Preservice Teachers Noticing About Discussions to Support Students in Revising their Design Ideas (RTP)

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Jamie Mikeska is a Research Scientist in the Student and Teacher Research Center at Educational Testing Service (ETS). Jamie completed her Ph.D. in the Curriculum, Teaching, and Educational Policy graduate program at Michigan State University in 2010. Her current research focuses on three key areas: (1) designing, developing, and conducting validation studies on assessments of content knowledge for teaching (CKT) science; (2) examining and understanding validity issues associated with measures designed to assess science teachers’ instructional quality, including observational measures, value-added measures, student surveys, and performance-based tasks; and (3) extending and studying the use of these knowledge and instructional practices measures of science teaching quality as summative assessment tools for licensure purposes and as formative assessment tools integrated within teacher education and professional development contexts. She currently serves as principal investigator on four National Science Foundation (NSF) research projects. One study (NSF #1621344) is designed to develop, pilot, and validate a set of performance-based tasks delivered within a simulated classroom environment in order to improve pre-service elementary teachers’ ability to facilitate goal-oriented discussions in science and mathematics. Prior to graduate school, she taught elementary school for five years in Montgomery County, MD and earned her National Board certification during her tenure as a public school teacher.

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Abstract

Noticing is an essential teaching practice that involves identifying salient aspects of classroom interactions, connecting those aspects to broader teaching principles, and using them to inform future instruction. Preservice teachers (PSTs) can develop their noticing practice by analyzing classroom teaching episodes. In this paper, we examine outcomes from using a series of activities—the Transcript Coding Assignment, a synchronous whole-class discussion, and an Identifying Strategies Assignment—to develop PSTs’ noticing practice within engineering education coursework. Activities were related to two 25-minute, video-recorded and transcribed discussions facilitated by two veteran teachers. These discussions were facilitated after students tested their initial designs and before they formally planned their second designs. These post-testing discussions were products of a prior study in which each teacher facilitated a small group discussion with five student avatars to support the students in working collaboratively to critique and revise each team’s initial ideas about design performance and improvement.

We focus on three features of these discussions, i.e., how teachers encourage students to: (1) engage with other teams about their designs, (2) talk about constraints, and (3) talk about criteria. We ask: What teacher prompts, questions, contributions, and strategies do PSTs notice with respect to each of these features within teachers’ discussions? We explored this question within two engineering education courses at two respective college institutions; 14 PSTs across those courses participated in the study. Data collected were PSTs’ independent coding of one teacher’s discussion transcript (the other was coded for the PSTs); a transcript of the synchronous class discussion within each course about what PSTs noticed about how the teachers addressed each feature; and PSTs’ written reflections about strategies these teachers used with respect to each feature.

Findings suggest that while most PSTs were able to notice two thirds or more of the instances of each feature in the teacher’s discussion transcript, they also associated non-examples with each feature (i.e., “over-coding” for the feature). Most especially, participants over-coded instances for Feature 1, linking many quotes to this feature even though the quotes did not encourage students to engage other teams about their designs; this finding was also evident in the synchronous discussion. In the Identifying Strategies assignment, PSTs collectively identified a total of 15 strategies that the teachers used with respect to the three features. The most frequently mentioned strategies for each feature were: having students call on a peer for critique or feedback (Feature 1), posing questions about whether constraints were met (Feature 2), and posing questions to particular students or teams about a criterion (Feature 3). Overall, the findings suggest that the assignments support PSTs in identifying prompts, questions, contributions, and strategies used by teachers in post-testing engineering discussions. However, more instructional attention may be necessary to help PSTs develop their ability to notice instances of teachers engaging students in discussion with one another about their designs. The ability to notice may help PSTs to learn to use such strategies in the classroom.
Background

Noticing

According to the seminal work of van Es and Sherin in 2002, noticing is an essential teaching practice that involves identifying salient aspects of classroom interactions, connecting those aspects to broader teaching principles, and using them to inform future instruction [1]. For most pre-service teachers (PSTs), noticing the most salient features of classroom interactions is challenging [1-4]. PSTs tend to focus on surface-level features of instruction—e.g., noticing social interactions between students or how students follow steps or processes rather than noticing student sensemaking—when they observe classroom interactions without support for how and what to notice [4, 5].

Teacher noticing has been a topic of mathematics education for about 20 years and science education for about 10 years [6]. From the mathematics and science education literature, one common way to hone PSTs’ and in-service teachers’ (ISTs) noticing practice is by having them watch and analyze videos of classroom interactions [5, 7-10]. These videos may be of the PSTs or ISTs themselves or of others’ facilitating classroom instruction, including video cases of teachers whom they do not know and teachers regarded as experts in aspects of instructional practice [8, 11]. The focus of analyzing teacher videos depends on the purpose of the methods instruction or professional development. Often, the focus is on what teachers notice within the classroom interaction about student thinking or engagement in disciplinary practices [3, 12, 13]. The focus may also be on teachers’ instructional strategies such as questioning and written responses during informal formative assessments [14].

Developing teachers’ noticing practice can occur using varied structures or approaches. They may analyze instructional videos in a collaborative setting, such as in a video club, methods course, or similar context [15-18]. They may also be encouraged to identify student or teacher contributions within videos by coding or annotating videos or video transcripts [16, 19-22]. In this way, the coding or annotating serves to connect what is noticed in classroom interactions to broader teaching principles [1].

Noticing in Engineering Education

Research on teacher noticing in engineering education is in its early stages relative to mathematics and science education [23-27]. We located five studies about teacher noticing in engineering education. Of these, four examined elementary in-service teacher (IST) noticing [24, 25, 27]; one included IST and PST participants [23]. Three of the studies exclusively examined what teachers notice when watching video clips of students engaged in engineering design [23, 24, 27]; two also included video clips of teacher-student interactions [25]. The emphasis on noticing student engagement is in part due to a focus in the studies on supporting the practice of “responsive teaching,” which necessitates that teachers (prior to responding to students with various talk moves) have noticed what students are saying and doing. Responsive teaching suggests that effective teaching responses to students are not pre-determined but rather emerge in response to what students say and do [28]. In the engineering context, this entails teachers posing questions or guiding conversations to broaden or focus attention to aspects of a design [29-31].
In their 2014 study, McCormick and colleagues investigated what five elementary ISTs noticed as they watched a video clip of a group of three third graders designing a water filter [27]. One finding from their work was that teachers frequently attended to the “social dynamics, particularly in how students collaborate while working on an engineering design project in a group” (p. 9). Teachers also noticed how students made decisions during the design process; what students shared about “what engineering is [and] … what the teacher wants”; and how the engineering activity was organized and assessed (p. 8).

Following McCormick and colleagues’ study and drawing from work on responsive teaching, Johnson, Wendell and Watkins’ 2017 study investigated what six elementary ISTs noticed in short (< 5 min) video clips taken from their own classrooms [24]. These clips “showed students working on-task and engaging in aspects of engineering design … [and] highlighted student-student interactions” (p. 27). They found that teachers noticed how students: “(1) framed (or interpreted) the project, (2) engaged in the engineering design process, (3) exhibited informed designer patterns, and (4) communicated with each other in ways that supported their engineering” (p. 32).

Dalvi and Wendell’s 2017 work involved developing and determining content and construct validity for a video-based assessment—Video Case Diagnosis (VCD)—to assess elementary PSTs’ responsiveness to engineering instruction [23]. The videos and accompanying video transcripts provided to the teachers were of elementary children engaged in an engineering design challenge. The noticing task for teachers involved them “describing in writing what they notice about students’ science ideas and engineering practices, and propos[ing] how a teacher could productively respond to the students” (p. 1101). They found that participants, including 25 elementary PSTs, 9 engineering majors, and 10 STEM ISTs, were more likely to notice students modeling and suggesting design solutions than they were to notice how students justified their decisions with evidence and refined design solutions.

Finally, two recent related studies—in 2019 and 2021—by Watkins, Portsmore, and Swanson examined evidence of effectiveness of their four-course online graduate program in engineering education for elementary ISTs [25, 32]. One aspect of their assessment involved interviewing program participants at three distinct points in their program for video of student engagement in engineering within their classrooms. The researchers selected a 2–7-minute video clip that included evidence of student thinking or teacher-student interactions. During each interview, researchers asked each teacher what they noticed within the clip. The 2019 study was a case study of the growth of one teacher in the program, Alma. Her video analyses were initially focused on which step of the engineering design process the children were doing. Alma’s final video analysis involved broader noticing. The authors wrote that by this time, late in the program, “she noticed the different ways in which the students’ activities reflect multiple steps of the [engineering design process] EDP” within the single clip, noticing how students were imagining, planning, drawing, creating, talking, and communicating (p. 12).

