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Comparing Instructor and Student Verbal Feedback in Design Reviews of a Capstone Design Course: Differences in Topic and Function*

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Recent implementations of design review meetings in engineering design courses encourage student peers to provide feedback, in addition to the course instructor and industry client. The purpose of this investigation was to compare feedback provided by students and course instructors and to determine how student peers' feedback related to their own performance in the design course. We collected verbal feedback comments provided by the instructor and student peers in twelve design review meetings of a management engineering capstone design course. A total of 553 comments were coded along two dimensions: topic (design, project management, or communication) and function (comprehension, evaluation, or recommendation). Comments falling in the comprehension function were also further coded using an existing question-type typology. A comparison of instructor and student feedback revealed that the instructor provided not only more feedback than individual students, but also distributed it better across the different topics and functions. Specifically, the instructor provides more feedback in the topics of design, communication and project management and is more likely to provide direct assessments and recommendations to student teams. Stronger student teams (i.e., those with better design outcomes) generally provide more feedback to their peers. Findings can help instructors promote better feedback-giving for themselves and students alike.

Keywords: instructor feedback; peer feedback; engineering design; capstone projects

1. Introduction

Feedback must be effective at all levels of student learning: cognitive, motivational, and behavioural [1]. In the context of design education in general and capstone engineering design courses in particular, formative feedback—defined as "*information communicated to the learner that is intended to modify his or her thinking or behaviour for the purpose of improving learning*" [2, p.154]—is regularly provided to students in design review meetings. These meetings often coincide with the completion of major design milestones, and are typically attended by students, the course instructor, the project client, and other stakeholders. Traditionally, in educational settings design reviews have been attended only by the students directly involved in the design under review. Yet, the broader education literature has long advocated for the use of peer feedback, which has been shown to improve students' ability to give and receive criticism [3], as well as increase collaborative learning in the classroom [4]. Multiple studies comparing peer and teacher assessment have unpacked the benefits of peer feedback [5]. Adding peer review to instructor review increases the overall quantity of feedback received by students [6], with the most benefit derived when feedback is provided by multiple peers [7].

There have recently been reported multiple, varied implementations of the use of peer feedback in engineering design courses (both at the capstone level, as well as in junior and intermediate years) at various universities. The trend is in part influenced by a successful tradition of the design critique in architecture programs, where student peers, in addition to course instructors and expert professionals are invited to critique design artifacts [8–10]. Accordingly, many of the reported implementations incorporate peer feedback consciously and in a larger context of explicitly adapted studio model to engineering [11, 12]. The quantity and type of peer review that is made possible in engineering design classes vary depending on the implementation, with reported examples ranging from inter-team assessment of oral presentations [13] to written reviews of design documents [14, 15] and artifacts [16].

An important question emerges on how the communication channel (e.g., oral versus written) affects the content of feedback. Structural and social barriers complicate and degrade the feedback process: students may not provide honest feedback

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during oral question-and-answer periods [17]. Artifacts, too, affect feedback provided by reviewers [18]. Well-developed artifacts can elicit more constructive feedback from reviewers, whereas incomplete or inaccurate designs cause students to receive limited dialogue from reviewers.

1.1 Characterizing feedback

In the engineering educational domain there is recent interest in understanding and characterizing feedback provided by instructors, peers and other reviewers in design review meetings [17–22]. For example, an exploratory multi-disciplinary study proposed a classification based on whether instructor feedback made students take *convergent* or *divergent* paths in their design processes [19]. Feedback suggesting convergent pathways was found to be more prominent than feedback suggesting divergent pathways. Possible explanations include the preference for students to favor convergent feedback over divergent feedback, since the latter promotes exploration, which is more risky and time-consuming.

In another study, written feedback of educators and first-year engineering students was classified using a coding scheme with two domains: **focus** and **substance** of feedback [22]. The focus domain included elements such as *direct recommendation*, *investigation or brainstorming*, *expression of confusion*, *provide detail/example*, and *positive/negative assessment.* The substance of the feedback included elements such as *communication, design concepts*, and *design ideas*. Educators' and students' feedback differed in both focus and substance. Educators focused on *investigation/brainstorming* comments and asked more thought-provoking questions. In contrast, students provided *direct recommendation* comments related to specific instructions on improving the design project. It is thought that educators try to motivate students to explore before choosing a solution whereas students, as novice designers, become fixated on a specific solution and continue to evolve that solution. Students also expressed confusion less often, possibly because they lacked confidence in admitting they did not understand. The study concluded that students need to develop more design thinking expertise in order to gain expertise in providing design feedback.

