AC 2009-1635: INSIGHTS INTO THE PROCESS OF PROVIDING FEEDBACK TO STUDENTS ON OPEN-ENDED PROBLEMS

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Insights into the Process of Providing Feedback to Students on Open-Ended Problems

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Abstract

One of the challenges of implementing open-ended problems is assessing students’ responses, as the open-ended nature of the problems allow for multiple appropriate, “good” responses. In particular, formative assessment—giving the students feedback on intermediate solutions—can be particularly challenging when it is hoped that students will understand and respond to the feedback in ways that indicate learning has taken place. This study is part of a larger project that focuses on the feedback that the students are given as they iterate through multiple drafts of their solutions to Model-Eliciting Activities (MEAs). In this paper, we report on findings related to Graduate Teaching Assistants’ experiences in providing their students with feedback. Two cases are presented: the experiences of a Teaching Assistant who is new to MEAs, and therefore new to the process of giving feedback on MEA solutions, and the experiences of a more experienced Teaching Assistant.

I. Introduction

Engineering educators nationwide as well as globally recognize the need for students to develop teaming and communication skills, proficiency in engineering science and design, as well as an ability to address open-ended problems replete with ambiguity and uncertainty. One instructional approach to developing these competencies is the use of open-ended, realistic, client-drive problems called Model-Eliciting Activities. This approach has been used with first year engineering students, as well as upper-level engineering students. One of the challenges in adopting this approach, however, is assessing students’ responses to the Model-Eliciting Activities, as the open-ended nature of the problems allow for multiple appropriate, “good” responses. In particular, formative assessment—giving the students feedback on intermediate solutions—can be particularly challenging as it is hoped that students will use this feedback to gain new insights into the problem they are solving and produce a higher quality solution in the next iteration.

Model-Eliciting Activities (MEAs)

Model-Eliciting Activities (MEAs) are client-driven, open-ended problems that are constructed using six principles for designing MEAs that have been modified for engineering contexts. The intention is to construct realistic engineering problems that (1) require student teams to develop mathematical models for clients and (2) provide a natural window on students’ thinking about the mathematics in the problem context. That is, the problems are “model-eliciting” and “thought-revealing”. Students’ solutions to these problems are generalizable mathematical models – meaning the models are shareable, modifiable, and reusable tools. To develop a generalizable mathematical model for a client, students must draw on and make new sense of
their existing knowledge (e.g. mathematical, scientific, practical ...). The point is for student teams to be involved in the creation and refinement of models.

**MEAs and Feedback**

An MEA implementation strategy that includes opportunities for students to revise their mathematical models has demonstrated that students can produce high quality solutions but that they need multiple attempts to achieve sufficient quality. While there may be a myriad of factors inducing students to put forth the effort necessary to improve their solutions, it is clear that they use feedback to transform their understanding of the solution process. Despite the clear influence that feedback has on a student’s ability to succeed, little is known about which elements of feedback cause students to improve their solutions. What is known is that more detailed feedback is more beneficial; however, the attributes of increased detail that cause such improvement are rarely discussed. Fuchs et al. found that good assessment rubrics were not enough to cause an improvement and that instructors need mechanisms for providing formative feedback.

Feedback can be provided to students through many formats, including electronic. In fact, electronic formative feedback can be returned more quickly while still being used to synthesize fair, relevant, and balanced feedback. However, the quality of the feedback provided is a key feature in any procedure for formative feedback. Some important qualities of successful instructor feedback are: easy to access, robust, unbiased, unambiguous, encouraging, timely, and iterative. However, the science education community is still beginning to understand the integral role of formative assessment in scientific inquiry teaching. If the quality of feedback is important, then investigating the qualities that make good feedback is important, as is investigating methods for teaching instructors to give good feedback.

Razmov & Vlasseva have studied the process of feedback on open-ended essays in software engineering classes where the instructors provided guiding questions about assumptions and alternatives. This open-ended approach allowed students to consider multiple correct solutions, which presented challenges to instructors. To allow for multiple solutions, instructors have to balance guiding open-ended feedback with specific feedback. They found that the most challenging aspect of giving feedback was to find a middle ground between the desire to guide students to certain solutions and allowing the students to own the solution. The ability to give balanced feedback also might be influenced by the experience of the instructor. In this paper, we further explore this theme.

