction, (d) utilizing STEM curricula and resources, and (e) incorporating physical science concepts. The four core assignments consisted of writing a teaching statement, developing and implementing a STEM unit, writing reflections after watching video-captured instruction of a science or engineering lesson, and pre-and post-tests.

Participants in this study included 17 practicing elementary school teachers from a suburban school district with about 8,000 students in PreK-12. Twenty-six percent of students in the district are of color and 8% receive free and reduced lunch. Of the 17 participants, 13 teachers had seven or more years of teaching experience, while four teachers had six or fewer years of experience. Additionally, the teachers had varying backgrounds, with a majority (70%) having degrees in early childhood and elementary education. Others reported previous degrees or certifications in literacy, marketing and communications, mathematics, history, Spanish, and the Arts.

## Method and Data

The course instructor and the teachers watched a video of a fifth grade teacher from Jersey City who taught lessons from the *Engineering is Elementary* unit—*Water, Water Everywhere.* The unit engaged students to explore the factors that contribute to water quality and pollution. The teachers focused on the third and fourth lessons that asked students to investigate and design a water filter using a coffee filter, cotton balls, gravel, sand, cheesecloth, and/or a screen. The water filter had to effectively remove particles out of a water sample as well as be the most cost efficient. The students worked in groups to plan their designs, create and test them, and evaluate their effectiveness. After viewing the video, teachers were given 10 minutes to complete the first written reflection. They were then asked to discuss their reflection with a partner for 10 minutes. After the partner discussion, a 15-minute class discussion about their reflections was held. The teachers were then given a second reflection sheet and asked to complete the reflection again, focusing on new ideas they learned through both discussions. The reflections were handed in for a course grade.

Both reflections contained the same six questions: (1) What worked well in this lesson? (2) What aspects of the lesson did not work well? (3) What would you do differently in the lesson? (4) To what extent or degree would you consider this lesson to be science inquiry and/or design? [5- Very high inquiry/engineering design and 1- Very low inquiry/engineering design] (5) How would you rate the teacher's instruction from (1) teacher-driven to (5) student-driven? and (6) Is there anything else you noticed in the lesson? (optional). Please note that in this study, we only reported teachers' answers to the first three questions. Moreover, due to the page limitation, we only presented our findings on the EDP practices mentioned by teachers. We did not include descriptions that contain their notions of general teaching pedagogy such as motivation of students, scaffolding students' prior knowledge, classroom management techniques, and others.

**Data Analysis**

The third author replaced the teacher's names with ID numbers before conducting our analysis, and we used pseudonyms in this paper to protect the identity of our participants. We employed the constant comparison method to identify themes and categories from the teachers' reflections (Merriam, 1998). We used the engineering design practices in the *Framework* to guide our analyses of the first three questions- *What worked well in the lesson? What aspects of the lesson did not work well?* and *What would you do differently?* Our analyses of the themes that emerged from their responses gave us insights to their notions of the EDP, aspects of instruction that they intend to change, and the extent to which they would incorporate the EDP in their proposed revised instruction. We provided the codes and examples that emerged from our analyses in Appendices A, B and C. Additionally, the first and third author met to examine the video, using the codes that were created as guide, in order to identify the engineering design practices that worked well, did not work well, or were missing in the lesson and that teachers should have mentioned in their reflections. The practices we identified and examples of each are provided in Appendix G.

Further analyses of the teachers' reflections provided insights to the parts (beginning, middle, and end) of the EDP that they attended to or emphasized. We created three categories: *Beginning Practices in the EDP, Middle Practices in the EDP,* and *End Practices in the EDP.* Practices that usually happen at the start of the design process and before investigations, such as *reviewing and engaging students in the EDP* and *identifying design criteria*, were classified as beginning practices. Practices, like *collecting data* and *recording and analyzing data,* that engage students in investigations or experimentations were categorized as middle practices. Finally, practices that typically occur after an investigation, such as *defending or justifying claim in discourse*, were classified as end practices. We provided our categories and codes from our analyses in Appendices D, E and F.

Two independent coders, the first two authors, analyzed the teachers' responses using the themes and categories that emerged from the constant comparison method. The first two authors double-coded 50% of the papers with 82% agreement. Any disagreements that occurred were discussed and negotiated. However, only agreed upon codes were included in this study. The remainder of the papers were analyzed by one of the authors. We then conducted a quantitative analysis of qualitative data to find frequencies, changes, and/or patterns in our codes (Chi, 1997).

## Results

### Question 1: What worked well in the lesson?

Teacher's responses to the first question gave us insights into their ideas of the EDP that worked well in the lesson. Based on teachers' initial reflections, before partner and class discussions (Reflection 1), about half of teachers mentioned *asking students to brainstorm, predict, ask questions, or make claims* (N=9, 53%) and *reviewing and engaging students in the engineering design process* (N=9, 53%). There were few teachers who mentioned *clearly identifying problem or question* (N=4, 24%) and *defending or justifying claim in discourse* (N=3, 18%) as effective lesson components. It is also worth noting that only two teachers (12%) cited *exploring of materials; testing of predictions, models, and variables; and making and recording observations* as well as *identifying design criteria* in their initial reflections.