Noticing in Post-Testing Discussions

There are many possible points throughout engineering design during which teacher noticing within classroom interactions could be investigated. Thus far, the engineering noticing studies have focused on parts of the design process that include no or little teacher facilitation. In the
present study, we examine noticing within a teacher-facilitated discussion that occurs after each team has tested their first designs and prior to teams formalizing their second design plan. We call this the post-testing discussion.

During the post-testing discussion, the teacher may encourage teams to do all or some of the following, not necessarily in this order: (1) share a description of their first designs; (2) share how their designs performed during testing and were scored according to the design criteria; (3) share ideas about how they might improve; (4) ask questions, critique, and give feedback to other teams about their designs; and (5) consider revising their initial ideas about their design performance and improvement in light of others’ critiques and feedback [33]. Also, within this post-testing discussion, the students and teacher attend to how the design solves the problem by examining design performance with respect to the criteria and checks to ensure that the design meets constraints.

The fourth of the above aspects of a post-testing discussion positions the student designers as participating in diagnostic troubleshooting with respect to others’ designs [29, 31]. Diagnostic troubleshooting, according Crismond, involves observing performance, diagnosing the problem(s), explaining why the problem(s) occurred, and proposing how to remedy them [29, 30]. Crismond and Adams make the case that at this stage of the design process—during and design testing—the instructor may need to intervene or else an unfocused analysis by beginner designers will occur:

Disparities between intended function and actual product behavior during prototype testing that go unnoticed cannot contribute to the iterative improvement of a design. The potential for what students can learn through iterative design gets diminished when students’ attention remains diffused and unfocused, and when students fail to notice and attend to critical and problematic features in their designs. (p. 768)

What we argue here is that students, with facilitative guidance from the teacher, can contribute to this diagnostic troubleshooting process.

Facilitating disciplinary discussions that encourage students’ sensemaking—such as the post-testing discussions we have described here—is an important and ambitious teaching practice [34-37]. PSTs need support in learning how to facilitate such discussions [38, 39]. Our work here suggests that one way to support PSTs in this effort is for them to analyze the discussions of others and connect what they notice in those discussions to broader teaching practices—with the ultimate goal (beyond the scope of this study) to help them apply what they learned to their own future teaching [1].

While most of the engineering noticing research explores what PSTs or ISTs notice within classroom interactions without direction from the researchers [e.g., 24, 25, 27], we utilized a more structured approach. We identified three discussion features that we wanted the PSTs to use as codes. In this way, we provided van Es and Sherin’s “broader teaching principles,” and then asked the PSTs to identify classroom interactions that were enactments of those principles [1]. We selected the following features of focus for the post-testing discussion: (1) engagement across student teams about one another’s designs, (2) talk about constraints, and (3) talk about criteria. These are not the only possible features of focus to attend to in a post-testing discussion. That said, we assert that explicit attention to constraints and criteria is essential in such a
discussion and the point of a “whole-class” post-testing discussion is for students to interact with one another, asking questions, providing feedback, and offering critique about one another’s designs.

Research Questions

Our research question has three parts and is as follows: What teacher prompts, questions, contributions, and strategies do PSTs notice within videos and transcripts of post-testing engineering discussions to:

(1) encourage students to engage with other teams about their designs (asking questions, providing feedback, offering critique);

(2) encourage students to talk about constraints and/or talk about constraints themselves; and

(3) encourage students to talk about criteria and/or talk about criteria themselves?

We refer to the bolded elements as “features.” Thus, Feature 1 is “Engaging with Other Teams about their Designs,” Feature 2 is Talk about Constraints,” and “Feature 3 is Talk about Criteria.”

In the assignments that we developed for PSTs and that we analyzed for this study (described in what follows), PSTs examined both teacher prompts, questions, contributions, and strategies and student contributions and responses during post-testing discussions. However, in the present study, we focus on PST noticing about teacher prompts, questions, contributions, and strategies only. We recognize the importance of student contributions and responses but wanted to limit the scope of the paper.

Context

Mursion® Simulated Classroom Environment

One of the unique aspects of this study is that the videos of classroom interactions that we use are of a Mursion® upper-elementary simulated classroom environment. The small classroom consists of five student avatars: Mina, Will, Jayla, Emily, and Carlos (see Figure 1). The avatars appear on a television screen or computer in front of the (real) teacher who facilitates the discussion. The avatars are operated by a highly trained human-in-the-loop called a simulation specialist who can respond as any one of the student avatars in real time in response to teacher prompts or in response to other students; the teacher facilitating the discussion only sees the avatars, not the simulation specialist. The simulation specialist is trained on the technical operation of the avatars and the content of the discussion, including the student work and prior learning experiences of the avatars. Each avatar has a unique voice via technology-supported voice modulation. The students can talk, raise their hands, look at one another, and write on their tablets, similar to real students in real classrooms.
Prior Work: Study Using the Mursion® Simulated Classroom Environment

In a prior study, authors Lottero-Perdue and Mikeska and a colleague designed task materials (i.e., a multi-page pdf) for IST participants to use as they prepared to facilitate a 25-minute post-testing discussion with the student avatars [33]. In the task, there were three student “teams”: Carlos and Emily worked as a pair, Jayla and Will worked as a pair, and Mina worked alone. The task provided the ISTs with key information including:

- Background science learning relevant to the design challenge
- The design challenge problem, constraints, and criteria
- Images of each team’s design before and after testing
- Each team’s testing results and scoring
- Each team’s written work about how they think their design performed and how they think it could be improved

ISTs were informed in the task materials that the purpose of the discussion was for student teams to share their initial ideas about design performance and improvement with one another and then work together to critique and revise these initial ideas. A total of 19 ISTs facilitated this post-testing engineering discussion and provided consent for their de-identified discussion videos to be used in PST education and for other purposes. We selected two of these videos for use in the present study—Ms. Green and Mr. Smith (pseudonyms)—because of the range of strategies that they used with regard to three aforementioned discussion features.

Prior Work: Design Challenge

The engineering design challenge used in this task was designed by the Lottero-Perdue and colleagues [40]. This “Shoreline” challenge involved the students designing a model shoreline to address the following problem:

A city on the bay has just purchased a piece of shoreline from a private company that had started to develop the land, exposing soil up to the water’s edge. The city council would like to hire an engineering company to re-design the piece of shoreline in the most
...affordable way possible that reduces erosion into the bay and creates more habitat, especially nesting habitat, for terrapins.

Prior to being presented with the problem, students had learned about erosion and that erosion of sediments and soil into bays and other bodies of water is problematic. They learned that riprap (stacks of rock) is often used to reduce erosion along shorelines. They also learned that coastal wetlands, which typically grow between water and soil on the shoreline (because they grow in wet soil), also reduce erosion. Additionally, they learned that terrapins find food and protection within wetlands. From the water, they look for a sandy area right on the coastline to lay their eggs. They have difficulty navigating riprap, often falling into cracks between rocks and dying.

Students, working in teams, created their model shoreline on a black paint tray in which the paint reservoir represented the bay and the shore contained 350 ml of loose soil as a starting point for the design (Figure 2). The constraints of the challenge included that only certain materials were allowed; each of those had an assigned cost. Materials were rocks and gravel, representing boulders and riprap; mesh and toothpicks, representing wire mesh or rebar to fasten rocks or gravel; sand for nesting sand habitat; and sponge pieces, representing wetlands. The testing procedure was also constrained: 350 ml of water needed to be rained over the surface of the shore over a 2-minute period to see how much erosion occurred into the bay and onto the nesting sand area (making it unusable if covered in soil). Two additional constraints related to background science were:

- Wetland constraint: Wetland must be between the water and soil.
- Sand constraint: Sand for nesting sand habitat must be adjacent to the water’s edge.

**Figure 2**

*Starting Model for Shoreline Challenge*

There were three criteria for the challenge: (1) Cost, (2) Terrapin Habitat Quality, and (3) Bay Quality. We will summarize criteria information here insofar that it is necessary to understand teacher noticing in this study. Additional detail can be found in our prior work [33, 40]. There were corresponding scores for each of these criteria (e.g., the Cost Score); each criterion could receive a score from 1 to 6 points. Based on the problem statement, the lower the cost the better;
this was based on adding up the material costs. Terrapin Habitat Quality was determined by counting the number of pieces of wetlands available to the terrapins and determining how much “accessible nesting habitat” was available to the terrapins both before and after the rain. Here, “accessible” means that an edge of the sand is adjacent to the water so that the terrapins can identify it as a good nesting habitat. Bay Quality was determined by the post-rain amount of sand erosion into the bay onto the grid squares (see Figure 2) and the amount of soil erosion into the bay as determined by a turbidity test.