Questions are an important subset of the conversations that occur in design review meetings; as such, question-asking behaviour of instructors, peer students and other stakeholders in design reviews has been studied extensively [24, 25]. Building on significant prior work on question-asking [25–27], Cardoso, Badke-Scaub, and Eris classify questions into two categories: **low-level** and **high-level** [28]. Low-level questions are information-seeking in nature—the aim is to get missing details to establish a baseline understanding of the design problem and/or progress. High-level questions, which "relate to higher-levels of reasoning" [28, p.62], are further sub-classified into Deep Reasoning Questions (DRQ) and Generative Design Questions (GDQ). DRQs suggest convergent thinking, where the reviewer seeks causal explanation of given facts, while GDQs suggest divergent thinking, where the reviewer attempts to imagine possibilities. The type and timing of questions in the design process can have significant effects on both the design process and outcomes. For example, high-level questions during the idea generation phase can reduce the effect of design fixation [28].

There also exists a wealth of prior work in characterizing and comparing peer and instructor feedback in other (non-engineering) domains. According to some models, feedback is composed of two main components: the *evaluative (or verification)* part, which assesses the quality of the answer, and the *informational* (or *elaboration*) part, which provides direction for progress [2, 29]. The evaluative component can be further broken down as either p*raise* (i.e., encouraging comments) or c*riticism* (i.e., pointing out weaknesses without suggesting an improvement) [30]. S*ummary*-type feedback comments (i.e., restating the main points of a portion or the whole work) usually lack an evaluative component altogether [30]. Feedback that is more informative relates to better performance, and, depending on the student's confidence in their own abilities (or self-efficacy), better motivation [29, 31].

Another way to categorize feedback is according to its *specificity* [2]. In the domain of learning a second language, for example, a distinction is made between corrective feedback that is *direct* (i.e., telling students exactly where the problem is and how to fix it) versus *indirect* (i.e., point out that there is an error without correcting it) [32]. Similarly, in the domain of English writing, feedback is classified as *directive* (i.e., specific suggestions for improvement) or *non-directive* (i.e., non-specific suggestions for improvement that could apply to any paper) [30]. While direct corrective feedback can be an appealing alternative when time is limited, indirect feedback can be better 'customized' to specific students' learning styles and improves student learning by allowing them to self-correct [33]. Typically, non-directive feedback results in more complex repairs to students work, whereas directive feedback results in mostly surface improvements [6].

Finally, feedback can be categorized according to its length/complexity. Studies have found that the length of feedback and the number of comments is larger for experts than for student peers, with experts providing more directive and non-directive feedback than student peers [30]. While longer feedback can be more informative, more complex feedback can be more difficult to understand by the novice; nevertheless, it is not clear whether the effect of complex feedback is entirely negative [2].

1.2 Purpose of study

The reviewed literature summarizes prior work on categorizing and understanding feedback from instructors, (expert) designers, clients, and student peers in both written and verbal forms. Building on this, we seek to answer the following research questions:

1. How can the formative feedback provided by students (novices) and instructors (experts) during design review meetings be characterized?
2. What are the differences between the feedback provided by students (novices) and instructors (experts)?
3. How does formative feedback provided by students correlate with their own design outcomes?

To answer these questions, we collected actual feedback provided by students and the course instructor in an engineering capstone design course and categorized it according to a two-dimensional and multi-level scheme. In the following sections, we describe the data collection and text coding process and present the results of our analysis. We conclude with a discussion of major findings and implications for practice and future research.

