Students and Engineering Educators' Feedback on Design

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Abstract

In this paper, we compared first-year engineering students' and engineering educators' written feedback on a sample of student design work. A coding scheme with two domains, Substance and Focus of feedback, was developed to analyze and compare the feedback provided by the two groups. Overall, not only did educators provide more and longer comments, but their Focus of feedback had no overlap with the students. Students' feedback was focused on giving Negative/Positive Assessment on the design work and giving Direct Recommendations for how to improve the work. Educators focused on asking thought provoking questions, indirectly challenging students' design ideas, and providing details or examples so the feedback could be easily understood. Educators' comments were mostly related to design ideas specific to the design problem while students' comments were related to communication issues with the design work.

Introduction

Design is recognized as central to engineering practice[1,2] although design has not always been maintained as central to engineering education[3,4]. In many engineering programs, design is saved for the final year of engineering education, as part of the capstone design experience. Students first begin to develop design skills while they are also integrating their engineering content knowledge and learning to apply it in authentic (or pseudo-authentic) contexts. In some cases, design is also introduced as part of a "cornerstone" experience in the first year of an engineering program. Generally, however, the bulk of the engineering curriculum consists of engineering science courses that rely heavily on theoretical mathematics and closed-ended problem solving.

Many design studies have investigated the difference between novices and experts in practicing design. Novice designers perceive the design task as a well-structured problem[5] and immediately engage in problem solving activity[6]. In contrast, expert designers tend to delay design decisions to understand[7] and frame the problem[8] as well as do research and gather information[9] to generate concepts and design ideas[6]. Thus, novice designers work with only a few ideas and do not spend time and effort to explore alternatives[10]. Expert designers, on the other hand, tend to generate a greater variety of ideas before problem solving[11]. In addition, expert designers use multiple representations to explore these ideas[12]. When evaluating different options, novices do not critically evaluate their design decisions[13], while expert designers conduct experiments and use systematic troubleshooting to find and correct flaws in their solutions[12]. Novice designers may not test their prototypes and use unfocused and inefficient ways to troubleshoot their solutions[12].

One way that helps novice designers improve their work and become more like experts is by providing feedback. Feedback is "information provided by an agent… regarding aspects of one's performance or understanding… Feedback is a 'consequence' of performance."[14]. Similarly, feedback is "information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning"[15]. The purpose of feedback is to narrow the gap between actual and reference level performance. It is believed that the nature of

the information provided by reviewers impacts the actions taken by the reviewee to reduce the gap.

Giving feedback is an important skill for engineering professionals both in industry[16] and academia[17]. In engineering education, this skill is linked to the fulfillment of multiple student outcomes, particularly those related to problem solving, design, communication, and professionalism[18]. Feedback provides a means for thinking deeply about someone else's work, reflecting on one's own work, and receiving and interpreting criticism. Although an ability to provide high quality feedback is an important skill in engineering, it is lacking among engineering professionals[19], professors[20], researchers[17], and students[21]. There is currently research being conducted to address this lack of feedback skills in industry at the professional level[19] and in education at the instructor[22] and student level[23].

For professors and teaching assistants, learning to give good feedback is an important aspect of their job. For students, it is an important aspect of becoming a professional engineer – giving feedback is one of the many things an engineer does as part of their job[16, 17]. Research also suggests that evaluating other students' design work and design processes helps improve the evaluator's understanding of design[24]. So providing feedback to other students helps students develop a better understanding of design and also helps students to develop a professional skill.

Research Purpose and Question

A holistic and generalizable theory to explain levels of engineering design feedback skill development from novice to expert would enable more effective development of pedagogies and assessment tools regarding feedback, benefiting both students and engineering educators. To develop this theory, we build on our prior and current research efforts related to characterizing students' design processes[25] and feedback on open-ended mathematical modeling activities[21] to investigate students and engineering educators feedback on sample design work.

To better understand characteristics of feedback on design, and how to help students become skilled at providing feedback, this paper investigates the following research question: What differences are there in the form and substance of feedback that students and engineering educators provide on design work?

Methods

Participants and Settings

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 during the first half of the semester. During this time, the students develop their feedback skills through in-class activities and homework assignments and then provide feedback on their peers' work. During the second half of the semester, students continue to work in their teams on a design project.

In Fall 2013, approximately 120 students were asked to provide feedback on sample student team's design work on 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. 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 selected for this study.

