Professional Development on Giving Feedback on Design for Engineering Students and Educators

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Abstract

The goal of this project is to create professional development materials for students, engineers, and engineering educators on giving feedback on engineering design. To achieve this goal, we first characterized and compared engineering students and educators' feedback on design and then used these comparisons to create professional development materials. In these professional development materials, we highlighted the differences between students' (i.e., novices) and engineering educators' (i.e., experts) feedback and emphasized how novices can provide feedback similar to experts. We implemented multiple professional development workshops using these materials. Since the feedback profiles for novices and experts were different, we encouraged the workshop participants to identify their feedback profile and try to provide feedback similar to experts.

Background

Design is a central[1] and defining[2,3] aspect of engineering practice. Many different educational agents can play a role in providing feedback on students' design work. Within the context of an undergraduate engineering course, these agents might include the professor, graduate teaching assistants, undergraduate teaching assistants, an external project partner (from industry or a community organization), and other students in the course. In this project, we focus on the potential for students to develop improved understandings of design and the engineering design process through the feedback that they receive on their design work. Our focus is on the people providing the feedback rather than the students themselves.

Research on feedback in other domains indicates that students benefit the most from specific forms and content of feedback[4], suggesting that there are different levels of quality in the feedback students might receive. Therefore we aim to identify characteristics of feedback on design work, identify expert-novice differences in feedback on design work, develop professional development (PD) opportunities for educators and students to learn how to give feedback on design work, and characterize the impact of PD, while taking into account the extent of feedback providers' prior experience with design and in providing feedback on design.

In education, PD activities are "meant to help teachers to revitalize their existing teaching and learning experiences, and motivate them to tackle emerging internal and external challenges"[5]. One such a challenge might be seen as raising the level of design instruction. Ideally, the goals of PD include increasing subject knowledge, enhancing pedagogical techniques, and improving classroom management skills. While there is not a single format for successful PD, researchers have identified best practices and characteristics of effective professional development. These include (1) addressing faculty and student learning goals and needs, (2) being driven by a well-defined image of effective classroom learning and teaching, (3) building content and pedagogical content knowledge, (4) being research based, (5) allowing collaboration among colleagues and other experts to improve practice, and (6) continuous evaluation and improvement of the PD[6-8].

Our work focuses on the development of content for PD on the topic of giving feedback on engineering design.

Training for university educators, and in particular teaching assistants (TAs), often focus on introductory topics - teaching responsibilities and grading (homework and exam). More advanced, yet still introductory, training topics include knowing students, lecturing techniques, leading discussions, classroom management, creating optimal learning environments, academic integrity, class planning, and instructor evaluations[9,10]. To achieve reform, like improving feedback on design, more in-depth training, or rather professional development (PD), for educators is necessary. Such PD must provide opportunities for instructors and TAs to provide input and feel valued in the research and reform effort[11]. Instances where TA PD in support of educational reform has been reported as being central to the research effort include inquiry-based instruction[11], intrinsic motivation (IM) supported instruction[12], and mathematical modeling[13].

Plan of Work

This project is being conducted in four phases as described in Figure 1. In Phases 1 and 3, samples of students' project work completed for a first-year engineering course were used as the prompt for collecting feedback. This data collection occurred in Phase 1, where we investigate expert-novice differences in providing feedback on design work, and in Phase 3, where we are engaged in educators and students in PD. In this paper we focus on Phase 3, developing professional development materials and implementing workshops. We start by describing the data that was collected and the findings of Phases 1 and 2 that lead to the development of the PD materials in Phase 3.