In their second reflections, after partner and class discussions (Reflection 2), more teachers mentioned *reviewing and engaging students in the engineering design process* (N=14, 82%) and *identifying design criteria* (N=4, 24%) than in their initial reflections. However, fewer teachers mentioned *asking students to brainstorm, predict, ask questions, or make claims* (N=5, 29%), *clearly identifying problem or question* (N=1, 6%), and *exploring of materials; testing of predictions, models, and variables; and making and recording observations* (N=0, 0%) in Reflection 2 than in Reflection 1. Finally, there was no change in the number of teachers who cited *defending or justifying claim in discourse* (N=3, 18%) from Reflection 1 to Reflection 2.

### Question 2: What aspects of the lesson did not work well?

Question two provided us with an understanding of what lesson components teachers see as ineffective in the engineering lesson. In their initial reflections, about a quarter of teachers mentioned *stated problem or question is not clear or communicated* (N=4, 24%). Only two teachers (12%) mentioned *missed opportunity to explain or identify engineering design criteria*; *no student investigation/design or self-directed discovery*; *confirmatory lab investigation*; and *no data collection* in Reflection 1. Additionally, only one teacher (6%) mentioned *did not ask students to brainstorm, predict, ask questions, or make claims* and *did not include analysis of data* as ineffective lesson components. Zero teachers mentioned *did not provide students opportunities to explain their thinking regarding investigation/design*.

In their reflections after partner and class discussions, more teachers cited *did not ask students to brainstorm, predict, ask questions, or make claims* (N=2, 12%), *stated problem or question is not clear or communicated* (N=5, 29%), *confirmatory lab investigation* (N=3, 18%), *no data collection* (N=4, 24%), and *did not provide students opportunities to explain their thinking regarding investigation/design* (N=3, 18%) than in Reflection 1. There were fewer teachers, however, who mentioned *no student investigation/design or self-directed discovery* (N=0, 0%) in Reflection 2 than in Reflection 1. Additionally, there was no change in the number of teachers who mentioned *missed* *opportunity to explain or identify engineering design criteria* (N=2, 12%) and *did not include analysis of data* (N=1, 6%) from Reflection 1 to Reflection 2 (see graph in Appendix B).

### Question 3: What would you do differently in the lesson?

The third question gave us an understanding into what lesson components the teachers would include to make the lesson more successful. In the before partner and class discussion reflections, more than a third of teachers mentioned *asking students to share, explain, or discuss their ideas, data, and findings, or support argument with evidence* (N=7, 41%). Additionally, few teachers mentioned *making problem/question clear and explicit* (N=3, 18%), *recording, analyzing, and communicating data* (N=3, 18%), *evaluating and revising designs and models* (N=4, 24%), and *exploring materials; testing predictions, models, and variables; and making and recording observations* (N=5, 29%) as things they would do differently in the lesson. Only two teachers (12%) mentioned *collecting data* while one teacher (6%) mentioned *asking students to brainstorm solutions and ask questions*; *allowing students to plan and create own investigations*; and *using a guided/directed investigation*. It is also important to note that zero teachers cited *asking students to predict outcomes of investigations*.

Compared to their initial reflections, more teachers mentioned *asking students to brainstorm solutions and ask questions* (N=4, 24%), *asking students to predict outcomes of investigations* (N=3, 18%), *exploring materials; testing predictions, models, and variables; and making and recording observations* (N=7, 41%), and *allowing students to plan and create own investigations* (N=3, 18%). There was also an increase in the number of teachers who mentioned *asking students to share, explain, or discuss their ideas, data, and findings or support argument from evidence* (N=9, 53%), *collecting data* (N=5, 29%), *recording, analyzing, and communicating data* (N=5, 29%), and *evaluating and revising designs and models* (N=6, 35%) from Reflection 1 to Reflection 2. Lastly, fewer teachers cited *using a guided/directed investigation* (N=0, 0%) in Reflection 2 than in Reflection 1 and the same number of teachers mentioned *making problem/question clear and explicit* (N=3, 18%) in both reflections (see graph in Appendix C).

### Teachers' Notions of the Beginning, Middle and End Practices of the Engineering Design Process

In regards to components of the lesson that worked well, teachers primarily focused on beginning practices in both Reflections 1 and 2. In Reflection 1, *Beginning Practices of the EDP* were mentioned by teachers 24 times, *Middle Practices* were mentioned only 2 times, and *End Practices* were mentioned 3 times. While there was no change in the number of instances teachers cited *Beginning* and *End Practices* from Reflection 1 to Reflection 2, *Middle Practices* were mentioned fewer times in Reflection 2 as teachers did not mention them at all (see graph in Appendix D).