Instructors and graduate teaching assistants (referred to as educators in this paper) of the same first-year engineering course were invited to participate in this study as part of their weekly instructors' meeting during the Fall 2013 semester. Before the educators began to review their own students' design work, they were asked to give written feedback on the sample student team's design work on the four milestones. Nineteen educators provided feedback on Milestone 1, and 14 on Milestones 2-4.

Design Problem

The sample work that the educators and students reviewed was created by a team of four first-year engineering students during the Spring 2013 semester. The project topic was novel for all of the educators and students completing the feedback forms and the participants in this study were not currently doing this design project. In the Spring 2013 design problem, "aliens" are coming to campus to study! Students were asked to consider how the university might prepare for the extraterrestrials' 9-month visit, to propose a critical need that would need to be addressed for the extraterrestrials to be able to succeed at the university, and then propose a solution to how this need might be addressed. Thus different teams of students focused their projects on a range of different needs. For this study, we selected project work from a team who decided that meeting extraterrestrials' drinking water needs was the most critical need that the university would need to address[26]. One solution that this team considered was re-designing the water fountains to accommodate the extraterrestrials' physical abilities.

Coding Scheme and Analysis

We iteratively developed our coding scheme based on the nature of feedback on the sample student team's design work, the coding scheme developed for conversational feedback on design[27, 28], and our previous analysis of students' and instructors' feedback on design. For more information on the development of the coding scheme see Marbouti, Cardella, and Diefes-Dux[22]. The coding scheme includes two domains: Substance and Focus of feedback. The Substance domain was taken from our previous analysis of students' and instructors' feedback[23,22]. The Focus domain was customized based on Dannels'[28] and Dannels and Martin's[27] coding schemes for conversational feedback. Focus includes seven different subcategories and Substance includes four (Table 1).

Table 1 – Coding scheme description and examples.

Domain	Category	Description	Example
Substance	Communication	Refers to writing or presentation of the design work.	"There are grammatical error[s] throughout the paper."
	Design Concepts	Explicitly refers to one of the design concepts taught in class by using terminology taught in class.	"The goal could [be] more specific."
	Design Ideas	Refers to design ideas specific to this team's project work, using terminology that is specific to the problem this team chose to work on.	"What are the aliens physical limitations specifically?"
	No code	Does not fit in any of the above codes.	"Confusing overall, but this is easy to fix."
Focus	Direct Recommendation	Gives specific advice of what to do.	"Provide a summary of project criteria/constraints."
	Investigation/Brainstorming	Requests specific information or asks thought provoking questions. May suggest new ideas, typically in form of questions.	"What if the water does not meet your PH requirement?"
	Expression of Confusion	Comments on having difficulty understanding the design work, implying something is wrong, does not provide a new idea.	"Still not sure why pH is a concern (water is from central supply)."
	Provide Detail/Example	Explains a previous comment (with the same goal) or provide an example to make sure the students will understand it.	" … For example, the team should be able to estimate the cost associated with each alternative solution."
	Positive Assessment	Explicit positive assessment of the quality of the design.	"The pros & cons table & rational provide clear evidence of how you reduced your ideas to 5. . .good job!"
	Negative Assessment	Explicit negative assessment of the quality of the design or missing information.	"Direct users not identified."
	Short/Un-interpretable Phrases	Typically short phrases (not full sentences) that cannot be interpreted by the coder.	"in-text citation"

Each feedback response was broken-down into smaller discrete comments and coded based on the coding scheme. For both students and instructors, the average number of comments per person per milestone and the average percentage of comments per person were calculated for each coding category. Bar charts were created based on these averages to compare students' and educators' comments across different coding categories. A t-test was performed to identify statistically significant differences between the students' and the educators' average number of comments and average percentage of comments.

Results and Discussion

On average, educators provided significantly more comments than the students (Figure 1). Based on the character count, educators' comments were also longer than the students. The breakdown of comments by Focus and Substance of feedback is shown respectively in Figure 2 and Figure 3.
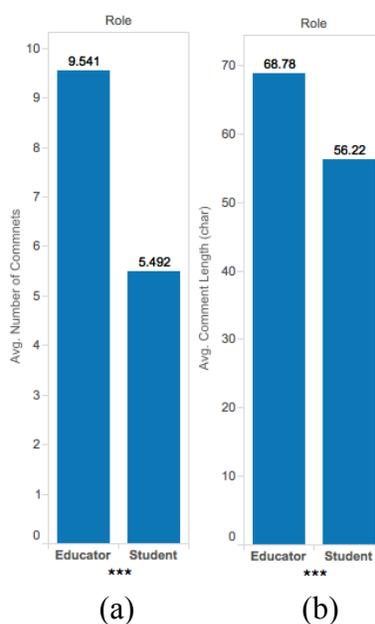

(a)   (b)

Figure 1. Students' and educators' (a) average number of comments and (b) average comment length. Significantly different categories have been marked with *** *p<0.001*.