2. Method

2.1 Data collection

The study was conducted in a management engineering capstone design course at a large engineering school in Canada. By the end of the 13-week course, students were expected to research and gather information on the design problem, identify the design requirements and specifications, produce at least three conceptual designs, and finally propose and describe a low-fidelity prototype of a chosen design for implementation. The class of fifty-five students self-enrolled in fourteen project teams, with all but one team having four members. Each team participated in three bi-weekly design review meetings, the third one of which was chosen for analysis. The meetings were formatted as 80-minute sessions, each attended by two teams and the instructor. Teams took turns presenting their progress (for 20 minutes), followed by a discussion period in which each team was questioned by and received feedback from both the instructor and the other team in attendance (for another 20 minutes). Two prior studies provide a more detailed description of the format and some preliminary findings on students' perception of the experience [34, 35]. While the reviews of all fourteen projects were video recorded, due to technical issues, only twelve of the recordings were of sufficiently good quality for transcribing and further analysis.

Excerpts of interest for analysis were statements uttered by instructors and peers that concerned the design project under review. Of those, we excluded any statements not directly related to the project, including comments related to meeting management and housekeeping (e.g., "*Should we get started?*"), agreement (e.g., "*Okay, I see*"), and directions (e.g., "*Can you go back to that slide?*"). The coding was made at the 'group' level; in other words, we did not distinguish between the individual team members conducting another team's project review.

2.2 Coding scheme

All feedback statements were categorized along two primary dimensions—**topic** and **function,** as summarized in Table 1. An earlier version of this characterization scheme is also presented in [36].

2.2.1 Dimension 1: topic of feedback

We took a grounded theory methodological approach [37] to identify the various **topics** of the conversations in the design review meetings. All feedback statements were found to belong to one or more of the following three topics:

- *Design*, including problem identification, problem formulation, concept generation, preliminary and detailed design, verification and validation, and design impact (e.g., "*What are the different [design] concepts that you considered?*")
- *Project management*, including scheduling, deliverables, and stakeholder management (e.g., "*Have you been meeting with your [faculty] advisor?*")

Table 1. Proposed typology of feedback statements

Dimension	Category	Sub-Category
Topic	Design Project Management Communication	
Function	Comprehension	Low-level questions Deep reasoning questions Generative design questions
	Evaluation Recommendation	

- *Project communication*, including oral and visual communication of the project progress and artifacts (e.g., "*You have some work to do on your presentation – just for people to understand your design concept*.")

This categorization is similar to the one provided by a similar study, in which an analogous category ("substance") comprised four sub-categories: communication, design concepts, design ideas, and "no code" [22].

2.2.2 Dimension 2: function of feedback

In its other dimension, feedback is seen as accomplishing one (or more) of three **functions**: (1) accurately pin-point the actual state of the project (labelled *comprehension)*, (2) compare that actual state to the expected/desired state (labelled *evaluation)*, and (3) provide suggestions to achieve this (labelled *recommendation)*. A more detailed justification for this breakdown is provided in [36].

In statements that are coded as performing a *comprehension* function the reviewer seeks to clarify details and to expand their understanding beyond what is already presented. Within this category, questions are further categorized according to their ***type****—low-level, deep reasoning,* and *generative design questions* (and respective sub-categories) — a taxonomy that is based on prior work on question-asking in design review meetings [23]. A list of question types, illustrated with examples, is provided in Table 2.

Statements directed at the group under review that are *evaluative* in nature generally provide a judgment about what is presented. Each evaluative statement is also assigned a "value" code, ranging from 1 to 5: very negative (1), negative (2), neutral (3), positive (4), and very positive (5). Judgment is closely related to an expected target; in other words, whether the judgment is very negative (e.g., "*As far as the presentation goes, there wasn't really any progress to be seen*"), neutral (e.g., "*That's a really important aspect of your design*"), or very positive (e.g., "*These [concepts] are very good*"), is an assessment of the distance between the current state of the design (or its communication or management) and the state it is believed it should be in by the reviewer. Note that both states are subject to the reviewer's perception. First, the perceived current status of the design is based on the reviewer's understanding of the presented information; questions are necessary to ascertain that the current state has been accurately pinpointed. Second, the expected state of the design is also subject to the reviewer's perception of the type and difficulty of the design project, the team's skill, the elapsed time in the project, as well as the reviewer's own design experience.

The expressed evaluation can take both explicit and implicit forms. When implicit, the evaluation can usually be extracted from the content of the recommendation component of the feedback (see below). In other words, the content of the recommendation provided also packs an implicit evaluation of what has been presented.