One aspect in which a study of the feedback for MEAs can contribute extensively is tied to the very nature of MEAs. As Davis discovered, formative feedback is most effective when the instructor recognizes that there may be multiple approaches and understandings and that forcing students towards a solitary solution path may not be beneficial. Due to the open-ended nature of MEAs, students and TAs are encouraged to be creative and unique in their methods for solving problems.

This study is part of a larger research effort to develop pedagogical approaches around feedback on open-ended problem solving that (1) improve instructor and peer feedback and (2) help
students learn to interpret and respond to feedback. In this paper, we begin to investigate the experiences of Graduate Teaching Assistants who provide feedback on MEA solutions in a first-year engineering course. Specifically, we address the question of:

*how do new (inexperienced) Graduate Teaching Assistants’ experiences in providing feedback differ from the experiences of Teaching Assistants who have had more experience in providing feedback on MEAs?*

II. Method

A. Setting

In Fall 2008, three MEAs, *Paper Plane Challenge, Just-In-Time Manufacturing, and Student Travel Modes*, were implemented in a required first-year engineering problem solving and computer tools course with an enrollment of approximately 1200 students. A brief description of each of these MEAs is provided by Zawojewski, Diefes-Dux, and Bowman. In preparation for these activities, the Graduate Teaching Assistants were provided with extensive professional development. Prior to the start of the semester, the 20 Teaching Assistants employed for Fall 2008 were provided with eight hours of MEA training that included introductory topics such as open-ended problems, understanding first-year students and their reactions to open-ended problems, and classroom implementation of MEAs. Each of these topics is described in more detail by Diefes-Dux, Osburn, Capobianco, and Wood. Particular emphasis was placed on assessing and providing feedback along three dimensions:

- **Mathematical Model**: Does the mathematical model adequately address the complexity of the problem?
- **Re-usability & Modifiability**: Can the client use the model on similar types of data and can the client modify the model for use in similar but different situations?
- **Audience (Share-ability)**: Can the client reproduce the results using the test case data provided in the MEA?

In training, Teaching Assistants were guided through the assessment of select pieces of prototypical student team work on the first MEA to be implemented, the *Paper Plane Challenge*. Following this training, each Teaching Assistant independently practiced assessing student work by applying the MEA Feedback and Assessment Rubric (see Appendix A) and providing written feedback on five additional pieces of prototypical student work (for an example, see ). The Teaching Assistants also used an Instructors’ MEA Assessment/Evaluation Package (IMAP) specific to the *Paper Plane Challenge* MEA that they were assessing while they were applying the rubric. The IMAP provided details about what constitutes high quality work within each dimension of the rubric. A course instructor reviewed the Teaching Assistants’ feedback and assessments, summarized common problems experienced by all Teaching Assistants, and provided individual guidance to each Teaching Assistant.

Teaching Assistants (in teams of 4 and supported by undergraduate assistants) co-facilitated the laboratory implementation of the MEA in which 30 student teams of 3-4 students developed the first draft of their MEA solution. Following class, each Teaching Assistant individually provided feedback and assessment on the work of 14-15 student teams. Student teams use the Teaching Assistant feedback to revise their solutions. Student teams revise their solutions a second time based on feedback received through a double-blind peer review. The Teaching Assistants...
provide feedback and assessment on this final team solution. Feedback provided at this stage is intended to help students perform better on the next MEA. The entire MEA implementation is supported by a web-based interface connected to a database system; this system manages iterations of student work, Teaching Assistant training as well as feedback and assessment to students, and the peer review process.

Prior to the start of second and third MEAs implemented in Fall 2008, the Teaching Assistants received one hour of professional development focused on assessing and providing feedback on student work associated with these particular MEAs. Again, the Teaching Assistants practiced assessing student work by applying the quantitative rubric and providing written feedback on five additional pieces of prototypical student work. Again, their work was reviewed by a course instructor and they were given guidance on how to improve. Each Teaching Assistant assessed and provided feedback on the first draft and final student team solutions for each MEA.

B. Data Collection

Interviews were conducted with 14 Teaching Assistants at two points during the semester: near the beginning of the semester, just after the Teaching Assistants have provided feedback to students on their first draft solution to the Paper Plane Challenge MEA, and near the end of the semester, just after giving students feedback on their first draft solutions to the third MEA, Student Travel Modes. These interviews were conducted with individual Teaching Assistants, lasted approximately 30 minutes, and were audio-recorded. The interview protocol for the first semi-structured interviews is presented in Appendix B. The second interview followed the same protocol, but the interview participants were also asked to reflect on any changes (in their experiences with grading the MEAs, such as changes in what they found challenging about grading the MEAs, changes in strategies, etc.) since the first interview.