In the analysis of Focus of feedback, in all categories, the educators on average made more comments than the students (Figure 2). However, the average number of comments made by the educators was significantly higher than the students in only three of the categories. In addition, in almost all categories, the average percentages of comments were significantly different for the students and educators. This suggests that students and educators have different patterns in providing feedback.

Both students and educators made more Negative Assessment comments than any other type of feedback. While the number of students' comments in this category was slightly lower than the educators, the percentage of Negative feedback was significantly higher for the students. This pattern was the same for Positive Assessment and Direct Recommendation comments. In the three other categories, the educators made on average significantly more comments than the students. In summary, educators' comments were more focused on providing feedback coded as
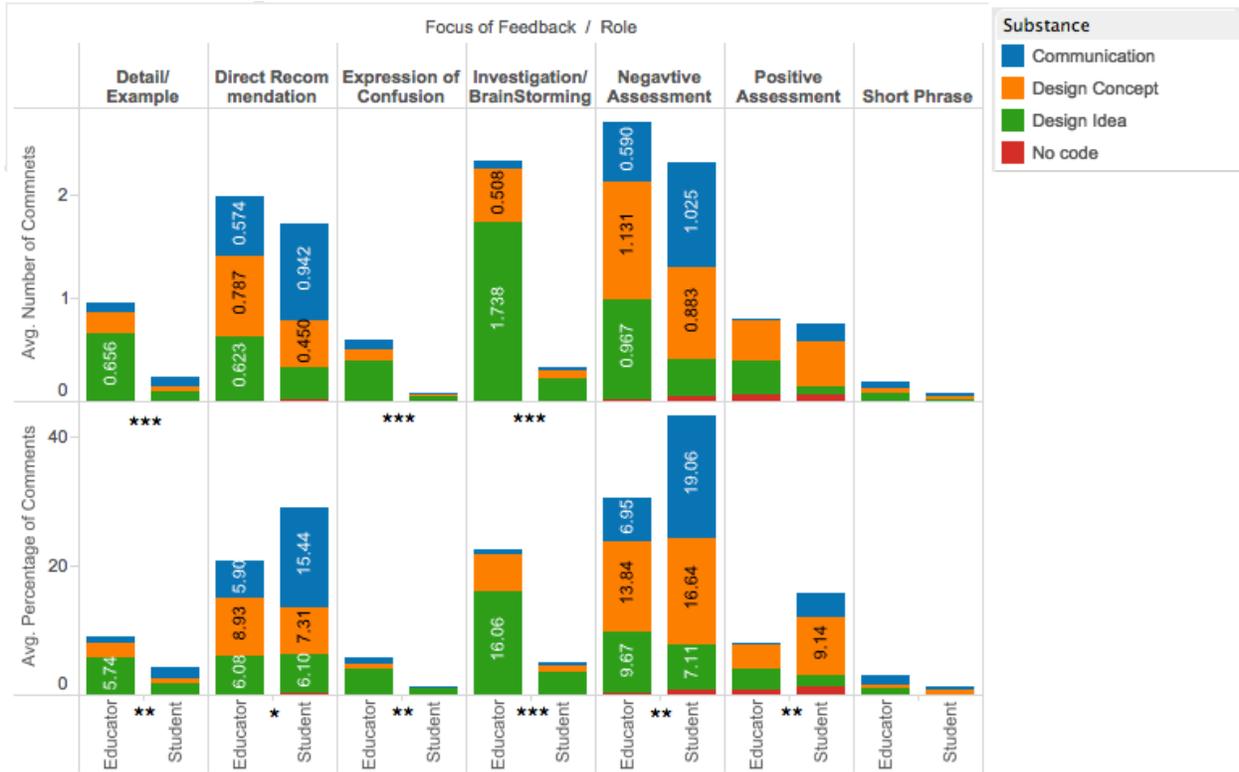
Figure 2. Students' and educators' comments break down by Focus of feedback and color-coded by Substance. Significant differences within category between students and educators have been marked with * *p<0.05, ** p<0.01, *** p<0.001.*
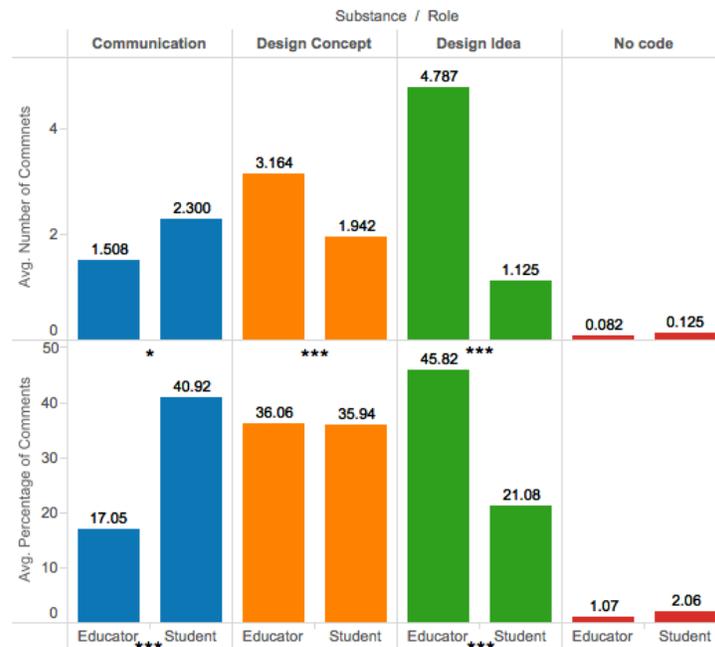