In the second question, teachers were more likely to mention *Beginning and Middle Practices of the EDP* compared to *End Practices*. Both *Beginning* and *Middle Practices* were cited 7 times in Reflection 1. Moreover, in the post-discussion reflections, there were increases in the number of instances in which teachers mentioned *Beginning* (N=9) and *Middle Practices* (N=11). However, it is also important to note that teachers did not mention any *End Practices* in both reflections (see graph in Appendix E).

Finally, looking at the teachers' explanations of what they would do differently in the lesson, they mentioned more of *Middle Practices* compared to the *Beginning* and *End Practices.* In Reflection 1, both *Beginning* and *End Practices* were mentioned in 4 instances while *Middle Practices* were mentioned in 19 instances. Importantly, there was an increase in the number of times each type of practice was mentioned from Reflection 1 to Reflection 2 (see graph in Appendix F).

## Discussion

### Assertion 1: Teachers mentioned more practices from the beginning and middle parts of the EDP, which suggests that teachers' learning of the EDP is an incremental process.

Our study showed that the development of pedagogical knowledge in teaching the EDP is a complex process particularly for elementary school teachers. Our findings suggested that the teachers were more familiar with the *Beginning* and *Middle Practices of the EDP* than with the *End Practices*, which included *defending or justifying claim in discourse* and *evaluating and revising designs and models*. Our findings support the work of Capobianco and Rupp (2014) who noticed that during instruction, teachers devoted less time to processes such as testing a design, communicating performance results, and redesigning their models. The teachers in our study demonstrated this lack of focus on processes, even after they created and implemented their own engineering design focused lesson.

### Assertion 2: Teachers were more likely to mention certain engineering design practices in their reflections after class discussions.

We believe that positive changes in Reflection 2 point toward the importance of individual reflection and discussion with peers. Specifically, our teachers emphasized certain engineering design practices when other teachers and the course instructor mentioned them during partner and class discussions. The teachers who participated in our study were enrolled in a teacher education course to develop their understanding of the EDP. In the course, teachers were able to learn the EDP through hands-on investigations, critiques and individual/group reflections of video-captured instruction using the EDP, and incorporation of the EDP through STEM unit design and implementation. The components of the coursework for our teachers mirrored some of the attributes of an effective professional development program (Avery & Reeve, 2013)—engaging participants in engineering challenges and the integration of STEM concepts into instruction. Furthermore, our study confirmed that using the video and reflection helped students critically reflect on instruction (Coffey 2014; Friel & Carboni 2000). The use of video-captured instruction in our course provided a rich opportunity for students to reflect on and discuss their ideas about the nature of lessons that incorporate the EDP. This study showed that STEM professional development can be enhanced by providing opportunities for teachers to watch examples of engineering design pedagogy in action. Our study demonstrated that combining this use of video with discussion and reflection was an effective way to help teachers communicate their emerging understanding of this pedagogy. This information is useful in planning further opportunities for teacher learning and professional development.

### Assertion 3: Teachers have notions of some practices, even though they did not consistently mention them in their reflections.

Our results showed a lack of consistency in the EDP practices mentioned by teachers when answering the three questions that guided their reflections. Similar to Gün (2012) who saw that a group of professionals observing the same lesson often noticed completely different features, our teachers saw different aspects of the EDP while watching the same video, potentially contributing to this inconsistency. Another possible reason for our teachers' inconsistency could be because teachers mentioned a particular practice under one question and then did not see the need to mention a closely related practice in another question in the same reflection.

Our research findings describe teachers' ability and struggle to pay attention to certain stages while neglecting other parts of the EDP. Based on our analysis of the lesson, we expected teachers to mention the practices that we identified as working well, not working well, or missing from the lesson in their reflections (see Appendix G for analysis). Our findings indicate that many teachers or more teachers in Reflection 2 did mention some of these practices in their reflections including, *reviewing and engaging students in the engineering design process*. Additionally, like the authors, most teachers or more teachers in Reflection 2 noted *did not provide students opportunities to explain their thinking regarding investigation/design* and *asking students to share, explain, or discuss their ideas, data, and findings or support argument with evidence* as practices that were missing or not done well in the lesson. However, most teachers failed to cite *identifying design criteria* and *planning, designing, and using models*, despite them being greatly emphasized or demonstrated in the lesson. Moreover, although teachers in our study were exposed to argumentation and revision of models based on evidence in our course, we believe that careful attention should be given to differentiate argumentation from presentation of ideas as well as to use evidence and models as part of argumentation while engaging in the EDP. One possible way is to provide teachers with a framework as they learn and implement evidence-based argumentation, similar to the claim-evidence-reasoning-rebuttal guide in Zembal-Saul et al. (2013). Another way is to provide more emphasis and time in the *Improve* stage of the EDP as described in the *Engineering is Elementary* module. Our research builds on the current literature by illustrating the unique challenges faced by elementary teachers who are beginning to develop their pedagogical content knowledge towards teaching the EDP.