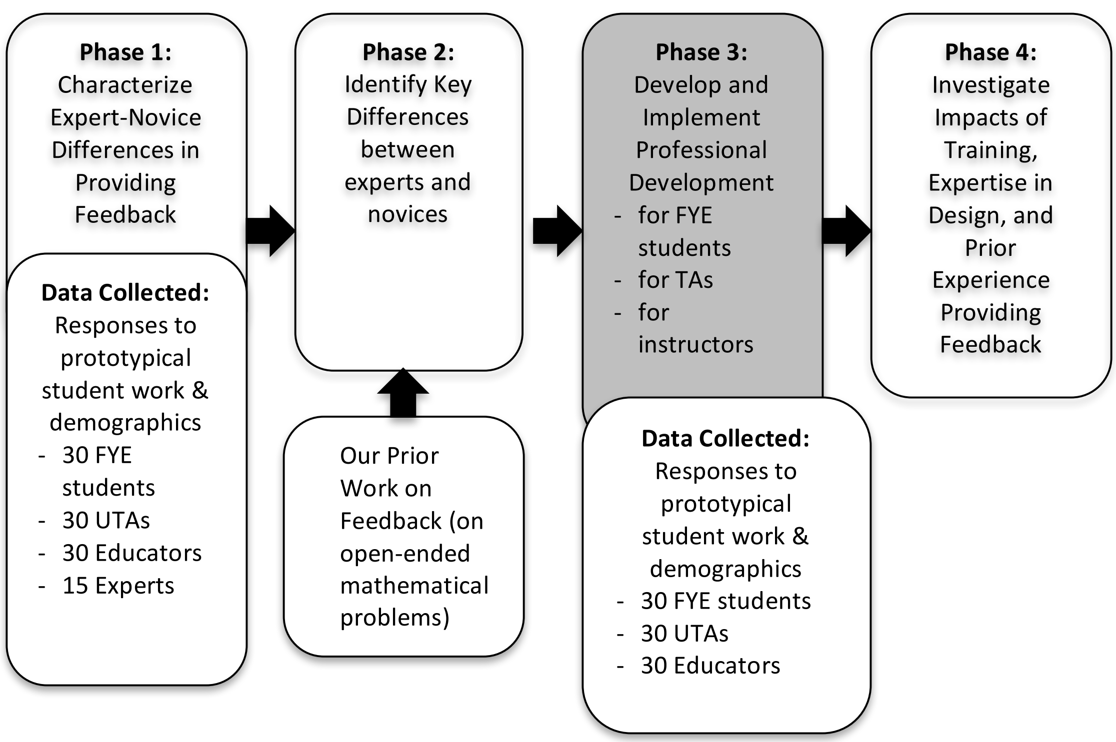

Figure 1 - Phases of the project and associated data collection. This paper focuses on Phase 3.

Participants and Settings
The data for this project were collected from multiple sources including students, engineering educators, and experts. Data was collected during feedback on design course training for students and educators training and workshops for educators and practicing engineers.

A) Students: At a large mid-western R1 university, in a required first-year engineering course, students work together in teams of four to develop solutions to open-ended mathematical modeling problems and design tasks. In Fall 2013, approximately 120 students were individually asked to provide written feedback on a sample student team's design work developed across four different milestones: Problem Scoping (Milestone 1), Concept Generation (Milestone 2), Concept Reduction (Milestone 3), and Concept Detailing (Milestone 4). Each milestone was a 2-4 page long document describing the team's progress on a particular aspect of the design project. After providing feedback, students were asked to share and discuss their feedback with their peers. The feedback from 15 students with at least one year of previous design experience (typically from high school) and 15 students without any previous design experience was used for this project.

B) Engineering educators: During the Fall 2013 semester, instructors and graduate teaching assistants (referred to together as educators in this paper) of the same first-year engineering course were invited to participate in this study. Before the educators began to review their own students' design work, they were asked to give written feedback on the same student team's design work (as described in *A)* above) during their weekly instructors' meeting. After providing feedback, educators were asked to share and discuss their feedback with their peers during the meeting. Nineteen educators provided feedback on Milestone 1, and 14 educators provided feedback on Milestones 2-4.

C) Experts (in progress): The analysis based on data that were collected from students and engineering educators was published as multiple conference papers including those for the America Society for Engineering Education (ASEE) annual conference and the Research in Engineering Education Symposium (REES). In addition, a feedback workshop was conducted at the International Council on Systems Engineering (INCOSE) great lake regional conference (GLRC). At all of these conferences, experienced engineers and engineering educators were invited to participate in this study. They were asked to provide feedback on the same student team's design work. These data are being collected and analyzed and will be published in the near future[14].

Phases 1 and 2 Findings

The professional development materials were constructed based on Phases 1 and 2 findings. In this section we briefly review these findings. To start, when looking at the length and detail in students' and educators' feedback on design, we found that not only was the number of educators' comments greater than the students' but the educators' comments were longer and included more details and examples[15]. This can be an indication that educators spend more time on task than students, which is similar to expert-novice differences on design[16]. These differences may be due to educators having more knowledge and experience with the design context and engaging more deeply in providing feedback than the students. Students may have just been trying to complete this required assignment with less intention than the educators.