Prior Work: Student Work Samples for the Simulated Classroom Environment

Student work samples are shown in Appendix A; appendices are after references. This includes a list of key design features and results for the teacher facilitating the discussion to consider.

Study Context: Instructional Sequence Development

For this study, we recruited instructors from institutions A and B to teach an instructional sequence. With no funding to support simulation costs, we did not have the ability to have the PSTs attempt to facilitate the discussion themselves; thus, the instructional sequence focused on Mr. Smith and Ms. Green’s discussions. Further, due to time and logistics, we were unable to have the PSTs do the design challenge themselves prior to investigating student work [41], and reading the discussions; rather, the PSTs read an article about the design challenge and are able to ask their instructors questions about the challenge as necessary [40]. (We address this issue later in the Limitations section of the paper.) Ultimately, the co-authors developed five elements of the instructional sequence. The second through fifth elements focused on the three features of post-testing discussions mentioned previously. As a reminder, these are how teachers encourage students to: (1) engage with other teams about their designs (asking questions, providing feedback, offering critique); (2) talk about constraints; and (3) talk about criteria. The elements are as follows:

1. PSTs read about the design challenge.
2. PSTs watch Ms. Green’s 25-minute discussion video, read about the three features, and read Ms. Green’s transcript, which was coded for each of the three features.
3. PSTs watch Mr. Smith’s 25-minute discussion video and code Mr. Smith’s transcript; this is the Transcript Coding Assignment that PSTs complete individually and submit for a grade.
4. PSTs participate in a whole-class synchronous discussion about what they noticed in Ms. Green’s and Mr. Smith’s transcript that addressed each of the three features.
5. PSTs complete the Identifying Strategies Assignment individually and submit for a grade. In it, they are asked to identify two teaching strategies from either Ms. Green’s or Mr. Smith’s transcript that address each feature.

The course instructors were available at each point in the instructional sequence to answer PSTs’ questions. They also provided feedback to our iterative development of the Transcript Coding and Identifying Strategies Assignments and the synchronous discussion protocol. The instructors chose to grade the Transcript Coding and Identifying Strategies assignment for completion.
Methods

Participants

Study participants were 15 PSTs who were enrolled in one of the two online engineering methods courses in fall 2020 and who submitted the Transcript Analysis and/or Identifying Strategies Assignments. Four were from Institution A (44% rate of consent) and 11 were from Institution B (64%). Note that these courses met at different days and times and thus could not meet together for the purpose of the study. These courses met online due to the COVID-19 pandemic.

When asked to identify their pronouns, 60% chose she/her and 40% chose he/him. Participants included sophomores (13%), juniors (47%), and seniors (40%). Participants’ majors included elementary and integrative STEM education (20%), middle school science education (27%), and secondary technology and engineering education (53%).

As part of the Identifying Strategies Assignment, PSTs were asked, “Have you ever analyzed a classroom discussion in your past? This could include analyzing a discussion that you witnessed live or on video and/or analyzing a discussion transcript.” Most (60%) responded that they had never done so and 20% responded that they had observed classroom instruction in real time (but did not mention transcript analysis). Just 20% responded that they had analyzed videos or transcripts of classroom discussions.

We did not include the course instructors as participants in this study. We invited them to be authors, but they declined. They were not informed of which PSTs in their class chose to participate in the study so as not to introduce bias.

Data Collection and Analysis

Transcript Coding Assignment

PSTs’ Coding Instructions for Mr. Smith’s Transcript. The Transcript Coding Assignment involved the PSTs coding Mr. Smith’s transcript only since Ms. Green’s transcript coding was provided. Mr. Smith’s transcript was provided to PSTs in Word in a tabular format with each turn or contribution by a teacher or student as a row of the table. There was one column for each of the three features. If PSTs identified a teacher or student contribution as being evidence of addressing one of the features, they would place an “X” in that column for that row. They also highlighted the corresponding text within the contribution as evidence for that feature. More than one feature could be attributed within a row. Also, rows could be left blank if none of the three features were addressed. See Appendix B for a part of Mr. Smith’s blank transcript for participants to code.

Developing Keys for Ms. Green’s and Mr. Smith’s Transcripts. The co-authors used an iterative process to come to consensus about applying feature codes to both Ms. Green’s transcript (to share with PSTs) and Mr. Smith’s transcript (to use as a key when analyzing PSTs’ coding of this transcript). Based on a coding procedure developed by Lottero-Perdue, we divided our coding into two categories for each feature: (1) locating the most obvious instances of each
feature within the transcript that we would expect PSTs to be able to identify easily, and (2) locating more subtle instances of a feature that PSTs may not as easily identify. We used our experiential knowledge of working with PSTs to determine which instances fit into which categories. Coming to consensus for the first category—what we called “required” instances—was straightforward for the co-authors; coming to consensus for the second category was more challenging, requiring multiple reconciliation discussions. For Mr. Smith’s transcript, the transcript that PSTs analyzed, we coded the following instances for each feature: Feature 1 (9 required, 2 optional); Feature 2 (3 required, 3 optional); and Feature 3 (12 required, 0 optional). See Appendix C for examples of a required instance, an optional instance, and a non-example for each feature.

Analysis. To analyze how the PSTs coded Mr. Smith’s transcript, we imported PSTs’ coded transcript tables into an Excel document in which Mr. Smith’s coded transcript key had been imported. For each feature, each PST’s transcript was compared to the key to assess whether the PST coded each of the required instances for that feature. Each transcript was also analyzed for when the PST associated a feature with a contribution that was not coded in the key as either required or optional; we refer to these as “non-examples.” For this study, we did not examine how the PSTs coded optional contributions; not coding those contributions did not “count against” PSTs as an omission. We used descriptive statistics to ascertain the extent to which PSTs coded required instances and non-examples for each feature.

Synchronous Discussion

Synchronous Discussion Details. After the PSTs had reviewed Ms. Green’s coded transcript and submitted their coded Mr. Smith transcripts, they engaged in a 50-minute synchronous whole-class discussion facilitated Lottero-Perdue and Figueroa, respectively, at the two institutions. The first 20 to 30 minutes were about the three features of focus in this paper. We used a discussion protocol to encourage PSTs to discuss how Ms. Green or Mr. Smith encouraged students to engage with other teams about their designs, talk about constraints, and talk about criteria (see Appendix D for the protocol questions). The remainder of the discussion focused on other features not included in this paper. Note that while participants did not have to code Ms. Green’s transcript, it was coded for them, we were still interested in learning about what the participants gleaned from reading this coded transcript in addition to coding Mr. Smith’s transcript.

Synchronous Discussion Video and Transcript Generation. The synchronous discussion was video recorded. At each institution we created a transcript that included verbatim contributions by consenting participants using pseudonyms, as well as paraphrasing without names or identifying information for other contributions. The video of the synchronous session was deleted as soon as the transcript was generated.

Synchronous Discussion Analysis. Authors Mikeska and Taylor led the analysis of the synchronous discussion transcripts. They generated a table summarizing observations and ideas that PSTs shared for each of the three features, indicating whether the PSTs descriptions or examples from the transcripts were accurately assigned to the feature or inaccurately assigned to the feature. For example, during the discussion about Feature 1 Engaging Students with Other Teams about their Designs, students at one institution contributed both observations related to
the feature (e.g., Ms. Green ended statements by asking students if they agreed or disagreed with their peers about their designs) and unrelated to the feature (e.g., Mr. Smith validated students’ ideas as important and accurate to keep the discussion moving forward).

Identifying Strategies Assignment

Assignment Details. In the Identifying Strategies Assignment, participants were tasked with identifying and describing at least two strategies per feature that Mr. Smith and/or Ms. Green used to facilitate a class discussion about teams’ first designs. For each strategy identified, participants were asked to include an example with a timestamp from Mr. Smith’s or Ms. Green’s transcripts.