### Study Limitations

Our study has several limitations. First, while reflections of video-captured instruction can elicit teachers' notions of EDP and their ideas of instruction, the teachers' reflections and their discussions may be limited to the EDP components that were captured and highlighted in the video. Moreover, reflections may not be accurate representations of what teachers' instruction would look like in the classroom. Second, this article only included the teachers' reflections on one video and did not include any additional data that would support our claims. Our analyses of pre-and post-tests, reflections on additional STEM video-captured instructions, teacher-developed STEM units, and pre-and post-course reflections can possibly provide additional evidence in the future. Third, our analyses and discussions in this study were focused on the teachers' notions and implementation of the EDP. We were not able to include the teachers' descriptions that contain their general teaching pedagogy such as motivation of students, scaffolding students' prior knowledge, classroom management techniques, and others.

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### References

Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal of Technology Education, 25*(1), 55-69.

Blomberg, G., Renkl, A., Sherin, M., Borko, H. and Seidel, T. (2013). Five research-based heuristics for using video in pre-service teacher education. *Journal for Educational Research Online, 5*(1), 90–114.

Capobianco, B. M., & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing engineering design-based instruction. *School Science & Mathematics, 114*(6), 258-270.

Chi, M. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences, 6*(3), 271-315.

Coffey, A. M. (2014). Using video to develop skills in reflection in teacher education students. *Australian Journal of Teacher Education, 39*(9).

Committee on K-12 Engineering Education. (2009). *Engineering in K-12 education: understanding the status and improving the prospects*. L. Katehi, G. Pearson, & M. Feder (Eds.). Washington, DC: The National Academies.

Cunningham, C. M., Knight, M. T., Carlsen, W. S., Kelly, G. (2007). Integrating engineering in middle and high school classrooms. *International Journal of Engineering Education, 23*(1), 3-8.

Friel, S. N. & Carboni, L. W. (2000). Using video-based pedagogy in an elementary mathematics methods course. *School Science and Mathematics, 100*(3), 118–127.

Gün, B. (2012). Views of teacher performance: To what extent do multiple observers converge? *Eurasian Journal of Educational Research, 46*(46), 81-100.

Hsu, M. C., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research, 1*(2), 31-39.

Ineson, G., Voutsina, C., Fielding, H., Barber, P., & Rowland, T. (2015). Deconstructing "good practice" teaching videos: An analysis of pre-service teachers' reflections. *Mathematics Teacher Education and Development, 17*(2), 45-63.

Macalalag, A. Z., & Tirthali, D. (2010, August). *Teacher professional development in elementary schools: Improving student achievement through science and engineering*. Paper presented at the P-12 Engineering and Design Education Research Summit, Seaside, OR.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach.* San Francisco, CA: Jossey-Bass.

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. *Journal of Educational Research*, *106*(2), 157-168.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academies Press.

Zembal-Saul, C., McNeill, K., and Hershberger, K. (2013). *What's your evidence? Engaging K-5 students in constructing explanations in science*. Upper Saddle River, NJ: Pearson Education.

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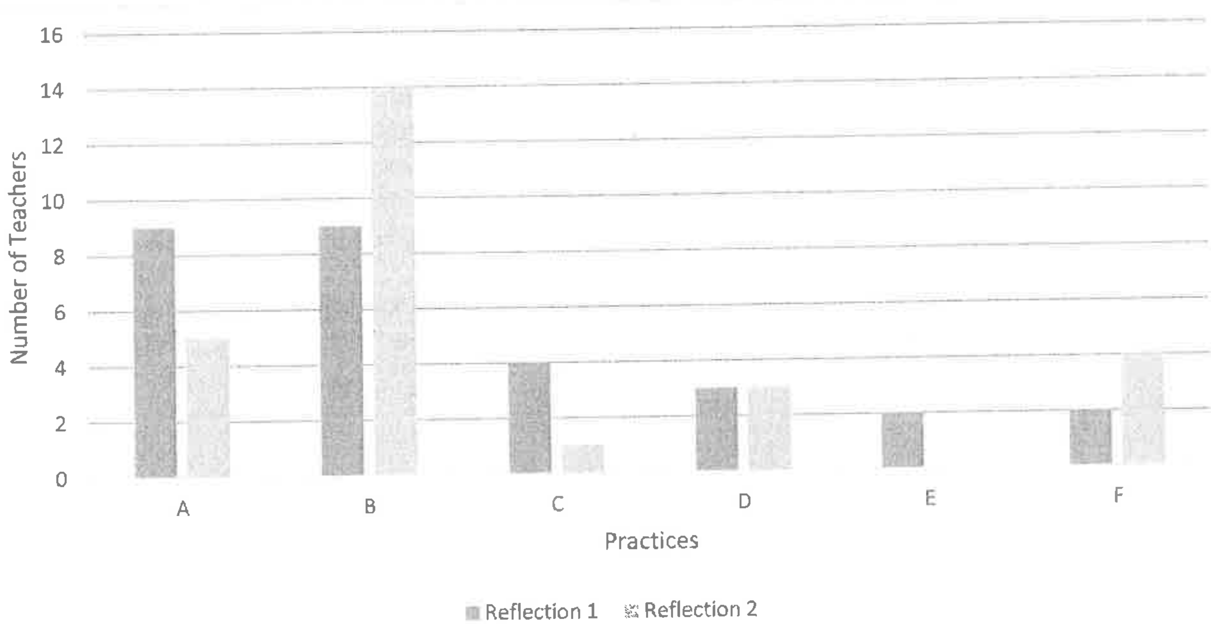
**Appendix A**