Finally, statements that are *recommending* in nature provide further elaboration/information about what the team can do to achieve a desired state. When the evaluation is negative (i.e., the current state is perceived to be lower than the expected state), the recommendation will provide steps for achieving an expected target performance (e.g., "*Just [analyze data] from one hospital at this point*"). When the evaluation is positive, the recommendation will either 'raise the bar' by setting a new performance target for the team (e.g., "*I know it's not in your scope, but it would be cool to give the client a report that will help them with forecasting*"), or simply give the team an opportunity to re-scope the project so that additional effort (above expectation) is not needed in future milestones (e.g., "*It's a great project idea, but you have to focus on what you actually want to do*").

In some excerpts multiple content and topic types overlapped. For example, the excerpt "*You have to show what is interfacing with what, and where it is happening*", touches on both topics of design and communication. This overlap explains why the number of feedback statements does not always coincide with the number of codes assigned those statements, as the reader may observe throughout the Results section.

2.3 Reliability

Once a general coding framework was agreed upon, all utterances were first coded by the first author. The second author coded "test" samples (approximately 20% of the total number of excerpts each time). After each iteration, and based on discussions between the two authors, the first author re-coded the entire set of transcripts, until inter-rater agreement of more than 70% was achieved on a new test sample.

3. Results

A total of 553 'codable' feedback statements were identified. Of those, 298 originated from students (peers) and 255 from the instructor, as shown in Fig. 1. Each team received 20 to 69 (M = 46) questions or comments from peers and the instructor. Of those, 18% to 74% (M = 53%) originated with peers.

Table 2. Categorization of comprehending feedback (i.e., questions), according to type

Type	Description (Example)
Low-level questions	
Verification	Is X true? (*Do they have TVs in the depots?*)
Definition	What does X mean? (*What do you mean [by] best performance?*)
Example	What is an example of X? (*What would be three top use cases you can envision right now?*)
Feature specification	What (qualitative) attributes does X have? (*What kinds are they?*)
Concept completion	Who? What? When? Where? (*What is the deliverable for preliminary design? Where is the processing happening?*)
Quantification	How much? How many? (*How many interact with your web app?*)
Disjunctive	Is X or Y the case? (*Is it mobile or web from here?*)
Comparison	How does X compare to Y? (*Tell me the difference between the data that comes from supply chain and the data that comes from sales*)
Judgmental	What is your opinion on X? (*Do you think [in general] each hospital will use it and will use it for its own data?*)
Deep reasoning questions (DRQs)	
Interpretation	How is a particular event or pattern of information interpreted or summarized? (*What do you think the need is based on where they're going?*)
Goal Orientation	What are the motives behind an agent's action? (*As far as the client, do you know what their main goal is?*)
Causal Antecedent	What caused X to occur? (*What keeps the costs up?*)
Causal Consequent	What were the consequences of X occurring? (*How did the new system affect their operations?*)
Expectational	Why is X not true? (*Why does it not store historical data?*)
Instrumental/Procedural	How does an agent accomplish a goal? (*How did you decide that these are the 3 tabs?*)
Enablement	What object or resource enables an agent to perform an action? (*Are there specific people that transport components? Is there a forklift driver and that's his job?*)
Generative design questions (GDQs)	
Proposal/Negotiation	Could a new concept be suggested/negotiated? (*Do you think they'll want to see some analytics?*)
Scenario Creation	What would happen if X occurred? (*How do you think having 10 hospitals would affect the models?*)
Ideation	Generation of ideas without a deliberate end goal (*How safe am I?*)
Method Generation	How could an agent accomplish a goal? (*How would you measure that?*)
Enablement	What object or resource could enable an agent to perform an action? (*What system are you going to use to create the UI?*)

Further breaking down the number of comments originating from the instructor and each *individual* student, it is found that, on average, in each design review meeting the instructor provides a significantly larger number of questions/comments compared to the individual student [$M_{Instructor} = 21.25$, $SD_{Instructor} = 7.99$, $M_{Student} = 6.26$, $SD_{Student} = 2.66$; $t(11) = 6.39$, $p < 0.01$].

3.1 Relationship between feedback topic and function

There are strong correlations between the topics and functions of feedback, as summarized in Table 3. (When taken separately, peer and instructor feedback follow very similar patterns.) The emerging picture suggests that while comprehension feedback (i.e., questions) are more likely to be on the topic of design, evaluations and recommendations are more likely to be on the topic of communication. No strong correlations emerge between the topic of project management and the various functions.