Analysis. Fourteen of 15 participants contributed responses about the teaching strategies used by Mr. Smith and Ms. Green. One participant was removed from the data set because their responses were copied verbatim from another participant. Since participant were asked to identify two strategies per feature, there were 28 strategies per feature across 14 participants. Thus, percentages in this section are calculated out of 28 strategies rather than 14 participants in our use of descriptive statistics to describe the data. Figueroa began the coding process creating an Excel document in which participants were in rows and coding for each feature occurred in columns. Each participant’s strategies were iteratively read and re-read and coded. Loterro-Perdue reviewed Figueroa’s analysis and the two arrived at a consensus regarding codes and assignment of participants’ strategies to the codes. Some strategies that participants shared fell into two or more strategy codes. Across all three Features, we created 15 strategy codes noticed across the participants: six for Feature 1, three for Feature 2, and six for Feature 3 (Table 1).

As an example, Daniel (all student names are pseudonyms) responded in the following way when asked to share two strategies that the teacher(s) used to address Feature 1 Engaging Students with Other Teams about their Designs. The use of italics represents Daniel’s explanation.

Strategy 1: “Who thinks that this [Mina’s improvement idea] will solve the problem or not solve the problem? Tell me what you think. … Mina, why don't you go ahead and call on somebody?” (Ms. Green @6:26) This results in Mina calling on Carlos who gives a rather long-winded answer and Ms. Green needs to prompt Carlos a couple more times but it is a sort of back-and-forth conversation between students so I’d call it a semi-success.

Strategy 2: “Did you want to add something that possibly Mina could improve?” (Mr. Smith @8:17) Mr. Smith asks a direct question for Carlos to answer Mina and this results in a brief back and forth dialogue between Mina and Carlos. Mr. Smith asks a lot of questions and interrupts the students a lot so this was one of his more successful attempts in prompting student conversations.

The first of these was coded in two categories: (1) prompting students to call on a peer and (2) posing questions about how designs can be improved. The second was coded in two categories, as well: (1) posing questions to specific teams/students to address others’ designs and (2) posing questions about how designs can be improved.
Table 1

Teaching Strategy Codes for Each of the Three Features

<table>
<thead>
<tr>
<th>Feature 1 Engaging with Other Teams about Their Designs</th>
<th>Feature 2 Talk about Constraints</th>
<th>Feature 3 Talk about Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prompting students to call on a peer</td>
<td>Posing questions about whether constraints were met</td>
<td>Posing a directed question to one student/team about a specific criterion</td>
</tr>
<tr>
<td>Implementing a Turn and Talk</td>
<td>Referencing the scientific reasons underlying a constraint</td>
<td>Discussing one or more specific scores, each of which measures a criterion</td>
</tr>
<tr>
<td>Posing questions to specific teams/students to address others’ designs</td>
<td>Offering an analogy to help students understand the reason for a constraint</td>
<td>Attending to teams’ ideas about criteria by drawing, restating and/or referencing those ideas</td>
</tr>
<tr>
<td>Posing questions about other teams’ design strengths</td>
<td></td>
<td>Reviewing original criteria before explicitly asking a question about it in terms of performance and improvements</td>
</tr>
<tr>
<td>Posing questions about key design elements</td>
<td></td>
<td>Letting a team identify their own design strengths/ weaknesses</td>
</tr>
<tr>
<td>Posing questions about how designs can be improved</td>
<td></td>
<td>Asking how design improvements might better meet criteria</td>
</tr>
</tbody>
</table>

Findings

In this section, we present findings from the Transcript Coding Assignment, Synchronous Discussion, and Identifying Strategies Assignment. This order is consistent with the order in which the PSTs completed these assignments and discussion.

Transcript Coding Assignment

The major findings from the Transcript Coding Assignment were as follows:

- Most PSTs were able to notice two thirds or more of the required instances of each feature in Mr. Smith’s transcript, i.e.:
  - 93% noticed two thirds or more of the required instances for Feature 1: Engaging with Other Teams about Their Designs
  - 74% noticed two thirds or more of the required instances for Feature 2: Talk about Constraints
  - 86% noticed two thirds or more of the required instances for Feature 3: Talk about Criteria
- PSTs also associated non-examples with each feature, with three or more non-examples identified by 54% of participants for Feature 1, 34% for Feature 2, and 7% for Feature 3.
- PSTs linked many of Mr. Smith’s quotes to Feature 1 even though the quotes did not encourage students to engage other teams about their designs (i.e., non-examples).

In what follows, we unpack these findings in greater detail for each of the three features.
Transcript Coding Findings for Feature 1: Engaging with Other Teams about their Designs

Coding Required Instances: Feature 1. Most participants coded the majority of the nine required instances (RI) that addressed Feature 1 Engaging with Other Teams about their Designs (RI = 9, M = 7.1, S = 1.7). Participants coded between two and nine required instances. Nearly three quarters of participants (73%) coded at least seven of the nine required instances.

Most instances were coded by most participants (M = 79.9%, S = 19.5%). Eight of the nine instances were coded by 73% or more participants. One instance was coded by all participants and the least coded instance was coded by 33% of participants (Table 2). This least coded instance was a follow-up question from Mr. Smith’s question about whether the team followed the constraints.

Table 2
Instances Coded by the Highest and Lowest Percentage of Participants for Feature 1 Engaging with Other Teams about Their Designs

<table>
<thead>
<tr>
<th>Percentage of Participants</th>
<th>Teacher Prompt, Question, or Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest (100%)</td>
<td>Mr. Smith @11:16: I see that you [Mina] identified that area is where most of your soil ran down … What does the rest of the class think about that idea of using some gravel in the high erosion area? Do you think that would shore up what we need to shore up there? Boy, I love the interactions there. I love it. Will, what do you think?</td>
</tr>
<tr>
<td>Lowest (33%)</td>
<td>Mr. Smith @23:52: [Following up from Mr. Smith’s question about whether the team followed the constraints; spoken to the whole class.] What do you think was missing? (Note that participants were not given the information in brackets.)</td>
</tr>
</tbody>
</table>

Coding Non-Examples: Feature 1. Participants coded between one and nine non-examples of teacher questions, prompts, or contributions for Feature 1 (M = 4.1, S = 2.9). All participants coded at least one non-example. Over half of participants (54%) coded five or more non-examples. The two most frequently coded non-examples involved the teacher referencing or agreeing with a student’s ideas, but not directly encouraging others to engage with those ideas. The most frequently coded non-example was coded by 80% of participants and was as follows:

Mr. Smith @ 9:31: Now, Mina, I look at your reflection here down at the bottom of your written response. And you say, "To make my design better, I need to stop the soil from getting into the bay." So Carlos, she actually identifies that she needs to do that. So that's good, right? [Carlos did not respond.] We want that to happen. So Mina, you're saying you could put some of your gravel between the wetland and the sand to stop the soil from running into the bay … Let me see if I've got this right. You want to put gravel here? …

Here, Mr. Smith responds to Carlos’s previous comment that the bay should be clean and then says that Mina already identified that she needed to keep the bay clean. Mr. Smith then turned to Mina to ask about her improvement idea. Instead of encouraging students to engage with one
another’s designs, Mr. Smith’s approach here limits students’ sensemaking with one another about their designs. Perhaps PSTs who coded this strategy did so because Mr. Smith acknowledged Carlos’s previous comment about Mina’s design.

Transcript Coding Findings for Feature 2 Talk about Constraints

Coding Required Instances: Feature 2. Participants coded, on average, two of the three required instances for Feature 2 Talk about Constraint (RI = 3, M = 1.9, S = 0.9). Nearly three quarters of participants (73%) coded two or all three required instances of teacher prompts to encourage talk about constraints (Figure 6). None of the required instances were identified by all participants. One was identified by 47% of participants, another by 80%, and another by 87% (M = 71.3%, S = 21.4%). Table 3 shares all three required instances and the percentage of participants who coded each. The least-coded of these involved Mr. Smith’s use of an analogy to help students understand the purpose of the sand constraint, but the word “constraint” was not used.