Codes and examples – What worked well in the lesson?

| Codes | Examples |
|---|---|
| A. Asking students to brainstorm, predict, ask questions, or make claims | "The students were encouraged to make predictions and question throughout," (Ms. Smith, Reflection 1) |
| B. Reviewing and engaging students in the engineering design process | "She repeatedly referred to the engineering design process, and the students were versed in the process," (Ms. Dwyer, Reflection 2) |
| C. Clearly identifying problem or question | "Establishing a problem," (Ms. Jacobs, Reflection 1) |
| D. Defending or justifying claim in discourse | "Defend your answers 'if you say yes, I need to know why,'" (Ms. Jacobs, Reflection 2) |
| E. Exploring of materials; testing of predictions, models, and variables; and making and recording of observations | "Students tested each filter material and observed particles that remained in the water," (Ms. McCormick, Reflection 1) |
| F. Identifying design criteria | "Class agreed upon established criteria when identifying their design problem (also including cost into the criteria)," (Ms. McCormick, Reflection 1) |

What worked well in the lesson? Responses in Reflections 1 and 2

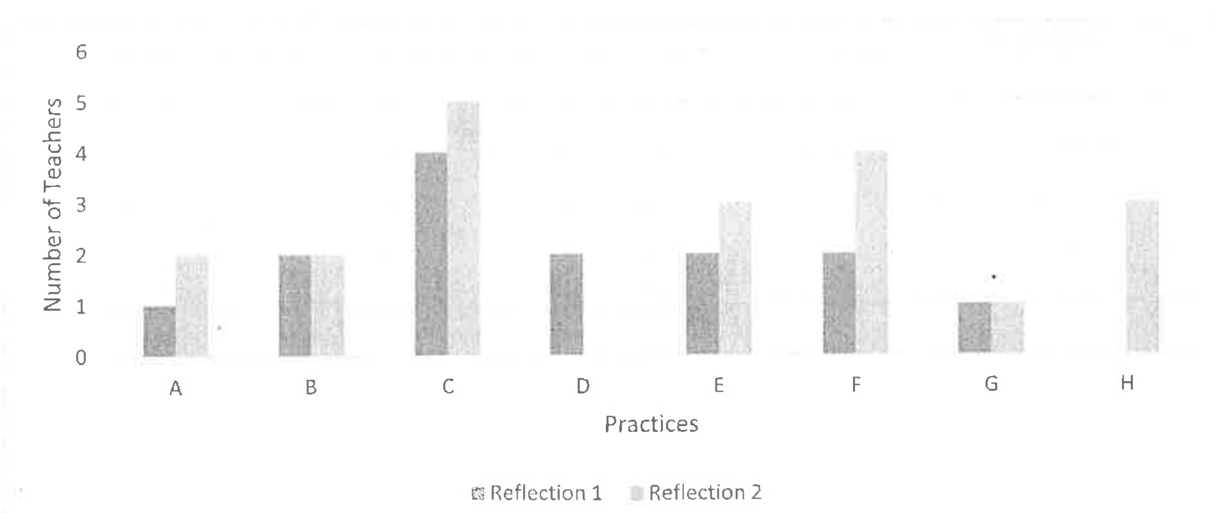


## Appendix B

Codes and examples—What aspects of the lesson did not work well?

| Codes | Examples |
|---|---|
| A. Did not ask students to brainstorm, predict, ask questions, or make claims | "Students do not have an opportunity to brainstorm and discuss the properties of the materials before sharing with the whole class," (Mr. Kiler, Reflection 1) |
| B. Missed opportunity to explain or identify engineering design criteria | "Developing models- no clear scientific model or guidance as to why they are redesigning. Students just reorder materials without knowing why," (Ms. Thompson, Reflection 2) |
| C. Stated problem or question is not clear or communicated | "Although a focus question was used, it was too broad a statement. Students could have been given better direction if the question was phrased differently," (Ms. Casterline, Reflection 2) |
| D. No student investigation/design or self-directed discovery | "Everything is very rigidly set, the students have no opportunity to try to figure things out on their own," (Mr. Kiler, Reflection 1) |
| E. Confirmatory lab investigation | "Teacher provides the question to be answered by the students. Teacher provided ways to describe materials. Teacher provided method for how to test materials, controlled variables for students," (Ms. Hastings, Reflection 1) |
| F. No data collection | "There wasn't really any data collected to evaluate and analyze," (Ms. Hoffman, Reflection 2) |
| G. Did not include analysis of data | "There really wasn't any data collected to evaluate and analyze to move them forward," (Ms. Hoffman, Reflection 1) |
| H. Did not provide students opportunities to explain their thinking regarding investigation/design | "Developing models- students just reorder materials without actually explaining or defining why those changes would be more effective," (Ms. Weaver, Reflection 2) |

