RESEARCH REPORT

Classroom Discourse as a Tool to Enhance Formative Assessment and Practise in Science

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This study details an innovative approach to coordinating and enhancing multiple levels of assessment and discursive feedback around an existing multi-media curricular environment called Astronomy Village®. As part of a broader design-based research programme, the study analysed small group interactions in feedback activities across two design cycles. The goal of this analysis is to develop an understanding of the ways that a situative approach to assessment and practise supports learning. Findings demonstrate ways that student and teacher engagement in collaborative activities support and constrain meaningful understanding, which we consider in terms of a trajectory of participation in and across conversations and written assessments, as well as individual learning gains on formal classroom examinations and standards-oriented external tests. Analyses of complementary formulations of domain concepts—discourse practises and assessment performance—suggest that participation in social forms of scientific engagement supports both learning and subsequent performance in more formal contexts. We suggest design principles for integrating the formative functions of discursive feedback with the summative functions of traditional assessment, through participation in different forms of science discourse(s).

Introduction

Increasingly influential voices in science education prioritize the value of learning to talk science over learning to read and write about science (Lemke, 1990; Roth, 2005). The dynamics of talk, more than the crafted prose of textbooks and tests, provide an interactive medium for exploring and knowing about the world scientifically. Peer and whole-class discussions provide opportunities to disagree with, reflect
on and otherwise interrogate scientific claims, and to foster roles and relationships with past, present, or future sources of knowing (i.e., a person, group, text) (Zack & Graves, 2001). Classroom tools (e.g., assessments, textbooks, conversation routines) not only aid such progress, but also become ways of thinking that are inseparable from these tools in crucial ways (Sfard, 2001).

Despite the fundamental role of classroom discourse for many approaches to learning, it is recognizably difficult to orchestrate (O’Connor, 2001). Discursive classroom activity can represent a push against more traditional expectations (i.e., teacher as disseminator of information) and a struggle to manage rich discourse in tandem with equally rich inquiry, both of which require effort and insight. Additionally, locally construed ways of knowing science in the classroom must often take into account ways of engaging science privileged by broader, further-removed contexts such as achievement tests.

The constraints of modern schooling are challenging to navigate. As one example, finite timelines and seemingly infinite content standards compromise the intensive inquiry experiences necessary to foster deep appreciation of science. Our assessment strategies coordinate curricular activities and multiple levels of assessment in order to foster deep learning that students and teachers expect, while also impacting performance on external achievement measures that some of the most influential stakeholders demand. We do this by scaffolding a discursive trajectory that begins with classroom talk about science and builds participatory norms across increasingly formal—technical and sophisticated representation central to the domain—ways to engage science through different levels of practice and assessment. In this study, we consider how research efforts to document and impact discursive classroom routines informed the process of advancing both participation in scientific inquiry and performance on high-stakes achievement across two annual design cycles incorporating implementation and revision.

**Overview of the Study**

This case study was conducted within a larger programme of research that organizes classroom assessment strategies to address the diverse goals discussed above. The overarching objective of this programme is to maximize attainment on large-scale assessments while also enhancing inquiry-based learning and instruction across three different multi-media curricula developed by the Classroom of the Future programme\(^1\) (in secondary biology, elementary ecology, and secondary astronomy). The present study focuses on Astronomy Village: Investigating the Universe\(^\text{®}\). A separate, complementary study that draws on the same curriculum reported statistically significant improvements across design cycles and details the design strategies driving refinements (Taasoobshirazi, Zuiker, Anderson, & Hickey, 2006).

Our present effort examines how the formative assessment activities central to our programme both support and constrain trajectories of participation across design cycles. We employ a situative view of knowing, learning, and assessment to develop case studies across two design cycles. Each case is an instance of student participation.
with (a) assessments that make curricular experiences visible in terms of a broader assessment context and (b) discursive feedback that leverages the assessment to foster participation in understanding, both informal and formal.

**Theoretical Framework: Situating learning and the notion of context**

Consistent with many variations of situativity theory (e.g., Gee, 2004; Greeno & Middle School Mathematics through Application Project Group, 1998; Lave & Wenger, 1991), we view learning as an appreciation for the ever-changing contexts through which one learns. Characterizations of knowledge (i.e., associations, skills, concepts, models, practises) therefore remain tied to the contexts through which it is experienced. By context, we do not simply refer to the various ways that concepts can be contextualized in a domain (i.e., *domain context*), but also the ways that a curriculum arranges encounters between students and a concept (i.e., *participatory context*). For example, consider the task of determining celestial distances. A written passage might abstractly discuss motion parallax in terms of geometric triangulation, the practices of modern astronomers such as interferometry, and/or a scenario through which a student works with actual parsec measures. Yet, while modern pedagogies would certainly incorporate these and many other strategies in written formulations, students encounter them by reading existing inscriptions (e.g., texts, diagrams, images, etc). Technological resources provide increasingly interactive representations as well. For example, Astronomy Village® includes a three-dimensional model of celestial space that students can manipulate in order to illustrate motion parallax. These variations, in sum, illustrate some of the many ways to contextualize the process of determining celestial distances and begin to underscore the situative contention that context matters. From this vantage point, determining celestial distances is a multifarious practise that can be contextualized with respect to a limitless range of domain subsets.