Table 3

Instances Coded by Participants for Feature 2 Talk about Constraints

<table>
<thead>
<tr>
<th>Percentage of Participants</th>
<th>Teacher Prompt, Question, or Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest (87%)</td>
<td>Mr. Smith @24:49: So if the sand isn't touching the water, if you don't have a beach, the terrapins won't be able to come up … I'm going to put this down, the sand must touch the … water.</td>
</tr>
<tr>
<td>80%</td>
<td>Mr. Smith @22:55: I'm looking at your written response here. It says, &quot;All we can do to improve is to reduce the cost. We spent the most money, $24. We aren't really sure how to change the cost without messing up our awesome design.&quot; So let me go back and show that picture again. … I want the class to look at that. And the first question I have is, did we meet the constraints of our design challenge?</td>
</tr>
<tr>
<td>Lowest (47%)</td>
<td>Mr. Smith @24:18: And if we remember back on our research, we saw that in order for terrapins to go up onto a sandy beach, they actually have to see it first. This is what I like to think of it as. Imagine you're driving down ... the highway, you're on vacation with your family, and you guys are hungry. You want to go eat at a restaurant. If you can't see the restaurant, you can't go eat there. Right?</td>
</tr>
</tbody>
</table>

Coding Non-Examples: Feature 2. Overall, participants coded few non-examples of this feature (M = 1.5, S = 1.6). Most non-examples were talk about criteria, not constraints, or about specific materials. The most frequently coded non-example, by 47% of participants was as follows:

Mr. Smith @22:14: So we've got wetlands here, we've got rocks here. Here's our soil, here's our sand. Very nice, squared off. It looks very well designed. And if I come down here to our response, let's take a look at our scores. All right, so our cost was definitely the highest price of all the groups. We spent $24 on that. Our terrapin habitat score is going to be six points. Very well done. Our bay quality score is six points. And I think that's actually because we didn't see any erosion from this at all, did we?

Here, Mr. Smith talks about materials and references scores, and thus, criteria. However, he does not reference constraints.
Transcript Coding Findings for Feature 3 Talk about Criteria

Coding Required Instances: Feature 3. Most coded the 12 required instances of teacher talk about criteria (RI = 12, M = 9.9, S = 1.8). Participants coded between 7 and 12 required instances. Most instances were coded by most participants (M = 83.3%, S = 14.6%) Three required instances were coded by all participants; two were coded by just 60% of participants (see Table 4 for examples).

We could not discern a clear pattern of why participants might be more or less likely to identify talk about criteria. One possibility with the lowest example shown in Table 4 is that perhaps given that constraints were mentioned explicitly, participants were reluctant to also code for criteria; that said, participants were able to code each teacher prompt, question, or contribution for one, two, or three features.

Table 4
Instances Coded by the Highest and Lowest Percentage of Participants for Feature 3 Talk about Criteria

<table>
<thead>
<tr>
<th>Percentage of Participants</th>
<th>Teacher Prompt, Question, or Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest (100%)*</td>
<td>Mr. Smith @6:18: Definitely. When we think about when people want to spend money on things, they definitely want to spend as little money as possible so that they can then go and spend money on the things they want to spend it on, rather than everything at once. So let's take a look at Mina's response. And Emily, I agree with you. Mina definitely had a good score here. She had a five out of six for her cost, and that's pretty high. Then we look at the terrapin habitat quality, and that's a four out of six, and the bay quality is a three out of six. So we had a bit of some turbid water there. Sand erosion's actually pretty good. The soil erosion is what brought that overall score down.</td>
</tr>
</tbody>
</table>
| Lowest (60%)**            | Mr. Smith @22:55: Yeah. And I'm looking at your written response here. It says, "All we can do to improve is to reduce the cost. We spent the most money, $24. We aren't really sure how to change the cost without messing up our awesome design." So let me go back and show that picture again. … I want the class to look at that. And the first question I have is, did we meet the constraints of our design challenge?

Note. There were two other instances coded by 100% of participants. ** There was one other instance coded by 60% of participants.

Coding Non-Examples: Feature 3. It was very rare for participants to code non-examples of talk about criteria (M = 0.2, S = 0.6). Most participants did not code non-examples (40%) or coded just one non-example (47%) of teacher talk about criteria. The most frequently coded non-example, by 33% of participants, was as follows:

Mr. Smith @5:39: Yeah, that's definitely good. And when we think about what we have to include into our design, Mina definitely hit there.

Here “what we have to include into our design” refers to constraints rather than criteria. Two other non-examples were about: (1) improvement, generally speaking but not about specific criteria (coded by 20% of participants); or (2) noticing features of a design (e.g., Mr. Smith
saying “we've got our soil, we've got some wetlands, we've got our sand, we've got rocks …; 13%). All other non-examples were coded by just one participant each.

Synchronous Discussion

The purpose of the synchronous discussion was for PSTs to have an opportunity to discuss what they noticed about the prompts, questions, and statements that Ms. Green and Mr. Smith related to each of the three features. During the discussion, PSTs shared relevant examples and made accurate observations of all three features in these two discussion transcripts. For example, PSTs at both Institution A and B noted how one strategy for engaging the students with the other teams’ designs occurred when Ms. Green asked if they agreed or disagreed with the previously identified strengths and weaknesses of the designs. The PSTs both institutions briefly mentioned how Mr. Smith provided an analogy during the discussion to help the student avatars consider why it was problematic that one team’s design failed to address a specific constraint. At Institution B, PSTs mentioned two instances in which Mr. Smith asked the students about constraints. The PSTs at Institution A also noted how talk about criteria tended to occur when the students described how to improve their own or each other’s designs. This feature, talk about criteria, was less a focus of the discussion at Institution A, with one student contribution about how Mr. Smith or Ms. Green would address issues related to cost.

During the discussion of Feature 1, Engaging with Other Teams about their Designs, we noticed that some of the PSTs included non-examples of this feature. They provided examples of generic strategies these teachers used during the discussion (e.g., starting with broad questions and then moving to more specific ones; validating student ideas; and providing teacher guidance or direction) but did not connect these strategies to how they could or were used to promote substantive engagement with other teams’ designs.

Identifying Strategies Assignment

**Strategies Identified for Feature 1 Engaging with Other Teams about their Designs**

We coded six strategies that participants noticed when asked to consider how teachers encouraged students to engage with other teams about their designs. We organized these strategies into two categories: (1) strategies to encourage student-to-student talk and (2) strategies to encourage students to focus on the design features of a particular team (Table 5).
<table>
<thead>
<tr>
<th>Strategy</th>
<th>% of strategies (n=28)</th>
<th>Example of participant’s description</th>
<th>Corresponding transcript quote</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategies to encourage student-to-student talk</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompting students to call on a peer</td>
<td>43%</td>
<td>“Mrs. Green also allows students to call on who they want to receive feedback. … This might make the students feel more comfortable receiving feedback and criticism by someone they are familiar with” [Natalie]</td>
<td>[Ms. G. @ 4:50] “And now Mina said that the weakness of her design was the soil erosion. Who agrees or disagrees with that? Mina, why don't you call on someone to tell you if they agree or disagree that this was a weakness”</td>
</tr>
<tr>
<td>Implementing a Turn and Talk</td>
<td>11%</td>
<td>“A strategy that Mr. Smith used was to have the students to discuss within their groups about Mina’s design.” [Cassidy]</td>
<td>[Mr. S. @ 4:03] “…I'm curious what others think of Mina's design. Will and Jayla, you guys work together, Emily and Carlos, you work together. Why don't you spend about 10 quick seconds, talk to each other, and talk about what you like about Mina's design.”</td>
</tr>
<tr>
<td><strong>Strategies to encourage students to focus on the design features of a particular team</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posing questions to specific teams to address others’ designs</td>
<td>32%</td>
<td>“Mr. Smith did a really good job of addressing specific students to make comments on their peer’s designs.” [Emma]</td>
<td>[Mr. S. @ 5:39] “Emily or Carlos, since you guys worked together, did you want to add anything? Was there anything in particular about Mina’s design that stood out to you?”</td>
</tr>
<tr>
<td>Posing questions about other teams’ design strengths</td>
<td>32%</td>
<td>“Ms. Green would ask a certain student to explain their design in depth to engage that group. Then after they were done, she would ask the student to call on another one [student] to see if they agreed or not.” [Vincent]</td>
<td>[Ms. G. @ 4:04] “Mina you call on a friend and ask to see if they agree that your design was cost effective?”*</td>
</tr>
<tr>
<td>Posing questions about key design elements</td>
<td>14%</td>
<td>“A strategy that Mr. Smith uses is opening up features of a student’s design as a class discussion to prompt other teams to talk about their peer’s designs.” [Olivia]</td>
<td>[Mr. S. @ 11:16] “What does the rest of the class think about that idea of using some gravel in the high erosion area?”</td>
</tr>
<tr>
<td>Posing questions about how designs can be improved</td>
<td>14%</td>
<td>“He successfully engaged one group with a different group to discuss the possibility of adding more wetlands.” [Adam]</td>
<td>[Mr. S @ 14:09 directed at Carlos and Emily’s team] “What is something that Mina could put into her design to overall improve the end quality for the terrapins?”</td>
</tr>
</tbody>
</table>

* This was also coded for “prompting students to call on a peer.”
Strategies Identified for Feature 2 Talk About Constraints

The most frequently identified strategy to encourage student-to-student talk (43% of the 28 strategies noticed by participants for this feature) was having students call on peers to comment on their designs. This strategy was used exclusively by Ms. Green. The other student-to-student talk strategy, the turn-and-talk, was exclusively used by Mr. Smith and identified in 11% of strategies noticed by participants. Regarding the other category—strategies to encourage students to focus on the design features of a particular team—participants most often noticed when Mr. Green or Ms. Smith posed questions to specific teams to address other’s designs (32%) or about other teams’ design strengths (32%).