What aspects of the lesson did not work well? Responses in Reflections 1 and 2

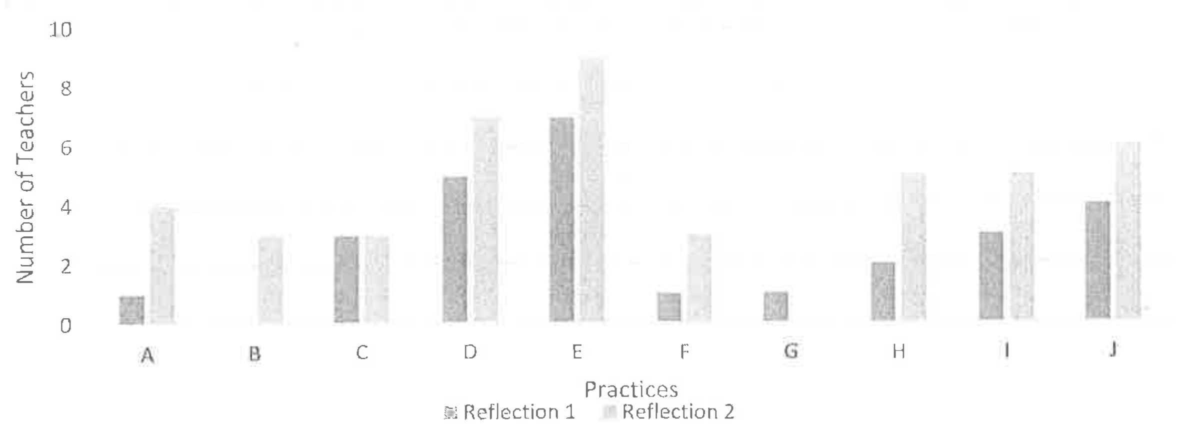


## Appendix C

Codes and examples—What would you do differently in the lesson?

| Codes | Examples |
|---|---|
| A. Asking students to brainstorm solutions and ask questions | "Have students brainstorm what other materials might be used to create a filter," (Ms. Weaver, Reflection 2) |
| B. Asking students to predict outcomes of investigations | "Should record predictions for students to refer to later," (Ms. Thompson, Reflection 2) |
| C. Making problem/question clear and explicit | "Focus question could be more precise? For example: What is the best combination of materials to use in our filters, taking into account cost and amount of material used?" (Ms. Dwyer, Reflection 1) |
| D. Exploring of materials; testing of predictions, models, and variables; and making and recording of observations | "Students should have had more time to observe the contaminated water and record their observations," (Ms. Casterline, Reflection 2) |
| E. Asking students to share, explain, or discuss their ideas, data, and findings or support argument with evidence | "I would facilitate more student discourse," (Mr. Fields, Reflection 1) |
| F. Allowing students to plan and create own investigations | "Give students more freedom to really create, plan, test & design with less guidance," (Ms. Perotto, Reflection 2) |
| G. Using a guided/directed investigation | "Allow students to determine a process for testing the materials," (Ms. Weaver, Reflection 1) |
| H. Collecting data | "Have students time and record the time for filtering 1/4 cup. Sort students' filtered water into darkest to lightest and list the amounts and types of materials used," (Ms. Weaver, Reflection 2) |
| I. Recording, analyzing, and communicating data | "I would try to incorporate a graph for both the testing and design parts to allow students a clear visual of the data collected," (Ms. Andrews, Reflection 1) |
| J. Evaluating and revising designs and models | "I would provide students the opportunity to redesign after testing and learning about other group results," (Ms. Andrews, Reflection 2) |