The notion of situated learning also suggests that the ways learners encounter contextualizations of a domain are fundamental (Young & Barab, 2000). For example, Aristotle and Hipparchus “encountered” parallax as a means of determining that the earth does not orbit the sun, while Ptolemy employed the same concept to calculate an accurate distance to the moon. By comparison, the *raison d’être* of motion parallax as encountered by many students is only as a concept used to answer homework and test questions. As the historical cases above suggest, however, other encounters are equally possible and probably situated in richer contexts.

The ways that students encounter parallax, or any other aspect of astronomy, largely depend upon participatory contexts. Astronomy Village®, for example, organizes its multi-media platform around a virtual laboratory community and investigations that scaffold a specific participatory context. For example, an investigation entitled “Search for Nearby Stars” coordinates multiple domain contexts of motion parallax in relation to the goals of a team of astronomers. In this way, it begins to arrange a relationship between a concept, whichever way it might be contextualized with respect to the domain, and a broader participatory context in which learners
encounter it. This contrast between domain and participatory contexts demonstrates not only different ways but the different levels at which context matters, underscor-ing the situative contention that context is not only dynamic but multiply-layered (Lave & Wenger, 1991).

Leveraging these distinct layers of domain and participatory context, we focus on the social genesis of knowing about a domain like astronomy as a kind of ongoing performance in and across activities. Classrooms provide a forum in which to develop social practises of science because students can always enact new ways of talking and doing science (Lemke, 1990). We specifically examine the ways in which these performances (re)emerge in both discursive feedback contexts and related assessment contexts (Sfard, 2001). Our analysis treats students’ differing representations of scientific understanding in conversations and on assessments as representa-tive of discursive moves along a trajectory toward central participation in and knowing about classroom science practises.

We view classroom assessment practises as opportunities to engage students with questions that frame curricular activities in terms of content standards. In turn, we view discursive feedback activities as opportunities to support and constrain learning in terms of these standards. Our assessment strategy (re)presents curricular experiences in terms of variable domain contexts and structures participatory contexts around assessment and peer discussions. Campbell and Stanley (1963) observed that assessments, like any learning measure, represent “a complex in which the relevant content is necessarily embedded in a specific instrumental setting, the details of which are tangential to the theoretical purpose” (p. 33). While we subscribe to the instrument-specific embedment of domain content, our work deliberately strives for degrees of theoretical embedment as well. We argue that the theoretical assumptions underlying assessment are another layer that structures an assessment “setting” or context (for a detailed discussion, see Hickey, Zuiker, Taasoobshirazi, Schafer, & Michael, 2006). This embedment occurs during discursive feedback activities that enlist these domain contexts to provide feedback on both curricular objectives and content standards in order to engage students with the broader domain contexts of science, specifically in ways that impact future inquiry and future attainment. These practises represent the core theoretical dimensions of the programme of research advanced in this study.

In this section, we have argued that learning always relates to the contexts through which it occurs and also illuminated two dimensions of context that we believe address demands for both supporting and understanding learning. Domain and participatory contexts coordinate student experiences during science instruction in important and useful ways. In the next section, we present a system of ideas about the various ways that context can be considered in terms of science learning.

Discourse and Learning

Situative and other sociocultural perspectives on learning construe knowing as fundamentally social (Gutierrez & Rogoff, 2003; Lave & Wenger, 1991; Roth &
Lawless, 2002) and view participation in discourse, for example, as primary characterization of learning and knowing. An individual’s understanding and skills are treated as secondary characterizations of participation. In this sense, enhancing participation in discursive practices is learning and not simply something that supports learning. We draw on sociocultural views of classroom discourse, which view social interaction as integral to meaning making and learning (e.g., Mercer, 2004; Wickman & Ostman, 2002; Wortham, 2005), but also consider the understanding and skills of individuals. We characterize the act of completing individual assessments as another form of participation in a trajectory of discursive practices that relate understanding in social situations to that which is “gathered” in more individualized contexts (often inevitable in formal education). We frame learning as a trajectory of participation in discursive practices in which students must engage the text and inscriptions of assessments in meaningful ways. This practice necessarily draws upon other, less formal, discursive representations. We consider this latter type in our analyses, which we refined across two design cycles with the goal of scaffolding students’ abilities to navigate more formal discursive representation such as those on achievement tests.

We assume that the enactment of a curriculum is socially constituted and sustained by individuals within participatory contexts that shape students’ and teachers’ engagement (Gutiérrez & Rogoff, 2003; Holland, Lachiotte, Skinner, & Cain, 1998). These contexts emerge throughout and can endure across the school year and within particular curricular units, but also in relation to broader cultural contexts (Wortham, 2005). Learning about social identity development in informal classroom contexts (such as our discursive feedback activities) is as important as content and process learning in more formal or “official” contexts (such as achievement tests).

In the next section, we detail an assessment framework for coordinating variable domain and participatory contexts. Specifically, we consider the ways that students engage one another during discursive feedback activities and how these conversations relate to the ways individual students engage the assessment questions featured in these activities.

**Approaching Assessment as a Discursive Trajectory**

We have developed an approach to structuring assessment that transcends the traditional dichotomy of “formative” classroom assessment and “summative” external assessment. Instead, we view any assessment practice as a kind of discourse with both formative and summative functions. Coordinating these functions within participatory contexts of curricula and classrooms can foster symbiotic relationships between assessment and scientific practise. We provide a general overview of the main features of this framework below (for more detail, see Hickey et al., 2006).