While this paper focuses on the Teaching Assistants’ experiences with giving the students feedback on intermediate solutions, and the challenges associated with this, we have also collected additional data to understand the students’ experiences in receiving and responding to feedback as well as their experiences in providing feedback to their peers. To investigate the students’ experiences, we conducted individual, semi-structured interviews with 35 students, video-taped 11 teams of students while they revised drafts of their MEA solutions, and collected copies of student work for all of the students in the course (approximately 1200). Future papers will discuss findings from this larger data set.

C. Graduate Teaching Assistant Cases

In this paper, we present two cases of Teaching Assistants’ experiences with providing feedback on MEAs to provide an in-depth examination of the challenges and experiences that instructors can face in providing feedback to students on open-ended problems. Additionally, the two cases were chosen in order to examine the differences in experiences that different types of instructors might face. The two cases we chose represented many of the interview responses from the larger set of participants, although they do not exhaustively cover all of the themes that are present in the larger data set. However, within these two cases, several interesting themes emerged as we listened to the interview recordings for the interviewee’s key points and also listened for key
differences between the two cases. While our analysis was initially based on the audio recordings of the interviews, we subsequently transcribed the interviews to confirm our analysis and to include quotations as evidence in this paper.

The main difference between the two cases selected for this comparison was length of experience with the MEAs: Robin is a Graduate Teaching Assistant who is new to MEAs, and therefore new to the process of giving feedback on MEA solutions, while Chris has one additional semester of experience as a Graduate Teaching Assistant for this course, and therefore is relatively experienced with giving feedback on MEA solutions. The two Teaching Assistants selected for this comparison were also chosen based on a similarity in academic background: both were graduate engineering students who had also earned Bachelor’s degrees in engineering at this same institution, and therefore both had participated as first-year engineering students in this same course for which they were now Teaching Assistants. It is worth noting, however, that the MEAs were introduced to the course in 2002 and have been consistently used since, but both Teaching Assistants’ enrollment in the course predates 2002, so neither Teaching Assistant experienced the MEAs as first-year engineering students.

III. Findings

There were several differences in the ways that the two Teaching Assistants approached giving feedback to students on the MEAs. We group the differences according to three themes: “Philosophical Approach: Guide vs. Grader,” “Major Challenges,” and “Strategies.” In this section, we give examples of each of these themes (including quotes from each of the interviews) and discuss the differences between the new Teaching Assistant (Robin) and the more Experienced Teaching Assistant (Chris).

**Philosophical Approach: Guide vs. Grader**

As a Teaching Assistant reviewing MEA solutions, there is an inherent potential for a conflict in role. While reading the first draft, the Teaching Assistants are encouraged to provide formative feedback to the student teams, based on their current solution. The fact that there is no one right answer, but rather that there are many potential good solutions, the Teaching Assistant need to “guide” the students as the students pursue their own solution; this can be challenging in itself. Additionally, the Teaching Assistants (and students) are also cognizant of the role that the Teaching Assistant must play two drafts later: the role of grader. Ultimately, the Teaching Assistant will assign a numerical score to the solution.

As Chris described the process of giving feedback to the students, he often tried to ask the students questions so that the students might be able to realize for themselves opportunities for improvement, but he also gave them examples to help them refine their solutions:

“Originally, with my feedback, I was just asking questions, but now like with the last couple of teams, I've been more like going in the direction of just giving them examples of what they could do and telling them how they could state things like for the reusability or also for the mathematical model. It's like – just from what I was seeing in my experiences last semester, I think a combination of asking them questions to kinda guide them in the right direction but also sometimes just giving them like a certain example of what I could
be looking for.” (Interview One)

At other times, Chris also gave the students some specific advice on how to refine their solution.

“I’ve just been encouraging them to get to be very specific about what they’ve been talking about and what the procedure is used for and what’s used with the procedure, and also just trying to guide them in the direction of how is their procedure limited by what they do.” (Interview One)

Depending on which dimension of the rubric feedback was being provided, Chris described the balance of questioning and commenting differently.