By far the most common strategy that participants identified to encourage students/teams to discuss constraints was when Ms. Green or Mr. Smith asked about constraints directly (72% of the 28 strategies noticed by participants). This typically took the form of questions such as Ms. Green’s “Did they follow all the constraints?” and Mr. Smith’s “Did we meet the constraints of our design challenge here?” All these questions were in reference to Carlos and Emily’s design, which did not follow constraints. Other strategies, as shown in Table 6, included referencing the scientific reasoning behind a constraint (in 25% of strategies noticed by participants in both Mr. Smith’s and Ms. Green’s transcripts) and using an analogy to explain a constraint (in 11% of strategies noticed by participants only in Mr. Smith’s transcript; only he used an analogy).

Table 6. Strategies Participants Noticed for Feature 2 Talk about Constraints

<table>
<thead>
<tr>
<th>Strategy</th>
<th>% of strategies (n=28)</th>
<th>Example of participant’s description</th>
<th>Corresponding transcript quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posing questions about whether constraints were met</td>
<td>72%</td>
<td>“Ms. Green only asks this question for Emily and Carlos’ design but not for Mina’s because she knows which groups followed constraints. She also gauges the audience and sees Mina has an answer so she calls on her. This approach gets to the root of recognizing a missed constraint.” [Grace]</td>
<td>[Ms. G. @ 18:40] “Yeah, it [the water] is very clear. I want everyone to take a close look on page 12 at their picture. It’s so clear, but did they follow all of the constraints? Mina, I see you shaking your head no. Can you tell us about that?”</td>
</tr>
<tr>
<td>Referencing the scientific reasons underlying a constraint</td>
<td>25%</td>
<td>“She allowed them to talk to one another about whether or not they met the constraints, and though the student wanted the points, she had to clarify and decide that what they just talked about determined that it was not a suitable nesting area and therefore did not meet the necessary constraints.” [Natalie]</td>
<td>[Ms. G. @ 21:23] “Yes, I understand that. I do agree though. I think those two would have to go because it's not an accessible nesting area.”</td>
</tr>
<tr>
<td>Offering an analogy to help students understand the reason for a constraint</td>
<td>11%</td>
<td>“Mr. Smith explains why the sand must be next to the beach and then relates it to seeing a food exit sign on the highway which I thought was beneficial to the student’s understanding.” [Daniel]</td>
<td>[Mr. S. @ 24:18] “…we saw that in order for terrapins to go up onto a sandy beach, they actually have to see it first.”</td>
</tr>
</tbody>
</table>
Strategies Identified for Feature 3 Talk About Criteria

Feature 3 refers to strategies used to get teams/students to talk about the design criteria. The strategy that participants most frequently noticed regarding this feature was when the teachers posed questions to one specific team/students to talk about a specific criterion (60% of the 28 strategies identified by participants) (Table 7).

Table 7
Strategy Participants Noticed for Feature 3 Talk about Criteria

<table>
<thead>
<tr>
<th>Strategy</th>
<th>% of strategies (n=28)</th>
<th>Example of participant’s description</th>
<th>Corresponding transcript quote (criteria shown in bold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posing a directed question to one student/team about a specific criterion</td>
<td>60%</td>
<td>“Ms. Green asks a question directly related to what the class can do to better meet criteria.” [Edward]</td>
<td>[Ms. G. @ 21:59 directed at Carlos] “Okay. So what can you do to lower the cost for the city council?”</td>
</tr>
<tr>
<td>Discussing one or more specific scores, each of which measures a criterion</td>
<td>36%</td>
<td>“Ms. Green begins discussions about criteria by posing a question directly about a criteria [sic] or about a design’s score… This question was a great diving board for criteria discussion, because scores were given out based on how well students achieved the criteria.” [Olivia]</td>
<td>[Ms. G. @ 8:22] “How would this improve her Terrapin habitat quality score as well?”</td>
</tr>
<tr>
<td>Attending to teams’ ideas about criteria by drawing, restating, and/or referencing those ideas</td>
<td>18%</td>
<td>“[Mr. Smith] used visuals to elaborate on improvements … This approach helps students to visualize where they can make changes which may be easier for some students to remember improvements than simply talking about them.” [Grace]</td>
<td>[Mr. S. @ 9:31] “[I actually want to] direct this question to Emily and Carlos. Thinking back to what the purpose of our design here is, in that we want to build a good habitat for terrapins, what is something else that could improve the overall design to build a better habitat for the terrapins?”</td>
</tr>
<tr>
<td>Reviewing original criteria before explicitly asking a question about it in terms of performance and improvements</td>
<td>14%</td>
<td>“This stuck out to me as well. He said, ‘thinking back to what the purpose of our design is…’. He defined criteria and then posed a question that the students could discuss back and forth. It was subtle but clarified the question he was about to ask.” [Natalie]</td>
<td>[Mr. S. @ 13:20] ”[I actually want to] direct this question to Emily and Carlos. Thinking back to what the purpose of our design here is, in that we want to build a good habitat for terrapins, what is something else that could improve the overall design to build a better habitat for the terrapins?”</td>
</tr>
<tr>
<td>Letting a team identify their own design strengths/weaknesses</td>
<td>14%</td>
<td>“[Ms. Green] ask[s] student[s] to identify their own successes/failures” [Grace]</td>
<td>[Ms. G. @ 16:57] “Carlos and Emily, can you tell us a little bit about your design and some of the strengths and weaknesses of that?”</td>
</tr>
<tr>
<td>Asking how design improvements might meet criteria (in general) more effectively</td>
<td>7%</td>
<td>“[Mr. Smith] asked students what they can improve on in order to prompt discussion of criteria.” [Olivia]</td>
<td>[Mr. S. @ 8:17] “Carlos, I saw your hand up. Did you want to add something that possibly Mina could improve in her habitat?”</td>
</tr>
</tbody>
</table>
For example, as Natalie describes, “Mr. Smith focuses on certain parts of the criteria instead of just going over it in a more general sense. For example, he focuses on the terrapin habitat part of the criteria for Mina’s design, even though her design has other flaws as well. That is a very good instructional decision because it helps to not overwhelm the student by pointing out everything that is incorrect all at once.”

The second most noticed strategy was posing questions that specifically address one or more of the three scores, i.e., Cost, Bay Quality, and Terrapin Habitat Quality (36%). These specific parameters allow students to think about where a team can make improvements. As Cassidy points out, “A strategy that Mr. Smith used was when he asks Mina about how she can improve her soil erosion score directly and allows her draw on the board to demonstrate what she would do.”

Discussion and Implications

Our research question asked about the teacher prompts, questions, contributions, and strategies that PSTs noticed within videos and transcripts of post-testing discussions with respect to three features. Those features were: (1) encouraging students to engage with other teams about their designs (asking questions, providing feedback, offering critique); (2) talk about constraints; and (3) talk about criteria. In what follows, we share what we learned about what PSTs noticed about each of these features and then summarize overall takeaways from the study across those features. We also share limitations related to this study and plans for our future work.

Feature 1 Encouraging Students to Engage with Other Teams about Their Designs

One of the key learning opportunities in the post-testing discussions is for students to learn from the questions, feedback, and critiques of those outside of their teams. We see this as a sort of collaborative diagnostic troubleshooting by the students and the teacher [29, 31], occurring prior to each team deciding on a firm course of action for their second design plans. The post-testing phase is an ideal place for an instructor to prompt a discussion about the performance of each design. When looking for evidence in the transcript of Mr. Smith encouraging student avatars Mina, Will, Jayla, Emily, and Carlos to talk about their designs, most PSTs (93%) located at least two thirds of the instances that our research team designated as “required” (i.e., obvious, evident, relatively easy to identify). That said, many participants “over-coded” for this feature—meaning that they coded many non-examples as being evidence of Mr. Smith’s encouragement related to Feature 1. More than half of the participants (54%) coded three or more non-examples. We also observed evidence of the use of non-examples within the synchronous discussion.