Our approach identifies multiple forms of assessment that feature increasingly formal and variable domain contexts of curricular objectives. These assessments differ in how they shape and are shaped by various participatory contexts. Borrowing from
Ruiz-Primo, Shavelson, Hamilton, and Klein (2002), who delineated immediate, close, proximal, distal, and remote levels of assessment, we focus on their middle three levels in our assessment practises. Ruiz-Primo et al. based their distinctions on the goals, content, and tasks most central to a curriculum as a way of classifying the instructional sensitivity of any particular assessment. Similarly, our levels vary from the central characteristics of curricula in terms of domain contexts, but also vary quite deliberately to arrange a participatory trajectory. Table 1 summarizes each of the three levels’ format, relationship to the curriculum, type of formative feedback, and analysis method.

In our approach to assessment, close-level questions align with both the domain and participatory contexts of a curriculum and targeted content standards. Proximal-level examination items and distal-level test items build from these particulars towards variable domain contexts that reflect a content standard and, in turn, typical items on large-scale, high-stakes assessments. Our approach features embedded cycles of formative feedback on close and proximal items. We pair items with answer rubrics during peer-led conversations, coaching discourse as a kind of feedback activity. We also assess gains in students’ understanding on the proximal-level examination and distal-level test in order to support claims that the feedback activities support increased participation across some of the domain contexts we characterized above.

The trajectory of participation in these shifting curricular contexts is re-enlisted in the discursive feedback activities. During these small group collaborations, students attempt to reach consensus about both an answer and a detailed explanation for close-level and proximal-level items on assessments. To support this process, these activities feature both learner-oriented answer rubrics and a four-step discursive routine. By consistently coupling multiple levels of assessment with this formative discourse routine, our framework creates two distinct participatory contexts in which students interact (a) with different forms of assessment and (b) with peers who have different answers and explanations. These participatory contexts, together, ideally engage students in intensive reflection and revision that is driven by the dialectics of discourse. Previous studies with a similar multi-level assessment framework generated compelling evidence of gains on distal-level measures (e.g., Hickey & Zuiker, 2005), while a complementary study demonstrated similar statistical significance in the implementations considered below (Taasoobshirazi et al., 2006).

Research Focus

Our approach assumes that student discourse (a) shapes and is shaped by participation, (b) can be refined via coaching and practise, and (c) is a fundamental part of the trajectory of scientific practise. We assume that this trajectory can lead to increasingly successful participation in other varied discourses, including highly formalized domain-specific discourse required of students on many achievement tests. The Astronomy Village® curriculum, when coupled with our approach to assessment, provides opportunities for students to more actively participate than traditional classroom spaces by fostering social meaning making within inquiry practises. These
Table 1. Trajectory of discursive practises across three assessment levels

<table>
<thead>
<tr>
<th>Assessment level</th>
<th>Assessment format</th>
<th>Relationship to curriculum</th>
<th>Scale</th>
<th>Primary discourse</th>
<th>Feedback format</th>
<th>Analysis method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>Activity-oriented <em>quiz</em>, informal and ungraded</td>
<td>Same content and context</td>
<td>Four times within the curriculum</td>
<td>Feedback conversation in small group discussion</td>
<td>Discursive</td>
<td>Discourse analysis of feedback conversation; in-class observation</td>
</tr>
<tr>
<td>Proximal</td>
<td>Curriculum-oriented <em>examination</em>, semi-formal and graded</td>
<td>Same content, different context</td>
<td>Once before and after the curriculum</td>
<td>Written representation and discursive feedback conversation</td>
<td>Written representations and discursive feedback conversation</td>
<td>Discourse analysis of feedback conversation; examination of responses to items.</td>
</tr>
<tr>
<td>Distal</td>
<td>Standards-oriented <em>test</em>, formal and scored</td>
<td>Different content and context</td>
<td>Once before and after the curriculum</td>
<td>Written representation only</td>
<td>Written representations only</td>
<td>Examination of responses to items</td>
</tr>
</tbody>
</table>
activities promote complex explanations and collaboration to advance explanations (Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003).

Study Design

We aligned a subset of existing Astronomy Village® curricular activities with three increasingly formal assessments based on targeted content standards. In Year One, we implemented these activities and assessments in one classroom and revised them based on our observations and analyses. We implemented these revised activities and assessments in two classrooms during Year Two. These classrooms consisted of 11th and 12th graders taking astronomy as an elective in three suburban, southeastern US secondary schools of about 2,000 students each. We examined the video-taped discursive practices of four groups’ formative feedback activities (two from each year) and how these enactments impacted the degree to which students were able to discursively represent understanding across different levels of interaction and assessment.

Curriculum and Assessments

Astronomy Village® organizes investigations that engage secondary science students in core astronomy topics. We tailored four investigations for a 20-hour curriculum that directly targeted selected astronomy content standards and linked curricular contexts with multiple levels of discursive activity and feedback on formative assessment. For example, the third investigation concerned stellar evolution and the ways that Cepheid variable stars are used to measure stellar distances. This was aligned with Standard 5.1 from the school system’s secondary astronomy content standards—students should be able to “define, measure, and compare distances in space as well as terrestrial distances using accepted methods and units”. By aligning the activities and assessments with specific content standards, we aimed to develop students’ abilities to engage the domain context through increasingly formal representations and participatory contexts.