3.2 Topic of feedback

Figure 2 summarizes the results of the analysis on the topic of feedback. For both the instructor and

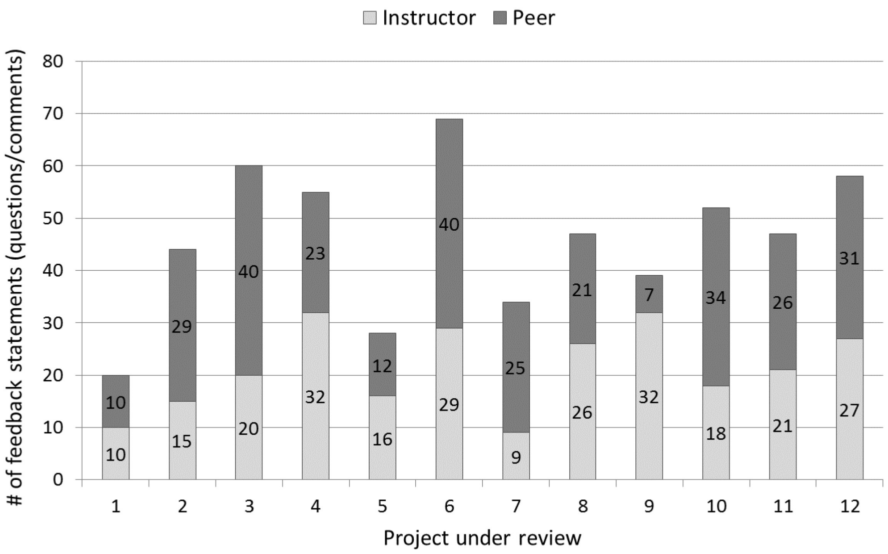

Fig. 1. Number of feedback statements directed at each project (1–12) by the instructor and paired student teams.

Table 3. Pearson's correlation (*r*) between the function and topic of feedback (df = 552)

		Topic	
	Design	**Communication**	**Project Management**
Function			
Comprehension	0.26*	–0.33*	–0.04
Evaluation	–0.23*	0.32*	0.06
Recommendation	–0.10*	0.15*	–0.03

* Statistically significant at 0.05 level.

student peers, the majority of comments/questions are on the topic of design. This is especially so in the case of feedback originating from peers, where 93% of feedback statements are on the topic of design. Compared to the instructor, peers provide less feedback on the topic of communication and project management. In particular, it is the instructor who provides 32 out of all 39 comments in the topic of project management. The instructor's feedback in this topic spans all functions; for example, to ask questions about the schedule (e.g., "*Is there any contingency?*"), assess the team's progress (e.g., "*There wasn't really any progress to be seen*", and make recommendations for project scope adjustment (e.g., "*I'd much rather you [reprioritize] your work according to the time left, rather than trying continuing to align yourselves with the initial needs statement*").

We believe that compared to student peers, the instructor places a greater emphasis on management and communication aspects of the design project for two main reasons. First, the instructor is more mindful of the limited time and resources available to the teams as well as the number of

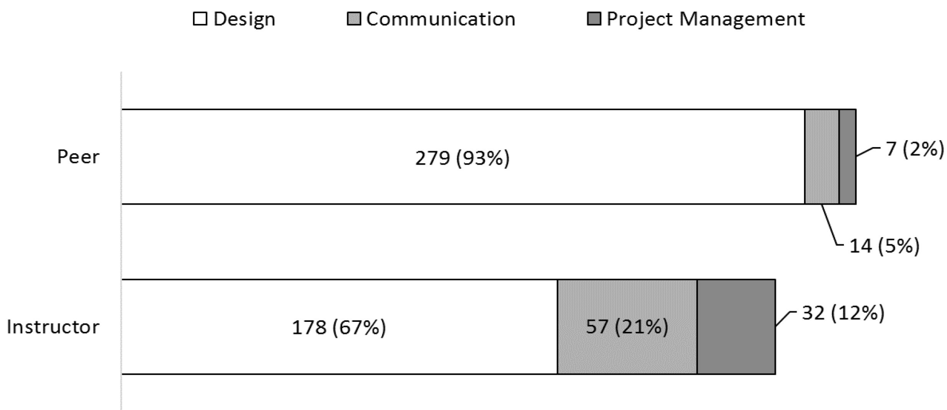

Fig. 2. Distribution of instructor and peer feedback statements according to topic.