“With the mathematical model comments, I have been just using a combination of just plain statements of stuff that would be really good for them to include, and also just questions to get them more thinking about what they could do.” (Interview Two)

In reference to Re-usability & Modifiability, Chris stated:

“There I seem to almost be saying the exact same thing for students, like that you’re missing you – you could really use your assumption. You have these things, and they are really helping your memo, but you also need limitations. … I pretty much give the same comments for everybody.” (Interview Two)

In reference to Audience (Share-ability), Chris stated:

“There it’s really been just as I was telling them how it was just reading their memo as a whole, and just to tell them if I could easily understand what they were doing, and if I could – and also giving them certain feedback on how they can improve just their memo in general.” (Interview Two)

Overall, it was important to Chris that he guide the students in ways that they might be able to improve their solutions without explicitly telling them the changes that they need to make.

“I tried to lead them in the right direction for a high quality model, but I haven’t really specifically said, ”To gain a level 4 for the mathematical model, you need to do this. To gain a level for usability, you need to do this.” So I would try to just lead them in the right direction with comments and questions I’ve had and notes I’ve made about where it’s confusing in their procedures.” (Interview One)

Ultimately, and throughout both interviews, Chris talked about his role as a guide in terms of working with whichever approach the students had decided to take, rather than steering the students towards one “best” mathematical model:

“The real challenge is just to really take their model that they developed, try to think about their thought process, and just try to help guide them in their right direction that’s easy for them to understand.” (Interview Two)

Throughout Chris’s interviews, it is apparent that Chris is concerned with what he can do and what he has done to help the students improve their understanding of and approach to the MEA, as a guide who is interested in seeing his students learn.

In contrast, there were multiple times when Robin talked about her Teaching Assistant role as that of a grader. For example, early in her first interview she discussed her attention to assessing and evaluating the students’ solutions:

“I want to give them as much chance as possible so I don’t want to dismiss the answer right away so I try to go through the answers.” (Interview One)

Later, Robin more explicitly talked about how the MEA Feedback and Assessment Rubric helped her assign the numerical score to the students’ solution:

“…I can know when to give points and when not to give points…” (Interview One)
Robin also talked about difficulties in using the rubric to assign points.

“The modifiability and usability. I have trouble with [inaudible] take off points if I cannot regenerate the results. Do I take it off on modifiability or do I take it off on reusability?”

( Interview Two )

“But as a whole, I don’t know if I feel like, comfortable penalizing them for the whole memo saying, “Oh, you did it wrong,” because they get it wrong in the introduction part but they did it right in the procedure part, the math model part.” ( Interview Two )

Robin was also became cognizant that omissions in feedback could lead students to a poor final grade.

“Most of them missed all the results. So that carries on in MEA 3, that reminds me to always remind them, make sure you have results because some of my students in MEA 2, they got a D because they didn’t put the results the way they should …” ( Interview Two )

Robin also commented that it was easier to grade when more details about grading were provided, as she perceived to be the case in the third MEA I-MAP:

“…the math model -- if we’d done it in MEA 3 style then it would be very useful. It shouldn’t be too open ended. We should at least have an idea what it should be, because although we are -- I know it’s hard to do that because we want them to think outside the box, but it’s kind of hard to grade when you don’t really know what you’re looking for. Or in my opinion it would be hard to be consistent from TA to TA if it’s up to us what is best.”

Finally, in Robin’s two interviews, she often mentioned the importance of identifying “the best kind of solution” ( Interview One ) and how she “struggle[s] with like, what is best” ( Interview Two ). This emphasis on a “best” solution type is in contrast with Chris’ approach to working with whichever solution type the individual team had chosen, and giving feedback to strengthening that particular solution type. In his interview, Chris recognized that when he was a new TA, he also was tempted to “advise [every team] to do the exact same thing” ( Interview Two ), which suggests that it may be common for new TAs to advise teams to adopt the “best” solution type, rather than helping teams to fully develop a strong solution for whichever solution type they had chosen.

Robin, as a new Teaching Assistant, often identified with the role of grader. An additional explanation for why this makes sense is that the Teaching Assistants regularly engaged in the role of grader—in addition to providing feedback on the MEAs, a primary responsibility for the Teaching Assistants was grading weekly homework assignments as well as the three exams. However, Robin also saw her role as guide in which she questions and comments on students’ work.

“… that’s the kind of feedback that I give, so like, I ask them back, “Why did you do this?” Or I pose a question to ask them, like do you realize this? And other than that I give them a sample of the best procedure. Example of the best procedure and then in the procedure, in case it’s not clear to them, I will pinpoint like, this is why I did this. This is why this is like this.” ( Interview One )

**Major Challenges**

**Time**

Another major difference between Robin and Chris’ experiences with the MEAs was the amount
of time that they spent giving feedback to students.