Figure 3. Students' and educators' Substance comments. Significant differences within category between students and educators have been marked with * *p<0.05, *** p<0.001.*

Detail / Examples, Expression of Confusion, and Investigation / Brainstorming, while students' feedback comments were mostly coded as Direct Recommendation, Negative Assessment, and Positive Assessment.

Educators provided more comments on Design Ideas specific to the design problem than the students (Figure 3). In contrast, students made more comments on the Communication aspect of the design. While educators' average number of comments on Design Concept was higher than the students, the two groups average percentage of Design Concept comments was similar.

Conclusion

In this study, we compared engineering students' and educators' written feedback on a sample engineering design work. While it was not surprising that the educators provided more comments than the students, this study provides new insights into the overall profile of a student's review compared to an educator's review. Students and educators' Focus of feedback did not overlap in any of the categories and demonstrated two dramatically different patterns in providing feedback. Educators provided more elaborated comments with examples and descriptions, asked more thought provoking questions, and indirectly challenged the design ideas by expressing confusion about the design choices. In contrast, students tended to state what was correct or incorrect and give specific direct recommendations on how to improve the design.

These findings can help us to further understand patterns we observed in an earlier study of feedback. In another context (i.e., open-ended mathematical modeling activities) students tended to respond differently to peer feedback than instructor feedback[21]. This may be because the nature of feedback students receive from peers and instructors is different. Unlike educators' feedback, peer feedback does not provide many investigation / brainstorming comments that include new ideas to help the design team improve their work. Peer feedback mostly has a negative tone with direct recommendations that may discourage the design team to act on the feedback.

While educators emphasized design ideas specific to the design problem, students had a greater focus on pointing out communication problems in the documents (e.g., grammar, quality of pictures). These differences may be a sign that students are not thinking deeply about the design work they are reviewing. Alternatively, they may not know how to engage deeply, may not understand what an appropriate level of engagement is, do not have design ideas to contribute, or are choosing not to engage deeply[29].

In light of the many differences between the educators' and students' reviews – both in terms of the quantity of comments but also the nature of the content – we might further consider the value of peer reviews. Other research on peer reviews suggest that students expressed liking to see others' work as it gave them insight into their own work[29]. At the same time, one of the goals of the current project is to not only characterize the differences between educators' and students' feedback, but also to develop strategies for helping students be able to give better feedback to their peers. Not only would this skill enable them to contribute to the learning experiences of their classmates, but it would prepare them for their future professional careers where providing feedback is critical to the work of educators as well as engineers. This work points us toward

making students aware of their feedback focus versus that of experts and developing strategies to help students engage more deeply in reviewing design ideas.

Next steps of this project, then, include investigating how providing feedback on sample design work influences the quality of the peer feedback students provide and how it influences their own work. In addition, we plan to analyze feedback on the different milestones separately to understand if students' and educators' feedback patterns change for different phases of a design.

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