future critical course milestones that heavily rely on the team's ability to communicate their project to a wider audience. Second, project management and communication are intended learning outcomes of the capstone design course and thus need to be regularly assessed by the instructor, both formatively and summatively. In fact, of the instructor's 32 feedback statements that were coded as belonging in the "project management" topic, 13 were coded as performing an evaluative function. In many cases the instructor expresses concern about the project's progress or the ability of the team to deliver according to schedule (e.g., ". . .*I'm more worried about your schedule in terms of what [ ] you hope to achieve by the end of this term*"). Similarly, of the instructor's 57 feedback statements in the topic of communication, 31 were coded as evaluative. Often, the instructor makes an assessment on the effectiveness of the presentation, identifying aspects that need improvement (e.g., "*With regards to the presentation, your slides are a bit text heavy*").

3.3 Function of feedback

Figure 3 summarizes the results of the analysis on the function of feedback. While a similar portion of both the instructor's and peers' feedback perform a recommending function, there is a significant imbalance between the two groups in the amount of both comprehension and evaluation feedback.

First, compared to the instructor's, a larger portion of the peers' feedback falls in the comprehension category (67% vs. 48%). Second, 33% of the function codes assigned to the instructor's feedback are evaluative, compared to just 16% of peers' feedback. Likely the main reason why students are hesitant to provide evaluative feedback is out of concern of inadvertently affecting their peers' grade in the course, especially since they would be providing their evaluations in the presence of the instructor. Another possible reason could be their self-perceived lack of authority in evaluating others' projects. In fact, the difference between peers and the instructor is apparent not only in the number of evaluation statements, but also in their content: peer's evaluative feedback is more positive than the instructor's feedback [$M_{Instructor} = 2.50$, $SD_{Instructor} = 1.06$, $M_{Peers} = 3.08$, $SD_{Peers} = 1.19$; $t(142) = 2.88$, $p < 0.01$].

The difference in the number of evaluative feedback statements can also be attributed to the differences in feedback topic, as noted earlier. The instructor provides more feedback in the topic of communication and project management—feedback falling in this topic often performs an evaluative function. Finally, one can speculate that without having read their peers' prior deliverables and having to completely rely on the presentation given in the design review meeting, students need to dedicate a larger portion of their feedback to questioning, leaving little room for evaluative feedback.

3.3.1 Type of questions

We further analyzed comprehension feedback and broke down the questions asked by peers and the instructor by type: low-level, deep reasoning, and generative, as summarized in Fig. 4. While both groups dedicate a similar portion to deep reasoning questions (12% and 10% of peer and instructor feedback, respectively), there is a larger difference between the two in the other categories. In particular, compared to the instructor, a larger portion of the peers' questions fall in the generative category (23% vs. 16%). In contrast, compared to the peers, a larger portion of the instructor's questions are in the low-level category (74% vs. 65%).

Within the low-level questions category, the biggest differences between the instructor and the students are observed in the portion of questions that are of the concept completion type (e.g., "*Who is the typical user?", "What are the inputs?", "What are the next steps?")*. One possible explanation for why the instructor places a greater emphasis on low-level questions in general and concept completion questions in particular is that they need to grasp the student team's design project progress very well in order to properly assess it. On the other hand,

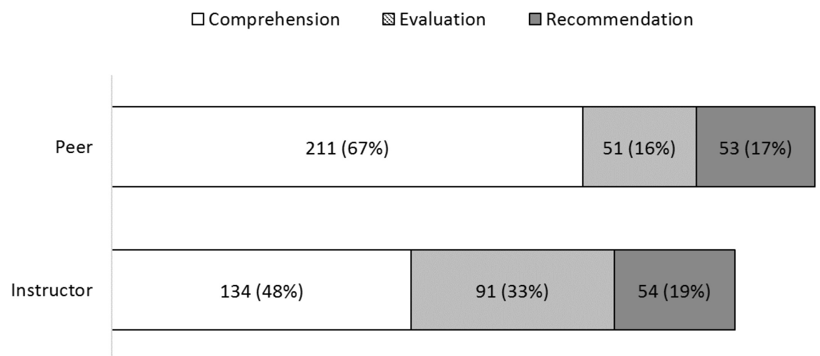

Fig. 3. Distribution of instructor and peer feedback according to function.