Chris was very concerned about spending an adequate amount of time on giving feedback to his students (which is consistent with his approach as a Guide): “it's still gonna take a good, decent amount of time to get through it all to consistently and fairly grade it all” (Interview One). During both interviews he estimated that he spent approximately 30 minutes per solution. His general process involved spending a couple of hours on the first half of a class set, then finishing the second half later on: “I kind of break them up a little bit. Do some for like a couple hours. Do the next half for maybe a few other hours” (Interview Two). One of the reasons that many of the Teaching Assistants spent half an hour to review the solutions was the fact that students’ approaches to the problem could vary greatly. At times, it took the Teaching Assistants some time to understand the students’ approach:

“For this one, it took me a little longer just to really read through their models and try to understand it with the different data types they were doing and see if I -- and just really try to make some logical sense of it.” (Interview Two).

While it took experienced Teaching Assistants like Chris 30 minutes to review students’ solutions, many of the less-experienced Teaching Assistants spent much more time. Part of the time disparity might be attributable to familiarity with the specific MEA; in Chris’ second interview, he commented that MEA 3 was more time consuming than the other two simply because he had not seen MEA 3 before, while he had previously evaluated the other two during his prior experience as a TA.

During Robin’s first interview, she explained how she spent an hour or more reviewing students’ responses and giving feedback: “Anywhere from one -- one hour’s the least and then it goes up from there.” (Interview One). While Robin did spend more time reviewing the MEA solutions than did the other new Teaching Assistants, the other new Teaching Assistants also tended to spend more time than the experienced Teaching Assistants. After spending an hour or more per solution for the first MEA, Robin worked with the course instructor leading the MEA training to consider strategies for reducing the amount of time she spent reviewing solutions, while still providing good feedback to students. By the third MEA, Robin spent closer to 45 minutes per MEA. She described this progression in terms of the first MEA being challenging because she was new to the MEA process, the second MEA being challenging because she was unsure of how to help students improve, and then the third MEA being a good engineering problem with good data.

Both Chris and Robin agreed that “The mathematical model is definitely the most time consuming” (Robin, Interview One) part of reviewing the MEAs. Chris further explained that “that's just because it's going through each one and I give comments for each one, and so that's probably one part of how I grade that's really tedious and takes more time” (Interview One). Chris and Robin also agreed that while “…it's time consuming. It's doable but time consuming” (Robin, Interview One) and they conveyed a sense that the long amount of time that they needed to devote the MEAs was a necessity; it took time, but was an important part of their role as a Teaching Assistant and an important part of the students’ learning experience.
Re-usability & Modifiability and Audience

As the Teaching Assistants reviewed the students’ solutions, they attended to three dimensions: (1) Mathematical Model, (2) Re-usability & Modifiability, and (3) Audience (Share-ability) (See section II.A. or Appendix A). As Chris reflected on these three dimensions, he recognized that evaluating the Re-usability of the solution and the extent to which the students addressed the Audience were more challenging than evaluating the Mathematical Model:

“…with the grading rubric that was given for this MEA for the mathematical model, it’s not very difficult to determine… what level they had for that but for the reusability and the audience, sometimes it’s a little difficult to determine the level for that…” (Interview One)

Upon further reflection, Chris decided that overall Re-usability & Modifiability was the most challenging aspect to grade. However, Chris acknowledged an increased level of detail provided in the second and third MEA I-MAPs:

“The rubric has been a little bit more difficult to use for the reusability and the modifiability, because it can get to be a bit subjective when you get into that regime, but -- at least in the audience section -- but with the reusability and modifiability [the instructor] actually did a very good job with giving us a rubric for the reusability in that, at least in the last two MEAs. Because she told us they have to -- because [the instructor] gave us more examples of just what constitutes Level 3, Level 4 and Level 2. Like if they’re missing most of the parts of the introduction, then they get a Level 2. If they are just missing two parts or three parts, Level 3. If they’re only missing about one, Level 4.” (Interview Two)

Robin’s interview responses were consistent with Chris’ estimation; she also indicated that the Re-usability & Modifiability of the solution and the extent to which the students addressed the Audience were more challenging than evaluating the Mathematical Model, and further clarified that part of the challenge was in applying the rubric:

“The rubric doesn’t really… it’s just -- say stuff about reusability and modifiability and audience and sharability but in MEA we have the response where we have to actually say whether they are this level or that level. Is there a level three or above or level four and above or whatever. So the rubric doesn’t actually specifically say it. It says that, oh, it’s up to you” (Interview One)

Robin also indicated that another challenge associated with evaluating the solutions for Reusability & Modifiability and Audience was that the students’ responses were unclear:

“The problem is with the students respondents they are often convoluted, what they’re doing. So I -- it’s really hard to extract out the two. And usually what I writing in usability I want to write it again in sharability. So that’s the problem. It’s not the fault of the explanation of audience as sharability and usability but the fact that they’re almost the same and whatever I take from a student respondent can apply to both.” (Interview One)

The challenge Robin described in differentiating Re-usability & Modifiability from Audience was common to several Teaching Assistants, both new and experienced; in reviewing the Teaching Assistants’ feedback during their training, many Teaching Assistants confused the categories and where to put which feedback. Overall, these two dimensions were challenging for both Chris and Robin, and for the larger group of new and experienced Teaching Assistants.
Progressive Grading Bias
A final challenge that the Teaching Assistants identified was the need to be consistent in their grading, which conflicted with the large amount of time required to review the solutions and the variation in responses. Chris described his experience in terms of realizing, at times, the possibility that he may have been inconsistent in his grading:
“…you kinda set your standard with one team but then you look at another team and another team and another team and then you can kind of like get a little skewed a little bit because you might say one team’s procedure had a level 3 for the reusability and shareability; however, there might be another team’s memo that almost just as clear and like with assumptions and then they stated what the procedure was for, however you might’ve given them level 2 or however I might’ve given them level 2.” (Interview One)
One point to note in his response is the potential danger in using a particular solution to set a standard. Robin also recognized that she tended to look for a good solution, from one of her student teams, to use as a standard of evaluating other solutions.
“- after grading a lot of MEA you can see a pattern, so I think in the -- the best way for -- the thing that I found out is, identify the best kind of solution and compare that. So if this -- if this solution come to that standard, then OK, it’s good. If not then I say, “Oh, you did not do this. You should have done this.”” (Interview One)
While having a clear reference point may have helped Robin to be consistent in her grading, it may have also diminished her capacity to recognize other good solutions that were equally appropriate but may not match the exemplar that she identified. However, both new and experienced Teaching Assistants expressed interest in seeing “exemplar” solutions that might help them calibrate their assessment practices.
“I would say probably an example of a high quality model, like maybe an example of a model that has like a level 4 mathematical model. It could include – it could have reusability and audience, … like lower but I think what would ultimately be really good is if we had an example of what a memo would be that’s a level 4 mathematical model, level 4 reusability, and level 4 of the audience.” (Chris, Interview One)
“…sometimes I wish I had like the perfect solution, so I could always refer to that if I’m not sure … I struggle with like, what is best.” (Robin, Interview Two)
Despite this keen interest in an exemplar, both Chris and Robin were able to identify other strategies for addressing the challenge of being consistent with their grading.

Strategies
Generally, Chris and Robin did not discuss strategies for overcoming the challenge of Time (although Robin did work to reduce the overly high amount of time she spent); it was more or less an accepted fact that it would take time to evaluate the MEA solutions. For the other two issues, however, Reusability & Modifiability and Audience (Share-ability), and Dealing with a Progressive Grading Bias, the Teaching Assistants were able to offer some strategies for overcoming the challenges. In general, Chris and Robin described the MEA Feedback and Assessment Rubric and Teaching Assistant training activities as valuable resources that helped them overcome challenges.

Dealing with the Difficulty of Grading Reusability & Modifiability and Audience
In terms of dealing with the difficulty of grading Re-usability & Modifiability and Audience
Chris and Robin used very similar strategies. Initially, Chris said that he "made sure to keep the rubric in front of me to...what exactly with the reusability and shareability is required for a really good mathematical model and try to look at different teams and try to keep a level of consistency" (Interview One).