We created four close-level quizzes to be completed immediately following each of four corresponding investigations. The quizzes are activity-oriented in that they build directly on the content and representations of the curricular activities and were designed to informally enhance collective participation in discourse and group understanding. While not intended for formal evaluation purposes, we did expect the quizzes and subsequent formative feedback activities to indirectly advance individual understanding. Figure 1 includes an item from the third quiz that aligns the third investigation to the aforementioned astronomy Standard 5.1.

After individually completing each ungraded quiz, students participated in collaborative “feedback conversations”—activities during which they reviewed their completed assessments and discussed their answers in small groups of three to four students using an answer rubric. As shown in Figure 2, these answer rubrics present concepts and reasoning relevant to individual quiz items in relatively formal scientific
The following items ask questions about the curricular activities you have just completed. Answer each item in the space provided and be prepared to discuss your explanations.

1a What is a Variable Star?

1b What are the characteristics of Cepheid variable stars that make them useful as distance indicators?

![Example of Cepheid light curve](image)

Figure 1. Quiz 3 item on Cepheid stars

registers of the specific domain without directly stating the correct answer. Figure 2 shows the answer rubric that corresponds to the quiz item above.

The proximal-level examination was used as a graded, curriculum-based assessment, much like a unit test. The examination is curriculum-oriented because the items directly assesses the concepts covered in each of the investigations, but in a more formal and general context than the quizzes. Figure 3 shows the examination item aligned with astronomy Standard 5.1. The examination is designed to serve both summative (graded by teacher) and formative purposes (students reviewed the completed examination in a fifth and final feedback conversation with an answer rubric prior to completing the distal-level test). We also administered the

![Answer rubric text for the quiz item in Figure 1](image)

Figure 2. Answer rubric text for the quiz item in Figure 1
examination alongside the pre-test to provide a sensitive (but biased) measure of student learning.

The distal-level test allows for comparisons of achievement gains with any curriculum that targets the specified standards and will not bias the implementation classroom. The test is standards-oriented because it addresses concepts from the quizzes and examination in a more abstract domain context that is aligned to the standards but not the curriculum. This allows us to make valid comparisons with other curricula targeting the same standards. This assessment also provides both a refinement target and valid evidence for claims that the Astronomy Village® curriculum, along with the two levels of formative feedback, may impact achievement on high-stakes tests that are aligned to the targeted astronomy standards. The test was administered before and after the Astronomy Village® curriculum by the research team under strict conditions, and was not shown to the teachers. The two test items aligned to astronomy Standard 5.1 are shown in Figure 4.

**Methods**

We videotaped two groups of students during each of the two implementation cycles while they engaged in feedback conversations around the close-level quizzes and proximal-level examination. Our analysis focuses on the recorded discourse associated with the quiz item and corresponding formative answer rubric shown above, and on student performance on the corresponding exam and test items also shown above.

**Group Selection**

We asked the teachers to assemble groups of three to four students based upon their ideas of what would promote interaction. The small group size allowed us to (a) maximize interaction between students and (b) mirror the computer-based investigations on which the quizzes were based. We consider the four videotaped groups for the case study we present here. Score gains on the examination and the test in the three implementation classrooms and one non-implementation comparison classroom are presented in Taasoobshirazi et al. (2006). This paper takes a much more focused look at that same data, examining the discursive practices of the four groups.
around one part of the feedback conversation and considering those same students’ performance on the examination and test items that were aligned with that same part of the feedback activity. These videotaped interactions occurred during the third week, allowing us to contrast discursive enactment along the same content for all four groups after they had some experience doing so.

This attention to a highly selected corpus allowed for a fine-grained examination of student engagement, the context for discursive representations, and understanding how feedback conversations provoked discourse (or not). While we do not aim to generalize to every science classroom based upon the insights we report here, we do believe that closely examining the details of discourse allows us to see some of the ways that knowing is constructed from a situative perspective and how it might relate to learning and discourse in more formal contexts.

**Discourse Analysis**

We closely transcribed the feedback conversations for all groups attending to verbatim content, non-verbal interaction and gestures, pauses, and inflection. We employed discourse analysis that prioritizes what is said, how it is said, and to whom it is said (e.g., Gee, 2004; Roth, 2005) in order to explore the ways that epistemic
stance (knowing what) influenced understanding. We consider how assessment materials, teacher strategies, and student interactions impacted classroom discourse and understanding in conversational formative feedback around informal classroom assessments. Directly influenced by sociolinguistic and sociocultural views of discourse and interaction as a site for understanding (Bucholtz & Hall, 2005; Gee, 2004) and participation in discourse as an important goal for science education (Duschl, 2000; Lemke, 1990), we focus on student and teacher interactions during formative assessment activities to suggest ways to improve teacher practise and student performance along a discursive trajectory of classroom science practise.

Results

In this section, we examine the range of assessments and discursive feedback activities that constitute the trajectory of participation detailed above. These assessment contexts and the way that they present the domain context work to re-situate the curricular experiences more abstractly. For the purposes of this analysis, the results of learning measures represent constrained forms of discourse between students and assessment items, which can then be triangulated within the broader forms of discourse between peers during feedback activities.