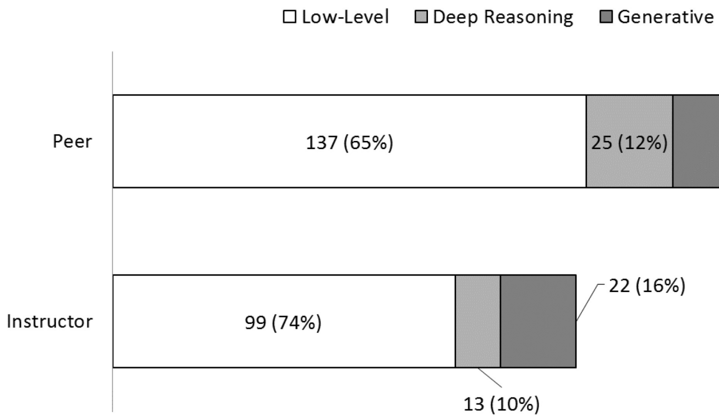

Fig. 4. Distribution of instructor and peer feedback in the comprehension function according to type.

students—who are not tasked with evaluating their peers—can instead focus more of their questions on future steps by using generative design questions, which made up 23% of all their questions). For students, generative design questions also play the role of recommendations; particular future steps are suggested, but when stated in the form of questions they do not carry the same weight (and attached accountability on the part of the team on the receiving end) as the instructor's recommendations. The fact that students ask relatively fewer low-level questions may also be indicative of their developing skills in giving effective feedback.

3.4 Feedback and design outcomes

Feedback provided by peers and the instructor—along the topic, form, and type dimensions—was compared to student design outcomes. The measure that was used to approximate design outcomes was the average grade of all design deliverables throughout the two-course design project sequence. Although we found a number of notable correlations, due to the small sample size, few were statistically significant.

One notable and significant relationship was found between students' design outcomes and the amount of feedback they directed to their peers: The number of questions and comments that students directed at a project (i.e., total feedback) was positively correlated with their own design outcomes, $r(10) = 0.52$, $p < 0.05$. In other words, stronger teams provided more feedback and weaker teams provided less feedback.

4. Discussion

A major outcome of this study was the successful application of a novel feedback classification scheme on a large corpus of feedback sourced from design review meetings of a capstone design course. The analysis of authentic feedback provided to capstone design teams by both their student peers and the course instructor revealed important differences between instructor and student peer feedback.

4.1 Major findings

The overall analysis of instructor and peer feedback demonstrated that the instructor provides more feedback (over three times as many comments/ questions) than the average student, a result that is in line with prior findings. For example, in their analysis of written feedback on the same sample student work, Cardella, Diefes-Dux and Marbouti found that the instructors provided more feedback (both in number and in length) than students [22]. Similarly, in their analysis of design review meetings, Cardoso, Eris, Badke-Schaub, and Aurisicchio found that instructors and clients asked more questions (per unit of time) than student peers [23].

In our study, we also found that the better the design outcomes of a team, the more feedback they provided to their peers. Taken together, the two findings—that the instructor and stronger teams provide more feedback—suggest that *the ability and confidence to critique a design is increased with design experience and expertise*.

An interesting finding that emerged from the correlation analysis of feedback along the topic and function dimensions is that feedback in the topic of *design* is significantly more likely to have the function of *comprehension*. In other words, *questions* directed at a student team, from both the instructor and peers, are more likely to concern (technical) details of the design. In contrast, *evaluative* and *recommending* feedback is more likely to concern the communication (i.e., presentation) of the design. No significant relationships were found between feedback in the topic of project management and the various functions, indicating that comments on that topic are a balanced mix of questions, assessments, and suggestions.

These correlations are also important in explaining the differences in feedback between instructors and peers. We found that the instructor provides more evaluative and recommending feedback than the peers. In addition, as also predicted by prior work [22, 30] the students' evaluative feedback was more positive than the instructors. Part of the reason for the difference is that, being more aware than students of the importance of effective communication of the design project and being obliged to evaluate all components of the design, including communication and project management, the instructor places greater emphasis on assessing all aspects of the project and providing suggestions for improvement.