When coding educators' and students' feedback, we found they were different in both Focus (i.e., type) and Substance (i.e., content) of feedback, which are aligned with novice-expert differences in how they approach design problems[17,18]. Figure 2 illustrates students' and educators' differences for the Focus domain. Experts, when doing design work, delay decision making to understand[19] and frame the problem[20], gather information[21], and generate[22] and evaluate difference design ideas [23]. Novices perceive the design task as a well structure task[24] and immediately start problem solving without exploring alternatives[22].

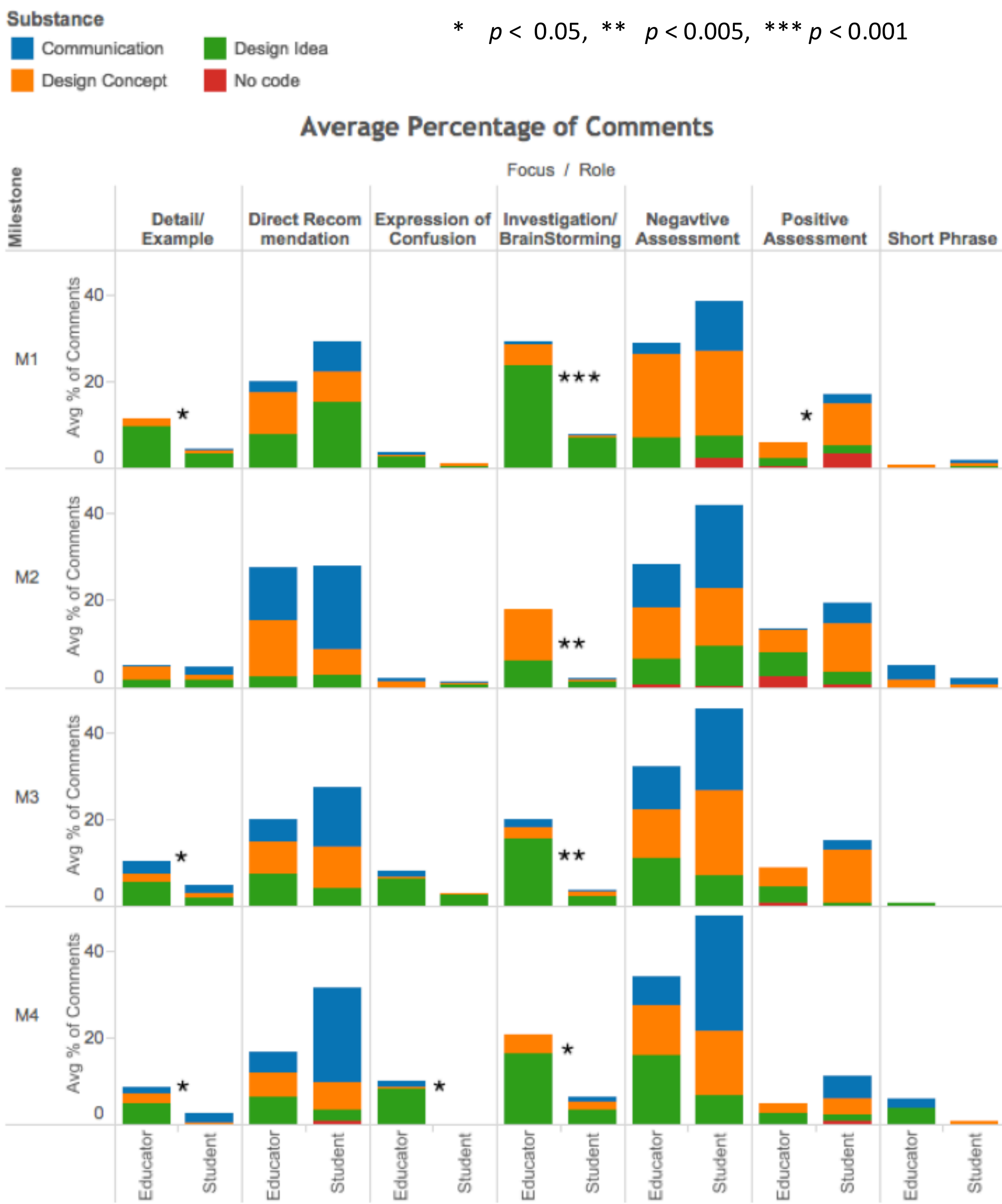

Figure 2 - Comments broken down by Focus of feedback. Significantly different categories are marked with * (image best viewed in color)[17].