Examining Discourse with Assessment

Our discourse analysis examines how students engaged in formative feedback on the topic of variable stars following the third quiz. Since students engaged in the related quiz feedback conversation on this item before taking the post-examination, we postulate that this discursive practise (along with the cumulative practise of doing so for four entire quizzes) would lend itself to examination performance as a related articulation of meaning-making along our discursive trajectory. This form of data triangulation (attending to analysis of both discourse and formal gains) allows us to relate different discursive forms of understanding across activities and assessments in a manner that is consistent with our underlying theoretical framework.

The ways that students’ articulated meanings appeared to transfer to subsequent individual assessments is reflected in Table 2, which presents the 13 videotaped students’ performance data on individual assessments relating to astronomy Standard 5.1. The table indicates whether each student answered items correctly on the pre- and post-measures, shows each class’s mean performance on each of the items, and shows each of the 13 student’s overall performance on the pre- and post-examination and test. Of the six videotaped students in Year One, four showed increased learning on one or more of the examination or test items aligned with Standard 5.1. Of the seven videotaped students in Year Two, six showed evidence of learning on one or more of items. Along with the discourse analysis below, we contend that this constitutes evidence that most of these individuals were able to engage a more sophisticated understanding of Standard 5.1 as it is manifested in conventional achievement measures based upon their participation in points along the discursive trajectory.
Discourse to Enhance Formative Assessment and Practice

Related results on students’ individual performance measures with their group feedback conversations aligns components of the discourse trajectory and therein illustrates the usefulness of discourse in light of particular subsequent assessments.

Examining Discourse across Peer Groups

We compared each group’s discursive interactions during feedback conversations for the focal quiz item for details of their engagement and understanding. Each conversation occurred after individuals completed the quiz and included students’ descriptions of their answers, hopefully with negotiations of claims and warrants that resulted in group consensus and consultation of the answer rubric to check and refine group understanding.

Across analysis of these four groups’ feedback conversations, student discourse highlights three aspects of the activity structure: (1) student engagement in conversation, (2) the role of answer rubrics, and (3) teacher facilitation of conversations. The analyses below illustrate how these three aspects interrelate to affect feedback conversations’ productiveness. Moreover, they demonstrate that our refinements in the second cycle better coordinated all three in order to scaffold more productive enactments. Specifically, we characterize the initial implementation cycle in terms of

Table 2. Pre- and post-examination and test performance of individual group members for focal items and overall percentage correct

<table>
<thead>
<tr>
<th></th>
<th>Examination Item 5</th>
<th>Test Item 9</th>
<th>Test Item 10</th>
<th>Examination percentage correct</th>
<th>Test percentage correct</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Year One</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jake (1)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Scott (1)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ryan (1)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Amy (2)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Elise (2)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kelly (2)</td>
<td>–</td>
<td>–</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Class average</td>
<td>0.15</td>
<td>0.83</td>
<td>0.42</td>
<td>0.78</td>
<td>0.92</td>
</tr>
<tr>
<td>Year Two</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eric (3)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Andy (3)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Chris (3)</td>
<td>0</td>
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<td>0</td>
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<td>1</td>
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<tr>
<td>Celia (4)</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<td>1</td>
</tr>
<tr>
<td>Nadine (4)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bron (4)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mike (4)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Class average</td>
<td>0.40</td>
<td>0.10</td>
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<td>0.60</td>
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</table>
the particulars of two groups (Groups One and Two) and contrast it with the second implementation cycle’s feedback conversations (Groups Three and Four). We show that these conversations consistently provide opportunities for productive dialectics at the intersections of the curriculum and a content standard, that answer rubrics invariably advance these dialectics, and, at the same time, that these opportunities often require specific teacher facilitation strategies. We contrast four groups’ interactions across these two implementations in order to detail and situate these points within the two design cycles of the study.

**Group One.** Group One participated in the first implementation cycle and included three males—Jake, Scott, and Ryan. The following excerpt is the initial discussion for the focal quiz item. (All names are pseudonyms. Numbers in parentheses indicate pauses in tenths of a second. = indicates latched speech. [---] indicates unclear speech. Non-verbal actions are in parentheses).

**Group One, Excerpt 1**

**Initial statement of individual answers**

Jake: I put the way the light changes.

Scott: I put that (0.5) Cepheid stars (0.5) their brightness their changes are easy to predict.

Ryan: I said the distance stays the same (1.0) which [...] (pointing pen at Scott) Did you make stuff up?

**Synthesizing group answers**

Jake: I put the way the light changes. Um, I guess it would be the same as yours, like I guess if the light doesn’t change a lot then it stays pretty constant unless light has to do with distance.

Ryan: I thought it would be like the star stays there but the brightness changes.

Jake: Right.

Ryan: Instead of moving further and closer to you.

Jake: (Reading) How does it make them useful as distance indicators? (0.6) I guess like the constant distance they stay?

Scott: But most stars stay at a constant distance.

Jake: Yeah.

Ryan: Not necessarily.

**Allusion to answer rubric**

Scott: I don’t know [...].

Jake: (3.2) I don’t know. We’re gonna have to wait for the sheet.

**Re-engaging the item**

Scott: Yeah, like (0.7) like it changes magnitude like the same.

Jake: (8.0) pointing to diagram on quiz Well look this is an example of the Cepheid light curve and the light doesn’t–doesn’t–

This group stated and then discussed their answers, responded to each other’s ideas, worked to reach consensus, referred to set inscriptions (i.e., quiz diagram), and, despite Jake’s suggestion, did not merely wait for “the sheet” (the answer rubric). We argue that this is evidence of their engagement in both the domain and participatory contexts of this activity. We cannot claim to know whether their motivation was to learn the content or to enact the expected participatory routine, but the
initial synthesis and re-engagement demonstrated productive interrogation of their understandings that arrived at a degree of consensus (though never fully realized).