In addition to using the resource of the rubric, Chris also found that it was effective to use the MEA solutions (the memos) themselves as a resource:

"...once you read a couple of memos and you kinda get the feel of what they're talking about with can this be applied to different situations and do they have like these certain things" (Interview One)

Robin also talked about these two themes. As a new TA still developing her understanding of the MEAs and the goals of the Reusability & Modifiability and Audience sections, she also found the rubric to be very helpful:

"But I remember in MEA 1 there’s -- actually if I -- because in MEA 1 I was still learning. I didn’t read completely grasp what is modifiability and reusability. And if I go back -- when I did read back [to the rubric or I-MAP] and it does exactly say what it is. So it helps. And the same -- and I think it’s the same thing for MEA 2 and 3."

(IInterview Two)

Additionally, like Chris, she used a similar strategy of reading several solutions to help her to be consistent in her feedback and assessment.

Dealing with a Progressive Grading Bias

Robin and Chris both discussed the strategy of reading a number of pieces of student work as a way to remain consistent in their assessment practices. This is not surprising, as it was explicitly covered in the Teaching Assistant training (although it is also not a foregone conclusion that the Teaching Assistants would necessarily adopt and find useful the strategies presented in their training):

"I think [instructor’s] idea of reading through a couple memos first just to kinda gauge the quality of the memos at first [was] a really good technique ... because then you can get a better feel for your grading, like how you want to grade the memos." (Chris, Interview One)

Robin also discussed this practice, in terms of trying to keep multiple solutions in her mind, in order to look for patterns:

"I always keep that in mind. If there’s something that I’m not sure. So I will like keep seeing if it’s a pattern with all the teams. And if so, I will make note of that and actually go and change the other teams’ response -- the response that I give to get a teams’ -- so that they are consistent. But so far I don’t really have that problem.” (Interview One).

However, as discussed earlier, there was also a danger associated with this strategy in that a Teaching Assistant might read through several solutions at first in order to select an exemplar, which might then limit their ability to accept other approaches. Chris had given this some consideration and took action to minimize this effect.

"I’ve definitely tried to keep a very objective viewpoint, not just let a few really good models or a few really bad models really affect, really influence my grading. Which is why in these last of weeks I actually started to read some memos down first just to get a feel for my group as a whole, for my section. And there I think I was able to grade a little more objectively and not just have it skewed just by one team. And so I’ve been definitely increasing my efforts not to be influenced by -- not let my grading by skewed by certain
Both Chris and Robin acknowledged that they would like to be given an exemplar so that they could see an example of a good solution. However, when they were not given an exemplar, Robin tried to look at a collection of student work to look for patterns that would lead to an exemplar while Chris was cognizant of the danger of letting any particular solution bias the way that he graded other teams’ solutions. Reviewing several solutions as a preliminary preparation for evaluating solutions was an effective strategy for Chris to remain consistent in his grading, and is likely effective for many other Teaching Assistants as well. However, it may be beneficial to caution the Teaching Assistants away from a proclivity towards using that strategy to select an exemplar.

**Conclusion**

This study builds on previous research that has been conducted to characterize the learning opportunities associated with the MEAs. This particular study focuses on the feedback that the students are given as they iterate through multiple drafts of their solutions to the MEAs. These preliminary findings suggest that more experienced Teaching Assistants have developed strategies that help them to efficiently provide feedback that is also effective (i.e. it is beneficial to the students). However, both new Teaching Assistants and experienced Teaching Assistants benefit from the training that they received in giving feedback to students, particularly in learning the strategy of reviewing several solutions in order to gain a holistic sense of the collection of MEA solutions. Additionally, both new and more experienced Teaching Assistants invest a considerable amount of time in evaluating MEA solutions, and providing feedback to their students, although this is an even greater challenge for new Teaching Assistants.

The findings from this study represent two opportunities for impact. First, the interviews with the Teaching Assistants revealed insights into the challenges associated with providing feedback to students on open-ended, complex problems. This information can help us understand this process better, and provide suggestions to other educators interested in adopting MEAs for use in their classrooms. Second, the interviews with the Teaching Assistants revealed insights into the Teaching Assistants’ professional development and their learning progression in terms of learning to give feedback. This information can help us understand how to better train and support Teaching Assistants in giving feedback on student work in general.

This study confirmed that the Re-usability & Modifiability and Audience (Share-ability) are difficult to provide feedback on and assess. Effort are underway to differentiate these terms and provide better descriptions of what high quality work entails along these dimensions.