What this suggests is that the PSTs may need more support in narrowing their ideas of what counts as a teacher encouraging students to interact with one another across teams, asking questions, providing feedback, or offering critique. The noticing work that needs to be done here is in connecting examples in the transcript to the larger teaching principle described by Feature 1, harkening back to van Es and Sherin’s first two aspects of noticing in teaching: (1) identifying salient aspects of classroom interactions and (2) connecting those aspects to broader teaching practices [1]. This is consistent with other studies that have suggested that PSTs may have difficulty in identifying salient features of instruction [1-5]. However, unlike many of these
studies, we suggested the features and then asked the PSTs in our study to find evidence of these teaching practices in the transcript.

One means of support for PSTs to improve their noticing about Feature 1 and the other features could be in the form of collaborative PST groups working together to code, rather than the more individual approach we took here. This would resemble the collaborative setting of video clubs mentioned previously [15-18].

One of the strengths of our study is that we have identified specific strategies that teachers use to address these specific features—and we have observed what strategies PSTs notice in Ms. Green’s and Mr. Smith’s discussions. PSTs noticed six strategies that Ms. Green and Mr. Smith used relevant to Feature 1 Encouraging Students to Engage with Other Teams about Their Designs. Three of these strategies were identified in about one third or more of strategies that participants noticed. These include the teacher: (1) asking a student to call on a peer to provide feedback or critique, (2) posing a question to a particular team to address another team’s design, and (3) posing a question to the class to identify strengths of another team’s design. These are all appropriate strategies that encourage students to talk to one another across teams and to engage their thinking about other teams’ designs [37].

Feature 2 Encouraging Talk about Constraints

While 74% of participants identified two thirds of the required instances of Mr. Smith encouraging talk about constraints, one of the three required instances was missed by about half (53%) of participants: his use of an analogy to explain the meaning of the sand criterion. That said, PSTs briefly discussed this analogy during the synchronous discussion at both institutions. Overall, the analogy seemed to be a less direct way to discuss constraints that was not as readily noticed by the PSTs in the coding process.

Some over-coding (associating non-examples with a feature) occurred for Feature 2, as well, albeit less often than for Feature 1. About one third of participants (34%) identified three or more non-examples as being about constraints. In these cases, the examples included talk about criteria. This mixing up of constraints and criteria is something that the first two authors have noticed anecdotally in their PST courses and in IST professional development. That said, we could not find literature exploring the reason for confusion.

The science-related constraints for the shoreline design challenge—which were introduced when participants read about the design challenge [25]—were the sand constraint (i.e., that sand needed to abut the water’s edge) and the wetland constraint (i.e., that wetlands must be between soil and water). Although the teachers did not address the wetland constraint, a topic we address in our accompanying paper for this conference [41], they addressed the sand constraint. PSTs noticed this in the discussion transcripts, citing three strategies that teachers used: posing questions about whether constraints were met, referencing the scientific reasons for the sand constraint, and Mr. Smith’s use of an analogy to help students understand these reasons further. We argue that these are useful strategies for the PSTs to notice when attending to constraints at this critical point in the discussion when students’ beginner-designer thinking about design performance may neglect this critical aspect of design [31].
Feature 3 Encouraging Talk about Criteria

As was the case for the other features, most participants coded most required instances of Feature 3. Specifically, 86% of the participants coded two thirds or more of those required instances. This feature was the least likely to be over-coded, with only 7% of participants coding three or more non-examples. This may have been due to the emphasis of the criteria on scoring, which was a very prominent feature of the students’ design testing results.

Participants identified six strategies that teachers can use to keep the post-testing discussion focused on design performance and improvement with respect to criteria. Importantly, many of the examples of these strategies that participants identified were not simply teacher comments or probes, but rather also involved the teacher encouraging students to talk to one another about whether designs met criteria or could be improved with respect to criteria.

Overall Takeaways

Across the feature s, Feature 1 Engaging with Other Teams about their Designs was most challenging for the participants to notice without capturing non-examples within Mr. Smith’s transcript. Evidence from the synchronous discussions supported the idea that this feature may have been challenging for participants to notice accurately. As mentioned above, this suggests that teacher educators may need to provide additional scaffolding to support PSTs accurate noticing about this important feature of post-testing discussions.

PSTs’ engagement in the sequence of assignments—coding, synchronous discussion, responses about Ms. Green and Mr. Smith’s strategies—provided PSTs with a unique opportunity to look closely at post-testing discussions. This close look enabled the PSTs to notice talk moves and other strategies used by Ms. Green and Mr. Smith to incorporate explicit talk about constraints and criteria and to encourage teams to interact with one another, asking questions of one another and providing feedback and critique. We have gathered evidence across the features that PST participants can identify these examples of the features playing out in the post-testing discussions from the videos and transcripts. With more support, more PSTs may be able to notice a wider range of strategies.

Limitations

One of the limitations of our study is that it is relatively small with just 15 participants. Another is that the PSTs, due to logistical issues described earlier, did not complete the design challenge on their own. Perhaps having done the challenge would lead to a stronger understanding of constraints and how they differ from criteria, for example. Further, and as we shared previously, the PSTs did not get to try to facilitate the discussion for themselves. If we had been able to do that, we may have been able to observe the application of strategies that PSTs saw in Mr. Smith’s and Ms. Green’s transcripts in PSTs’ own discussions with the student avatars. Finally, and due in part to our lack of funding and time constraints, we did not employ pre-post measures to assess change in PSTs’ perspectives.
Additionally, the noticing within our study has been of a discussion within a simulated classroom environment. The teacher is a real, but the student avatars are played by highly trained simulation specialist, as described previously. One of the benefits of this environment is that it reduces the complexity of a real classroom environment. One of the downsides is that it is, put simply, not a real classroom with real children. There are many different factors that could influence what and how PSTs notice classroom interactions. A factor could be that the simulated classroom environment affects what PSTs notice.

Future work

Our future work involves a second iteration of the study in which PSTs will have done the engineering design challenge first before engaging in the instructional sequence. We also plan to clarify some aspects of the assignments based on PST feedback and to assist with our analytical processes. We also plan to seek funding in the future to support a simulation specialist to enact the discussion with the PSTs so that they can facilitate the discussion themselves. In the long term, we would be interested in investigating how such practice teaching in a simulated classroom environment translates into improved practice in real classrooms with real students.

Conclusion

Our primary objective was to develop an instructional sequence of assignments to support PST noticing about post-testing discussions—assignments capable of use in a purely online learning environment—and to notice what it was that the PSTs noticed in teachers’ discussions. We were able to achieve these goals. We learned about what the PST participants noticed with respect to the features within many but not all instances of Mr. Smith’s transcript and how PSTs sometimes captured a bit too many quotes (what we called non-examples) in their noticing. We also observed how the PSTs identified teaching strategies used by Mr. Smith and Ms. Green to facilitate their post-testing discussions that encouraged team-to-team talk about designs, talk about constraints, and talk about criteria. The ultimate goal of this work is to support PSTs’ developing abilities to notice these salient classroom interactions connected to important aspects of post-testing discussions to influence their instruction within field experiences, student teaching, and beyond [1].

Acknowledgements

We would like to thank all participants and their instructors for their participation.

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1 A complete response by a participant included an example from the transcript, the strategy described or explained, and the corresponding timestamp. Some incomplete responses came from participants who only gave a description of the general strategy observed without example from the transcript while others gave only a timestamp but no explanation of the strategy. We included both complete and incomplete responses in our analysis, inferring strategies when obvious within responses that did not include a description or explanation, but included a quote/timestamp.
References


[21] L. Kucan, "Insights from teachers who analyzed transcripts of their own classroom discussions," The Reading Teacher, research-article vol. 61, no. 3, p. 228, 2007, doi: 10.1598/RT.61.3.3.


## Appendix A

### Table A1. Summary of Team Designs Before and After Rain Tests*

<table>
<thead>
<tr>
<th>Team</th>
<th>Before Rain Test</th>
<th>After Rain Test</th>
<th>Key Design Aspects for Teacher to Consider in the Discussion</th>
</tr>
</thead>
</table>
| Mina’s Rocky Wetland Design               |                  |                 | • Followed both constraints  
• Had excessive soil erosion  
• Had negligible sand erosion  
• Improvement plan was to stop erosion between wetland and sand  
• *Needed to also consider preventing erosion between soil and sand (e.g., by placing rocks or gravel between sand and soil).*  
• *Could also consider increasing cost* |
| Will and Jayla’s Team Rip-rap Design      |                  |                 | • Followed both constraints  
• Had some sand erosion  
• Had some soil erosion  
• Did not use wetlands  
• Was high cost  
• Improvement plan was to use less rocks to reduce cost  
• *Could consider adding wetlands to improve terrapin habitat quality* |
| Carlos and Emily’s We Love Wetlands Design |                  |                 | • Thought that they followed both constraints  
• Had no soil or sand erosion  
• Was high cost  
• Said only way to improve was to reduce cost, but didn’t know how  
• *Scoring was higher/better than it should have been because sand was not actually accessible*  
• *Did not actually follow sand or wetland constraint (i.e., three wetland pieces in front of sand should not be there)* |

* Italics in rightmost column denotes information for the teacher that the student(s) did not consider in their writing about design performance or improvement.
## Appendix B

**Excerpt of Mr. Smith’s Transcript for PSTs to Code**

Note about Instructions: Participants place an X in the box for Features 1, 2, or 3 in the associated column. They are also asked to highlight the corresponding text that is evidence of the feature(s) selected.