A useful tension appears to have developed about the domain context through their engagement of the participatory context. This group’s articulated understanding of the concepts of distance and magnitude remained unresolved at the end of the exchange. However all three students had elements of accuracy in their stated answers, which their conversation pushed further (as evidenced by Jake’s comparison of his answer with Ryan’s, their ensuing co-construction of a refined understanding of the concept, and Scott’s re-engagement of the concept after Jake’s suggestion to wait for the answer rubric). This productive conversation with an unresolved conclusion left the group well placed to benefit from the answer rubric, which we return to below.

**Group One: teacher influence.** The first cycle teacher’s strategy for participation in student discussion included primarily inserting rhetorical questions and examples. It seemed that the participatory context the teacher was building framed the goals of discussion as mastering conceptual knowledge as opposed to embedding it as a tool within discursive practice. The following excerpt began where Group One’s feedback conversation left off (they had discussed the item together for 31 lines of transcript). The teacher inquired about the group’s progress, and they stated that they “got it wrong” because they had not reached consensus on an understanding yet. This suggested to us that the teacher’s question prompted their shift to a conceptual focus (knowing the “right” answer) from the discursive participatory context they had been engaging (exploring articulated understandings), which they had been doing quite successfully.

**Group One, Excerpt 2**

**Summarizing item**
Teacher: We know that the Cepheid star is a variable star. And it’s getting lighter and brighter in a cycle of about six days from peak to peak.

**Rhetorical question**
Now how might that help us with distance?

**Student response**
Scott: Um, (0.5) you can compare it to other stars I guess, um.

**Rhetorical example**
Teacher: You know the light bulbs that have three different switches and it’ll go from dim to sort of bright? Well if you were reading a book and you put it on dim you would have to get pretty close to read your book good, wouldn’t you.

**Rhetorical question**
But if you put it on the brightest setting could you get farther away?
Jake: Yeah.

**Rhetorical question**
Teacher: So does that brightness and distance kind of have some sort of relationship?
Jake: Yeah.

**Strategy suggestion**
Teacher: That’s sort of what they’re using here since there’s a variation in light and you know that light and distance are related you might can actually work backwards.
The teacher’s moves here included two rhetorical examples to explain the relationship between distance and magnitude with known-answer questions as probes. We argue that these strategies changed the dynamic of this group’s participation as he re-oriented and re-framed the discussion. In hindsight, it does not appear entirely productive as it evoked a conceptual focus rather than the discursive one we had been intending. Realizing that this was probably due to usual teacher practices along with our insufficient professional development, we addressed this concern in our refinements for the second design cycle, which we discuss later.

The following exchange occurred immediately after the teacher left the group and illustrates the unproductiveness of the above exchange.

**Group One, Excerpt 3**

**Summarization of misconception and confusion**

Jake: So if what he’s saying is true with the whole lamp thing, at day zero it’s further away. Then at 3.5 days it’s closer and then back at 5.5 days it’s further away. So he’s saying that every six days, the star moves close to us and then back every six days.

Scott: Yeah.

Jake: *Which still doesn’t make sense* because the further away it is the brighter it should not be.

**Statement of final confusion**

Jake: *I’m stumped man. I don’t understand [---] I understand what he was doing, but I already know that. I got that part.* (5.2) Well to know what a Cepheid variable star is, is not simple.

Jake’s final comment confirms our belief that the teacher’s strategy of inserting generic rhetoric can be unproductive when it does not consider the discursive understanding students had already been developing, especially in a dialogic activity such as this. Despite his confusion, however, we argue that Jake exhibited perseverance in working through the ideas and his misunderstanding with the group. This is the type of discursive interaction that we argue aids understanding that transfers to more formal assessment discourses. Incidentally, as shown in Table 2, both Jake and Scott missed the corresponding examination item on the
pre-examination but answered it correctly on the post-examination. Jake’s score also improved for one of the test items addressing this particular Standard (5.1) from pre-test to post-test.

**Group Two.** Group Two participated in the first implementation cycle and consisted of three females—Amy, Elise, and Kelly. The following excerpt begins as the group starts to discuss the quiz item.

*Group Two, Excerpt 1*

**Statement of individual answers**

Amy: The second part, (reading) what are characteristics of Cepheid stars that make them useful as distance indicators? Um, I just put that they stand out more and they’re used as a marker—like a landmark or whatever.

Kelly: I said that they exert different magnitudes over time and therefore help to determine distances of different objects over time or whatever.

Elise: Yeah, I talked about magnitude too.

This group stated their answers but offered little to no explanation for them, and Kelly’s explanation—the most detailed and accurate of the group—was not taken up for discussion. For these reasons we view this exchange as unproductive engagement in the activity as the group failed to articulate understandings of the concept. Group Two’s conversation did not appear to advance their understanding, and their engagement of the participatory context seemed formulaic and non-invested. We argue that Group Two’s lack of productive discourse was influenced by their lackluster navigation of the activity. Amy and Kelly ended their answers with “whatever” (indexing disengagement); they spent less than four turns of talk on this item (as opposed to Group One’s 31 lines); and Kelly’s response, although well articulated and technically accurate, was not discussed. This contrasted with Group One who discussed the concepts and their understanding, failing to simply wait for something (namely the answer rubric) to happen.