What would you do differently in the lesson? Responses in Reflections 1 and 2

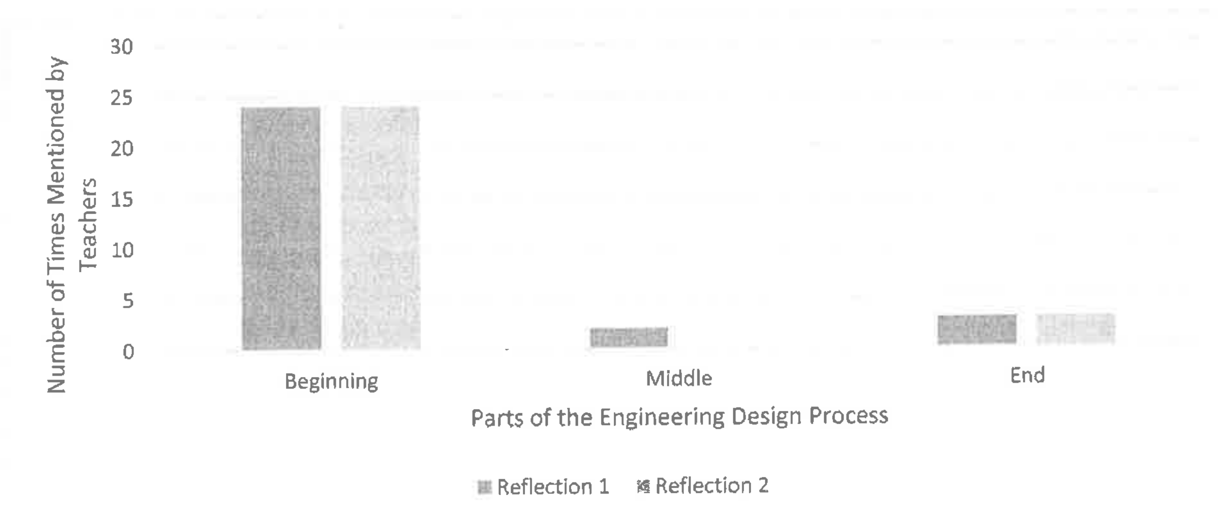


## Appendix D

What worked well in the lesson? Practices identified as beginning, middle, and end of the EDP

| | |
|---|---|
| Beginning Practices of the EDP | ▪ Asking students to brainstorm, predict, ask questions, or make claims<br>▪ Reviewing and engaging students in the engineering design process<br>▪ Clearly identifying problem or question<br>▪ Identifying design criteria |
| Middle Practices of the EDP | ▪ Exploring of materials; testing of predictions, models, and variables; and making and recording of observations |
| End Practices of the EDP | ▪ Defending or justifying claim in discourse |

What worked well in the lesson? Number of times teachers mentioned the beginning, middle, and end parts of the EDP in Reflections 1 and 2

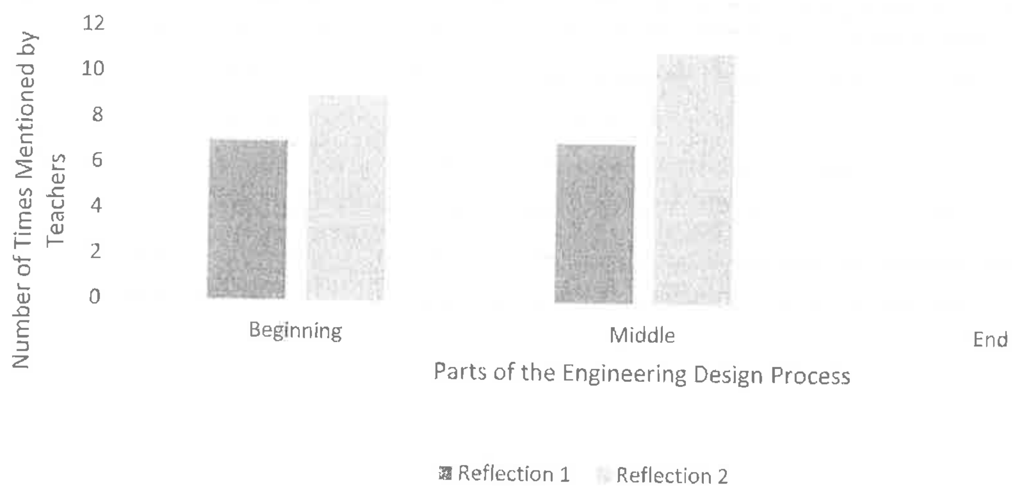


**Appendix E**

What aspects of the lesson did not work well? Practices identified as beginning, middle, and end of the EDP

| | |
|---|---|
| Beginning Practices of the EDP | ▪ Did not ask students to brainstorm, predict, ask questions, or make claims<br>▪ Missed opportunity to explain or identify engineering design criteria<br>▪ Stated problem or question is not clear or communicated |
| Middle Practices of the EDP | ▪ No student investigation/design or self-directed discovery<br>▪ Confirmatory lab investigation<br>▪ No data collection<br>▪ Did not include analysis of data<br>▪ Did not provide students opportunities to explain their thinking regarding investigation/design |
| End Practices of the EDP | *Note: Teachers did not mention any practices in this category. |

What aspects of the lesson did not work well? Number of times teachers mentioned the beginning, middle, and end parts of the EDP in Reflections 1 and 2