On the other hand, students focus more on asking questions (comprehension feedback) to their peers; in their case "recommendations" are made in the form of generative design questions. It appears that proposing changes or new directions for the design project in the form of a question is easier for students than giving outright recommendations.

Our finding that students ask more questions than the instructor (in proportion to other types of feedback) may seem to contradict earlier findings [22] in which students expressed confusion less often than instructors, possibly because they lacked confidence in admitting they did not understand. The inconsistency can be attributed to the significantly different settings in which the two studies were run. In our case, feedback is provided in an informal, conversation-based design review, in which students—all in their senior year—know each other fairly well. Students expect their questions to be answered during the meeting. In [22], feedback is written and reviewers—first-year students- do not know the author of the sample work. As such, it makes sense that in that setting, students would provide fewer questions than instructors in their feedback.

The literature suggests that expert designers spend more time in the information gathering and problem definition phases compared to novices [38, 39]. It would seem that our results here—that a higher portion of the students' feedback (compared to the instructor) was spent on asking questions (comprehension)—would contradict this. This is not the case, however: in absolute terms, the instructor provided more feedback (including in the function of comprehension) than the average student. In addition, the instructor has more opportunities to ask comprehension questions in prior design review meetings, where as, for students, the design review meeting under study was their first opportunity to learn about and provide feedback to their peers' projects. Moreover, a good portion of the student's questions are of the generative type; rather than to help the students converge on important problem details, their aim is to expand the solution space, implicitly serving the function of (weak) recommendations.

4.2 Limitations of the study and future research

It has been previously hypothesized that structural and social barriers complicate and degrade the feedback process [17]. In the case of the mixed-review format described in this paper, the instructor is not only reacting to the presented material but also to the feedback provided by the students in the meeting. Thus, it is plausible that the instructor's feedback in this context may differ—in quantity, content and type—from the feedback they would have provided if the meeting was in the instructor-only format. The same could be said for the students' feedback. The feedback provided by the instructor, and more importantly- the presence, itself, of the instructor in the design review—likely affects the feedback that students provide to their peers. A more rigorous comparison of feedback between instructors and peers would occur in a setting where design reviews are only attended by either student peer reviewers or the instructor. Nevertheless, the characterization of student and instructor feedback in design reviews, as described in this paper, is valuable. In teaching practice, design reviews would rarely occur without the presence of or other involvement from the instructor; student peers' feedback is always, to some extent, conditioned by the physical presence of the instructor and/or their perceptions of the instructor's expectations.

Another gap in our current understanding of instructor and peer feedback is its value, both objectively and subjectively (as perceived by the students). In a prior related study [35], we found that students perceive the instructor's view as slightly more helpful than that of peer students, but that overall preferred the mixed-review format to instructor-only feedback. While in this study we found that stronger teams provided more feedback, we cannot be sure that stronger teams also provided *better* feedback. In particular, we do not know if students assign more value to certain feedback topics or functions over others. Future studies will need to characterize feedback and describe the sensitivity of "value" according to a number of factors, including the feedback's source and timing in the design process. A better understanding of what makes for good questions/comments in a design review meeting would help instructors improve the efficiency and effectiveness of these meetings and better train students in asking good questions and providing good feedback in their future careers as engineering professionals.

Finally, a general limitation of our study is its small sample size—one instructor and fifty-five students, which reduces the findings' generalizability. Nevertheless, even though the feedback generated in a small and specific context, the amount of feedback that was collected and analyzed was quite large. Moreover, the results of the comparison of instructor and student feedback generally support and complement prior work in this area.

5. Conclusions

We have described a systematic characterization and comparison of student and instructor verbal feedback in design review meetings of an engineering capstone design course.

A two-dimensional classification scheme captured both the topic of the feedback statements (design, communication, and project management) and the function being performed by the feedback (to comprehend, evaluate, or recommend). The findings provided insight into what the instructor and peers choose to communicate to student design teams, as well as how they choose to communicate it. This augmented understanding of how peer and instructor feedback differ can help instructors promote better feedback-giving not only in students but also in themselves, by encouraging balanced feedback that addresses all components of the design project and performs a variety of functions.

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