*Group Two: teacher influence.* Similar to his interaction with Group One, the Year One teacher inserted rhetorical examples focused on general conceptual understanding in his conversation with Group Two. Group Two’s unproductive engagement of discourse in the excerpt above points to the potential for productive engagement if the teacher’s influence had redirected this unproductive participatory context. Unlike Group One, however, the teacher’s efforts did not redirect the group’s conversation or alter the activity structure.

*Group Two, Excerpt 2*

**Rhetorical example**

Teacher: Ok, let me throw in a couple of things that these guys said that I thought was interesting. One of the people thought it varied because the distance between us and it varied.

**Rhetorical question**

Do you think that’s part of it or not really?

Elise: No
**Student inquiry**

Kelly: That would explain this though wouldn’t it? [pointing to quiz] But I don’t think that’s it, I think it’s just=

**Continuation of example**

Teacher: =But then one of the other guys said the star itself was getting lighter or brighter. So I don’t—you know.

Elise: Ok.

**Student inquiry**

Kelly: I would think that more cause don’t stars stay pretty stationary?

Teacher: Well now stars are moving in their galaxy too. You know we’re going around our sun, stars are moving, but overall you got to decide is that changing the distance very much between us and them. And then you know the idea of the binary star you know the two stars going around each other.

**Rhetorical question**

That might affect that some too, right?

The teacher began with a rhetorical example and did not engage what the group had (or had not) already established as their understanding. His rhetorical questions were taken up literally by Kelly, who responded with questions and conjectures about the content. However, the teacher continued with his strategy rather than engage Kelly in the type of discursive engagement we were hoping for. We argue that this exchange might have been more productive if the teacher had engaged Kelly’s attempts to work through articulations of specific ideas rather the general conceptual understanding (which we argue the teacher was promoting). This may have allowed him to engage the group in terms of the discourse, and not the concept (via rhetorical questions) to foster a more productive dialectic. However, Group Two failed to engage the concept via the teacher’s formulation. We return to this topic below in our discussion of refinements for the second design cycle and offer facilitation strategies.

The following exchange occurred when the teacher left and illustrates the conversation’s failure to facilitate dialectical engagement of the concept.

*Group Two, Excerpt 3*

**Expressed defeat**

Kelly: So we don’t know it now.

Amy: We don’t know the answer. (silent laugh)

Kelly: And we’re not gonna know it in 5 minutes until somebody explains it to us.

Elise: Yeah.

**Learned helplessness**

Amy: They give us our paper. (answer rubric)

This group seemed resigned to their lack of understanding, which is a markedly different orientation to the activity than Group One exhibited. Group Two’s seeming disinterest and resignation appeared further complicated by the fact that their reasoning was never articulated as a group or with the teacher. The group’s first genuinely co-constructed agreement, unfortunately, was one of resignation that contrasts Group One’s orientation towards the still withheld answer rubric. This leads us to believe that the formative feedback routine was not ideally set up to redress unproductive engagement. In addition, the teacher’s use of the same strategy.
with each group (including the same examples) appeared to detrimentally alter Group One’s participation and failed to redirect Group Two’s unproductive engagement. This leads us to the refinements we made to the second design cycle.

**Improvements after the first implementation.** As mentioned above, we worked to refine teacher facilitation strategies in Year Two based on insights gained in Year One. We prompted the two second-year teachers to use open-ended and reflective questions (e.g., “So what does that idea mean in terms of brightness?”) instead of known-answer, rhetorical questions. We hoped that this would prompt discourse and more opportunities for deepening group understanding. We also provided the students with an explicit four-step routine to guide their feedback conversation, which included: state answer, explain answer, come to group consensus on understanding, and use answer rubric to check understanding. These strategies are both reflected in the Year Two teacher’s interactions with Group Three and Group Four around the answer rubric, even though both leave room for improvement.

**Group Three.** Group Three participated in the Year Two implementation and consisted of three males—Eric, Andy, and Chris. Their feedback conversation began as the teacher approached and asked about their progress. The teacher was present for this group’s entire conversation around this item.

*Group Three, Excerpt 1*

Teacher: What about 2a? **How’d you guys get that?**
Eric: No idea
Andy: I have no idea
Chris: I made something up

**Student articulation of reasoning**

Eric: (Reading) Unlike other variable stars, Cepheid variable changes in brightness periodically. It’s like—it’s periodic instead of like a supernova or, like something.

**Reformulation**

Teacher: Ok so you said it’s more measurable?
Eric: Yes measurable, significantly.

**Open-ended probe**

Teacher: **How do you know that?**
Eric: You measure it. You just look at it. Like the image processing thing. It’s a like a blip every second unlike=

**Reformulation**

Teacher: = So you can see it. So it’s something that’s easily measured. Ok. Alright.

**Focused probe**

Does that graph have anything to do with that?
Eric: Yeah. Graph goes (motioning with arm in upward arc) like that—it’s bright and then (0.3) like you know bright and then some other day—well it’s period pretty much periodic.