Educators, similar to experts at design, focused their feedback on provided brainstorming comments (Investigation/Brainstorming in Figure 2) and asked thought provoking questions to help students explore different alternatives and delay decision-making. Students, similar to novices at design, gave comments with direct recommendations on what needs to be changed and specific instructions on how to improve the design work[18]. A number of reasons may be in play. Educators try to encourage students to be similar to expert designers, who explore and critically evaluate multiple ideas before choosing a solution. In contrast, students, similar to novice designers, get fixated on a specific solution and give direct recommendations on how to improve the solution rather than look at other alternative solutions. The difference for Investigation/Brainstorming is especially high for Milestone 1 (Problem Scoping)[18]. At this stage, experts usually spend more time exploring different ideas while novices quickly choose a solution and start working on it. This also can explain why a higher percentage of students' comments included positive or negative assessments or the design work without any elaboration on new ideas. Students just try to fix the current solution without thinking about the alternatives.

Another difference between the educators' and students' comments concerned the Expression of Confusion; these comments indicate something is possibly wrong with the design decisions and encourage students to reevaluate their design choices[17]. It seems educators see the feedback as a dialogue to express their confusion and hope the student designers will respond by improving their work. In other words, they see themselves as a "guide" to help students improve their work. However, students perceive this task as an assessment task and see themselves as a "grader" who should point out positive and negative aspects of the work[25]. Another reason for this difference may be that educators have more confidence to express their confusion while students' lack of confidence may prevent them from admitting they do not understand a part of the design work and asking for clarification.

Figure 3 illustrates students' and educators' differences in the Substance domain. In Substance of feedback, students' comments were mostly related to the Communication aspects of the design, and unlike the educators, did not provide as much feedback on specific design ideas[18]. This is similar to expert-novice differences in the design context - experts try to generate new ideas more than novices[22]. Educators' and students' comments were similar for Design Concepts (also referred to as design process). This feedback activity occurred after students completed an open-ended mathematical modeling activity in which they get familiar with some of the design concepts. Unlike design ideas that change for every design problem, design concepts are the same. For these reasons, students were more expert-like (i.e., similar to the educators) in providing feedback on design concepts. However, lack of time, critical thinking ability, domain knowledge, and real world experience prevented them from focusing on the Design Ideas (also referred to as design product) that were specific to this design task. Instead of providing feedback on the design ideas, students focused on the communication aspects of the design, which were more familiar to them and for which they were able to point out strengths and weaknesses. It is also possible that students were trying to understand the design ideas by asking about communication aspects. Finally, since this feedback was a part of a course assignment and the instructions and guidelines were more related the design concepts, students may have thought that to receive a good grade on this assignment, they had to focus on design concepts.