The need for search for or a desire for an exemplar is concerning as it could limit Teaching Assistants’ openness to other good solutions. To some degree, this need may be filled by better explicating the Re-usability & Modifiability and Audience (Share-ability) dimensions and perhaps providing multiple good examples of how students might address these dimensions that are extracted from entire team solutions.
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Bibliography

Appendix A

MEA FEEDBACK AND ASSESSMENT RUBRIC
(Fall 2008 Implementation)

Overriding Option
☐ No progress has been made in developing a model. Nothing has been produced that even resembles a poor mathematical model. For example, simply rewriting the question or writing a “chatty” letter to the client does not constitute turning in a product. (Level 0)

Mathematical Model
☐ The procedure fully addresses the complexity of the problem. (Level 4)
   ☐ A procedure moderately addresses the complexity of the problem or contains embedded errors. (Level 3)
   ☐ A procedure somewhat addresses the complexity of the problem or contains embedded errors. (Level 2)
   ☐ Does not achieve Level 2. The procedure does not meet minimum requirements for addressing the complexity of the problem or meeting the clients’ needs. (Level 1)

The procedure takes into account all types of data provided to generate results OR reasonably justifies not using some of the data types provided. (Level 4)
   TRUE ☐
   FALSE ☐

The procedure is supported with acceptable rationales for critical steps in the procedure. (Level 4)
   TRUE ☐
   FALSE ☐

Provide Written Feedback About the Mathematical Model Here:

Re-Usability and Modifiability
Re-usability = can be used by the client for new but similar situations
Modifiability = can be modified easily by the client for slightly different situations
☐ The procedure not only works for the data provided but is clearly re-usable and modifiable. Re-usability and modifiability are made clear by well articulated steps and clearly discussed assumptions about the situation and the types of data to which the procedure can be applied. (Level 4)
   ☐ The procedure works for the data provided and might be re-usable and modifiable, but it is unclear whether the procedure is re-usable and modifiable because assumptions about the situation and/or the types of data that the procedure can be applied to are not clear or not provided. (Level 3)
   ☐ Does not achieve Level 3. (Level 2)

Provide Written Feedback about Re-Usability and Modifiability Here:

Audience (Share-ability)
Share-ability = can be used by the client to reproduce results
Results from applying the procedure to the data provided are presented in the form requested.
- TRUE □ (Level 4)
- FALSE □ (Level 1)

☐ The procedure is easy for the client to understand and replicate. All steps in the procedure are clearly and completely articulated. (Level 4)

☐ The procedure is relatively easy for the client to understand and replicate. One or more of the following are needed to improve the procedure: (1) two or more steps must be written more clearly and/or (2) additional description, example calculations using the data provided, or intermediate results from the data provided are needed to clarify the steps. (Level 3)

☐ Does not achieve Level 3. (Level 2)

There is no extraneous information in the response.
- TRUE □ (Level 4)
- FALSE □ (Level 3)

Provide Written Feedback About Audience (Share-ability) Here:
Appendix B

TEACHING ASSISTANT INTERVIEW PROTOCOL
(Interview One)

The purpose of this interview is to reflect on your attempts to give feedback to your peers on their work and to reflect on your attempts to respond to feedback you have received from both your peers and your TAs. Your feedback is very important for helping us to improve our understanding of how people learn to give and receive feedback to mathematical modeling problems and for helping improve future instruction and learning activities. This interview will take approximately 30 minutes. All your responses to my questions will be recorded and later transcribed. At no time will I identify your actual name in the recording of your responses during this or any other interview. I will assign a pseudonym to your responses, and I will store and label all the recordings with the pseudonym.

Part I: Experiences providing feedback
First I would like to talk with you generally about your experiences in providing feedback to students on their MEA response.

1. What kinds of feedback did you provide to the different teams you were evaluating?
2. Did you encounter any challenges in trying to provide feedback to the students’ solutions? If yes, Please describe these challenges.
3. How did you work around these challenges?
4. Can you think of anything that would have helped you to give better feedback to your students?

Part II: Experiences Using the Rubric
Now I would like to talk with you more specifically about your experiences in using the rubric to provide feedback to students on their MEA responses.

5. Please describe your experiences with using the rubric to provide students with feedback on their MEA responses.
6. Were there aspects of the rubric that were difficult or challenging?
7. Were there aspects of the rubric that were particularly useful or helpful?
8. Please describe your experiences in trying to evaluate and provide feedback on students’ mathematical models.
9. Please describe your experiences in trying to evaluate and provide feedback on the re-usability and share-ability of students’ solutions.
10. Please describe your experiences in trying to evaluate and provide feedback on students’ ability to address an appropriate audience.