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Time</th>
<th>Response</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Smith:</td>
<td>04:03</td>
<td>So let's start with Mina … I'm curious what others think of Mina's design. Will and Jayla, you guys work together, Emily and Carlos, you work together. Why don't you spend about 10 quick seconds, talk to each other, and talk about what you like about Mina's design.</td>
<td></td>
</tr>
<tr>
<td>Will:</td>
<td>04:49</td>
<td>[Students are talking to one another in a turn-and-talk about Mina’s design].</td>
<td></td>
</tr>
<tr>
<td>Mr. Smith:</td>
<td>05:02</td>
<td>All right, bring it back together. All right, so what is something about Mina's design that you like? Go ahead, Will.</td>
<td></td>
</tr>
<tr>
<td>Will:</td>
<td>05:14</td>
<td>So one thing that I liked about Mina's design is I know she had a sandy area next to the water for the terrapins to nest in, which you highlighted. Which is good, because they can nest there. So I liked that.</td>
<td></td>
</tr>
<tr>
<td>Mr. Smith:</td>
<td>05:39</td>
<td>Yeah, that's definitely good. And when we think about what we have to include into our design, Mina definitely hit there. Emily or Carlos, since you guys worked together, did you want to add anything? Was there anything particular about Mina's design that stood out to you?</td>
<td></td>
</tr>
<tr>
<td>Carlos:</td>
<td>05:53</td>
<td>Do you want to go?</td>
<td></td>
</tr>
<tr>
<td>Emily:</td>
<td>05:54</td>
<td>Yeah, yeah, I can take it.</td>
<td></td>
</tr>
<tr>
<td>Carlos:</td>
<td>05:56</td>
<td>Okay.</td>
<td></td>
</tr>
<tr>
<td>Emily:</td>
<td>05:58</td>
<td>So one thing that I liked about her design is that I think it's really cool that she kept her [cost] score so low … because her score is pretty good. But her cost score was pretty low, so she didn't spend a lot of money, which is good.</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix C

### Required Instances, Optional Instances, and Non-Examples

#### Table C1. Example of a required instance, optional instance, and non-example for Feature 1: Engaging Students in Talk about Others’ Designs

<table>
<thead>
<tr>
<th>Type</th>
<th>% Participants (N=15)</th>
<th>Teacher Prompt, Question, or Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Instance</td>
<td>100%</td>
<td>Mr. Smith @11:16: I see that you [Mina] identified that that area is where most of your soil ran down … What does the rest of the class think about that idea of using some gravel in the high erosion area? Do you think that would shore up what we need to shore up there? Boy, I love the interactions there. I love it. Will, what do you think?</td>
</tr>
<tr>
<td>Optional instance</td>
<td>20%</td>
<td>Mr. Smith @25:45: Cool. All right, excellent talk today. Thank you all for being so willing to share and to critique each other's work. That is definitely the sign of a good scientist, or an engineer in this case. And like I said, we'll carry on tomorrow. <em>Optional because it was said at the very end of the discussion as a wrap-up.</em></td>
</tr>
<tr>
<td>Non-example</td>
<td>33%</td>
<td>Mr. Smith @9:15: Okay. So what we have here is actually a discussion of which particular score we value more. Mina, you really chased down that cost score. And Carlos, you were chasing down that bay quality score, weren't you?</td>
</tr>
</tbody>
</table>

#### Table C2. Example of a required instance, optional instance, and non-example for Feature 2: Talk About Constraints

<table>
<thead>
<tr>
<th>Type</th>
<th>% Participants (N=15)</th>
<th>Teacher Prompt, Question, or Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Instance</td>
<td>87%</td>
<td>Mr. Smith @24:49: So if the sand isn't touching the water, if you don't have a beach, the terrapins won't be able to come up … I'm going to put this down, the sand must touch the … water.</td>
</tr>
<tr>
<td>Optional instance</td>
<td>13%</td>
<td>Mr. Smith @23:52: What do you think was missing? <em>Optional because while it referred to missing constraints, that wasn’t directly stated in this quote.</em></td>
</tr>
<tr>
<td>Non-example</td>
<td>27%</td>
<td>Mr. Smith @25:26: What is one thing we could do to reduce the cost of this overall design?</td>
</tr>
</tbody>
</table>
### Table C3. Example of a required instance and non-example for Feature 3 Talk About Criteria

<table>
<thead>
<tr>
<th>Type</th>
<th>%</th>
<th>Participants (N=15)</th>
<th>Teacher Prompt, Question, or Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Instance</td>
<td>100%</td>
<td></td>
<td>Mr. Smith @6:18: Definitely. When we think about when people want to spend money on things, they definitely want to spend as little money as possible so that they can then go and spend money on the things they want to spend it on, rather than everything at once. So let's take a look at Mina's response. And Emily, I agree with you. Mina definitely had a good score here. She had a five out of six for her cost, and that's pretty high. Then we look at the terrapin habitat quality, and that's a four out of six, and the bay quality is a three out of six. So we had a bit of some turbid water there. Sand erosion's actually pretty good. The soil erosion is what brought that overall score down.</td>
</tr>
<tr>
<td>Non-example</td>
<td>33%</td>
<td></td>
<td>Mr. Smith @5:39: Yeah, that's definitely good. And when we think about what we have to include in our design, Mina definitely hit there. Emily or Carlos, since you guys worked together, did you want to add anything? Was there anything particular about Mina's design that stood out to you? Mr. Smith’s mention of “what we have to include in our design” is about constraints.</td>
</tr>
</tbody>
</table>

Note. There were no optional instances for this feature.
Appendix D
Synchronous Discussion Protocol

Instructions: During the discussion, the researcher, who is the lead facilitator of the discussion, will pose the following questions and, as necessary, follow-up questions. Gray shading indicates what will be included in a slide deck to serve as a reference during the discussion.

1) Introduction (7 min)
   a) “I’m _________ and I will be joining the class and facilitating our 1-hour discussion today. [Share other pertinent introductory info about self.] Before I start, do you have any questions?” [If you haven’t already started recording, start recording now.]
   b) “I have some questions that I would like for you to discuss, not only with me but with one another. Let’s start with an open-ended question: What are some things that you noticed about both teachers and their approaches to the discussions?”

2) Feature 1. Engaging with Other Teams about Their Designs (10 min)
   a) “What did you notice about what Ms. Green or Mr. Smith said to encourage students to engage with other teams about their designs. This is Feature 1, which includes when students question, provide feedback, or offer critique to other teams.”
      i) If complete silence, offer an example. “For example, one strategy that Ms. Green used was to get a student on one team to ask a student on another team what they thought about their design. This happened at 4 minutes and 50 seconds when Ms. Green asked: “Mina, why don’t you call on someone to tell you if they agree or disagree that this [which referred to soil erosion] was a weakness.””
      ii) When a PST responds to part a), if they do not provide an example from the transcript, ask: “Can you provide an example of when ________ (Ms. Green or Mr. Smith) did that during the lesson?”
   b) For each strategy/example pair shared, ask:
      i) “Does anyone want to add on to that? If so, please share.”
      ii) “Does anyone disagree? If so, please explain.”

3) Feature 2. Talk about Constraints (10 min): Similar sub-questions as for #2 yet for Feature 2.

4) Feature 3. Talk about Criteria (10 min): Similar sub-questions as for #2 yet for Feature 3.

… [Discussion of two additional features not included in this study].

5) Conclusion (3 min)
   a) “Do you have any other ideas to share about Ms. Green or Mr. Smith’s transcripts?”
   b) “For homework, you’ll be responding to short answer questions about Ms. Green and Mr. Smith’s discussions and their strategies. Just as we did today, you’ll use examples from the transcripts as evidence to support your responses!”
   c) “Thank you for participating in the discussion today!” [End recording]