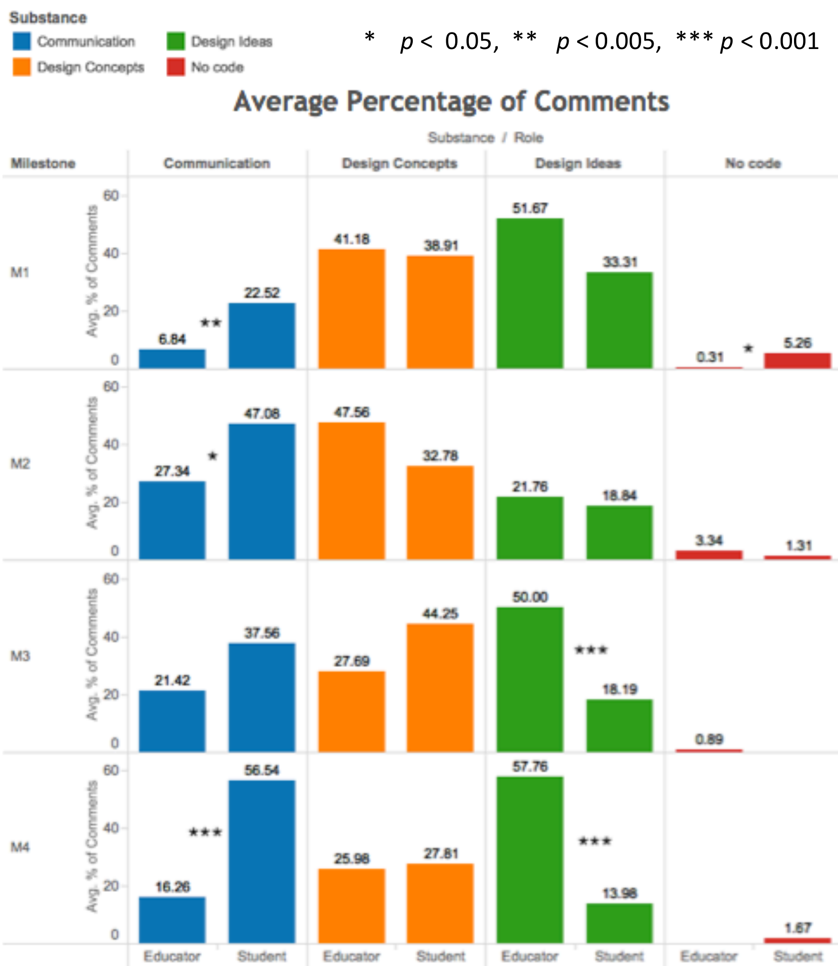

Figure 3: Comments broken down by Substance of feedback. Significantly different categories are marked with * [17].

Phase 3 Development and implementation of professional development

In addition to professional development opportunities for engineering students and educators during these data collection sessions, we have developed workshops and training sessions to help the participants provide constructive feedback on design work. After students were asked to provide feedback on the sample team's design work, they shared their experience with peers and discussed the feedback they provided. This was a professional development opportunity for students as they were able to learn from their peers. Similar to the students, when educators were asked to provide feedback in their weekly meetings, they discussed and shared their feedback with their colleagues. These interactions among the educators helped them be aware of the feedback their colleagues provided on the same design work.

After characterizing the feedback provided by the students and engineering educators (in Phase 1) and identifying the key differences between the two groups (Phase 2), and reviewing the literature on constructive feedback[26-28], we developed professional development materials for our feedback on design workshops. In the development of the workshop materials we focused on the differences between novices and experts and highlighted these differences. This helped the participants learn which aspects of their feedback are similar to experts and which aspects need improvement.

As explained in the previous section, for Substance (or content) domain of feedback, novices provided more feedback on the communication aspects of the design work and experts focused on the design ideas (i.e., design product). The feedback on the Design Concepts (i.e., design process) was similar for both groups. Thus, in the workshops we added more emphasis on the design ideas and discussed with the participants different ways they can provide feedback on design ideas.

For the Focus domain of feedback (i.e., type), novices provided more direct recommendations and positive or negative assessments while experts focused on indirect feedback by asking thought provoking questions, expressing their confusion related to design decisions, or providing brainstorming. To highlight these facts, we provided examples of these different types of feedback and had discussions during the workshop on how and when to provide different types of feedback.

Further, the Focus domain had seven categories. To make it easier for the workshop participants to understand to apply our findings when providing feedback, in our workshop, we divided the Focus of feedback into three major categories: (1) Non-constructive feedback that does not prompt any changes, (2) Constructive-direct feedback that gives specific directions and asks for specific changes, and (3) Constructive-indirect feedback that includes guidance and prompts for change to solve or improve problems without clear directions.

Figure 4 illustrates the overall preparation and plan for the workshops. Before each workshop we identified a sample design task and a student-team solution to this design task based on the participants' expertise. For example for systems engineers, the task was to design a public transportation system for a metropolitan area. We asked a number of experts to provide feedback on this design solution and used this feedback as examples during the workshop. In total the workshop was 90 minutes long. For the first 25 minutes of each workshop, we asked the participants to provide feedback on the same sample student design work. This provided the participants with a chance to practice providing feedback. For the next 50 minutes, we presented information on the Focus and Substance of feedback domains. During this time, we also asked the participants to identify and discuss examples of different types of Substance and Focus feedback in their feedback. We also used examples of different contents and types of feedback related to this design solution. Examples were intended to help the participants understand how they can provide different types and contents of feedback. For the last 15 minutes of the workshop, participants had a chance to ask questions and share their thoughts.

After the workshop, we analyzed the participants' feedback in order to adjust our understanding of different types and contents of feedback on design. The analysis of their feedback adds responses from individuals with a variety of experiences and expertise to our database and helps us to enhance our feedback framework in order to make it more comprehensive. It also helps us adjust our professional development materials as needed.