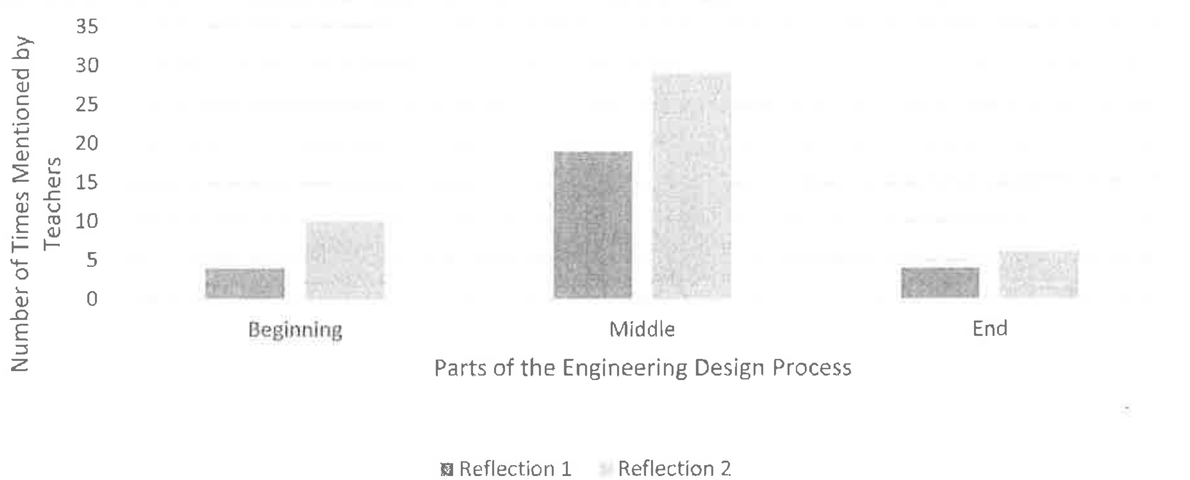


**Appendix F**

What would you do differently in the lesson? Practices identified as beginning, middle, and end of the EDP

| | |
|---|---|
| Beginning Practices of the EDP | ▪ Asking students to brainstorm solutions and ask questions<br>▪ Asking students to predict outcomes of investigations<br>▪ Making problem/question clear and explicit |
| Middle Practices of the EDP | ▪ Exploring of materials; testing of predictions, models, and variables; and making and recording of observations<br>▪ Asking students to share, explain, or discuss their ideas, data, and findings or support argument with evidence<br>▪ Allowing students to plan and create own investigations<br>▪ Using a guided/directed investigation<br>▪ Collecting data<br>▪ Recording, analyzing, and communicating data |
| End Practices of the EDP | ▪ Evaluating and revising designs and models |

What would you do differently in the lesson? Number of times teachers mentioned the beginning, middle, and end parts of the EDP in Reflections 1 and 2



## Appendix G

Authors' analysis of the video: Engineering design practices identified by the authors as working well in the lesson and examples of each.

| Codes | Examples |
|---|---|
| Reviewing and engaging students in the engineering design process | Teacher (T)-"We are going to work on the first part of our engineering process. We're going to ask questions." (Lesson 3, Classroom 1, 2:52) |
| Clearly identifying problem or question | T- "Remember, we are asking a question. 'What are the materials we could use to create our filter or to use in our filter?'" (Lesson 3, Classroom 1, 3:04) |
| Asking students to brainstorm, predict, ask questions, or make claims | T- "So, if I can see the holes (talking about the piece of screen) what does that tell me about if I pour something through this?"<br>Student (S)- "It will fall through."<br>T- "It will go straight through. But let me ask you this question, if I were to pour this one (pointing to a jug of water with soil mixed in), what do you think would happen?"<br>S- "The dirt is going to stay on top."<br>T- "The dirt would stay outside. It would pretty much take out, screen out the bigger particles, the particles that we can definitely see." (Lesson 3, Classroom 1, 5:27) |
| Exploring of materials; testing of predictions, models, and variables; and making and recording of observations | Students are testing each type of material by pouring contaminated water over it and collecting the filtered water in a cup. They are making observations of the filtered water and recording their observations on a sheet of paper. (Lesson 3, Classroom 1, 6:57) |

| | |
|---|---|
| Collecting data* | Students collected data about the effectiveness of each type of material, recording how long it took to filter the water as well as the amount of particles in and color of the filtered water. (Lesson 3, Classroom 1, 7:40) |
| Recording, analyzing, and communicating data* | The students shared their data with the rest of the class and then analyzed this data to determine which materials were the most and least effective. (Lesson 3, Classroom 1, 8:05) |
| Identifying design criteria | Teacher and students are reviewing the criteria for judging the effectiveness of their water filter design- particles in water, color of water, time, and cost. (Lesson 4 Part 1, Classroom 1, 2:00) |
| Planning, designing, and developing a model based on evidence | Students are planning their filters and drawing their model on paper based on the data they collected about each material. (Lesson 4 Part 1, Classroom 1, 8:00) They then create and test their model. (Lesson 4 Part 2, Classroom 1, 0:41) |
| Evaluating and revising designs and models | Students are evaluating their designs using the identified design criteria. Then using their evaluation, they revise their design. (Lesson 4 Part 2, Classroom 1, 6:04) |

*These practices were implicit in the video