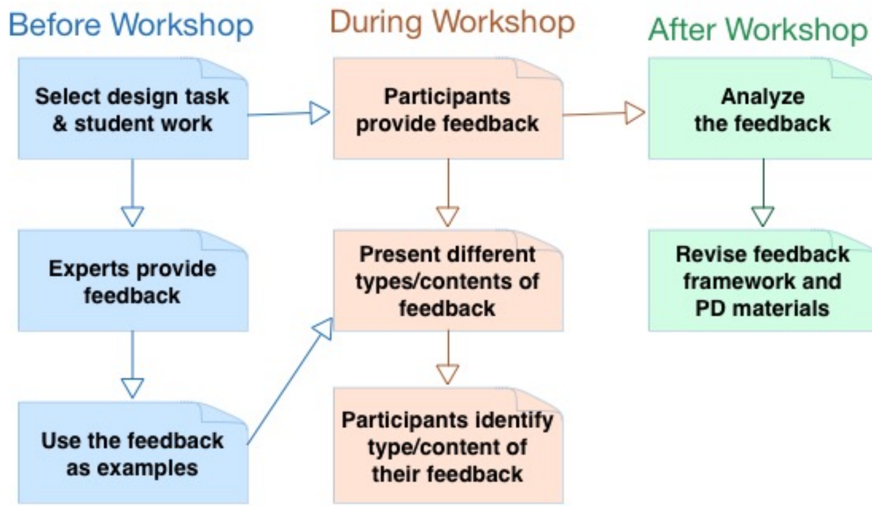

Figure 4 – Overall workshop preparation and plan.

To date, we have had three professional development workshops:

- *First-year engineering (honors sections) teaching assistants:* Prior to the workshop, we collected 30 undergraduate TAs' feedback on a student team project. Feedback was used in the presentation to provide examples of different types of feedback. Thirty undergraduate and five graduate TAs attended the workshop. Twenty-eight TAs filled out the evaluation forms at the end of the workshop. Twenty-seven TAs rated the workshop "good" or "very good". Twenty-three TAs indicated that their knowledge of constructive feedback and/or likelihood to provide constructive feedback improved after attending the workshop.

- *Systems engineers at INCOSE GLRC:* We designed and implemented workshop on feedback for systems engineers. We selected a student design work related to systems engineering for participants to provide feedback on during the workshop. Before the workshop, we asked three engineers to provide feedback on the sample solution and used that in our presentation as for the examples of different types and contents of feedback. Participants were 12 experienced system engineers who attended the regional conference. Although they found the workshop useful, they mentioned that this workshop would be more helpful to early career engineers.

- *First-year engineering peer teachers (undergraduate teaching assistants) training:* About 65 peer teachers were asked to provide feedback on the sample student team design work as a calibration exercise. At the end of each milestone, they were given some samples of educators' feedback on the same design work. After all peer teachers provided feedback on all of the four milestones, their feedback was analyzed to highlight the similarities and differences with educators' feedback. An analysis of educators' and students' feedback was presented to them to make them aware of what aspects of their feedback was similar to educators and what aspects of their feedback was similar to students and needed improvement.

Conclusion

Development and implementation of professional development workshops gave us a chance to use our project results to help engineering students, educators, and practicing engineers provide better feedback on design work. The majority of participants in the workshops had a positive experience during the workshop and found the content helpful in improving their feedback skills.

To develop the professional development workshops, we characterized expert-novice differences in feedback on design. The findings suggest that as we develop approaches for teaching students how to give better peer feedback, we might specifically teach students to critically engage with peers' design ideas, ask more thought provoking questions than giving specific instructions, and provide more details and examples. How students can give more feedback related to Design Ideas while they do not have enough knowledge or experience remains an open question.

The workshops we have developed for providing feedback on design can also be used for other open-ended problem solving contexts. The Focus domain is generalizable to other contexts because it categories how the feedback is being delivered. While the Substance domain is specific for the design context, it also can be used as an example to develop similar domain specific frameworks. For many contexts, similar to design, it is meaningful to provide feedback based on communication, process, and product or solution. This framework enables more effective development of pedagogical approaches for instructing students as well as how to design professional development for educators.

Next Steps

As explained in the plan of work section, we are collecting and analyzing educators' and experts' feedback on design. By incorporating the feedback Focus and Substance characteristics of feedback of engineering educators (from a broad range of expertise) and practicing engineers, we will be able to refine our professional development framework for feedback on design In Phase 4 of this project, we will investigate the impacts of training and expertise in providing feedback on design.

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