The teacher’s strategy in this example includes reformulations of Eric’s articulated reasoning, asking open-ended questions, and forming specific probes based on Eric’s
comments. These teacher facilitation practises created potential for further discourse and understanding (“How’d you guys get that” instead of simply “What did you get?”). By modelling these types of interactive moves, we argue that this teacher’s facilitation strategies created possibilities for improved engagement. While not an optimal feedback conversation in our overall vision (Eric was the only student to contribute), the teacher succeeded in getting him to move further in his articulated understanding. The teacher also reflected on what Eric said, adding on to and reformulating it throughout the interaction. As shown in Table 2, both Eric and Chris missed the corresponding examination item on the pre-examination but answered it correctly on the post-examination.

**Group Four.** This group also participated in Year Two of our implementation and consisted of two females—Nadine and Celia—and two males—Bron and Mike. The following excerpt depicts their initial feedback conversation around the quiz item.

**Group Four, Excerpt 1**

**Statement of answers**

Celia: With them changing brightnesses all the time, it’d be hard to tell the distance because you couldn’t=

Nadine: =You’re supposed to tell how they’re useful. You’re telling why they’re not useful (laughing). Well I guess that means they’re farther apart if they change=

Celia: =No, I’m saying they change brightness all the time which means the distance would be really hard to find.

Nadine: (to Mike) What did you put

Mike: Oh um brightness of=

Celia: =They can’t be useful, rar!

Bron: Their brightness can change so slowly giving a longer time to judge distances.

Nadine: Yeah.

**Co-constructed understanding**

Bron: Giving it=

Nadine: = Giving it a long time for the distance to remain the same or something like that. Sounds alright=

This group’s conversation included highly overlapping and collaborative discussion in which students (mostly) listened to and responded to each other. After Celia’s inaccurate formulation, Nadine quickly redirected Celia with her own claim. While not an accurate claim, Celia explicated her reasoning and demonstrated that she understood at least how Cepheid stars’ brightness varies. Despite the fact that Celia’s fervour thwarted Nadine’s attempt to draw Mike into the conversation, and that her reasoning is inaccurate, her contributions along with Nadine and Bron’s jointly constructed opposing views that we argue constitute a productive engagement with the participatory context. Their conversation resulted in ambiguous conclusions regarding their understandings, which, like Group One, leaves them ripe for the answer rubric. As shown in Table 2, Bron, Celia, and Mike missed the corresponding examination item on the pre-examination but answered correctly on the post-examination. Nadine, Bron, and Mike each also improved for one of
the test items addressing this particular standard (Standard 5.1) from pre-test to post-test.

**Use of the Answer Rubric**

As we mentioned above, Group Four was the only group to productively engage the answer rubric as a tool to further deepen the feedback conversation and students’ discursively developed understandings. As we show in the following excerpts, Groups One and Two did not use the rubric to return to their earlier unresolved articulated understanding (in Group One’s case) or lack of articulated understandings (in Group Two’s case).

*Group One, post-answer rubric*

**Group moves on**

Scott: No for like the Cepheid stars their like the brightnesses change a pattern so they're easy to predict.

Jake: Well I put half of that the way that like-

Ryan: And I just got it totally wrong. (Writes on paper)

*Group Two, post-answer rubric*

**Group moves on to next item**

Amy: Ok and then #2, a Cepheid variable star is a type of star that changes its brightness in a distinctive, regular way. (pause as she reads to herself) Makes it easier to study.

*Group Four, post-answer rubric*

Nadine: We were somewhat right. This one um 2a was like=

Bron: =Cause I mean they're talking about like the corresponding brightness [---] the astronomer to say the absolute brightness of (0.4) whatever. It can be compared to the apparent brightness. I don’t know. (Laughs)

Nadine: They use a—they use a similar—Mmmmm!

Nadine: You can compare it—I just read something from there, the “C one”, they changed over time.

Bron: (Laughs) They change, what? Where are you?

Nadine: Right here, um the-1, 2 the third paragraph. (Official voice) third paragraph, second sentence.

Bron: Second sentence or second line. Variable stars are=

Nadine: =But ya’ll the “C ones” change over—they change because the star changes itself=

Bron: =(Reading) Yeah change in brightness over a period of time because the star itself changes in size and temp.

Celia: Bron can read.

Bron: On the other hand— (Laughs, reads to herself)

Nadine: So does everybody understand to a point where they can look like they understand it. (Laughs)

The qualitative differences in the discourse around the answer rubrics of these three groups is noteworthy. Nadine and Bron animatedly connect what they scanned from the answer rubric to their ambiguous but explicated understanding. Both
students rephrased the content of the answer rubric in their own words and scanned for pertinent information (rather than reading aloud in an automated fashion). None of the groups had demonstrated understanding or even established consensus around the item; however, Group Four problematized their differences in understanding using the rubric. While Group Four’s conversation seems to derail before arriving at an explicit shared understanding, they productively engaged the rubric to complexify its still-emerging meaning.

**Discussion**

This analysis represents one initial foray into the use of discourse analysis to understand and improve participation in feedback conversations by students and teachers and the impact of that participation on individual learning outcomes. It illustrates how a situative theoretical orientation allows researchers to treat individual student performance on individual test items as examples of specific types of discourse, allowing a coherent examination of transfer of understanding across very different ways of knowing.

The above episodes of small group conversation underscore the influences of both teacher facilitation and group dynamics. The impact of the four groups’ interactions contrast differing ways of “doing the science” and “doing the lesson” (Duschl, 2000). The differences in density and productiveness of these episodes of classroom discourse point to the ultimate goal of our programme of research. While we would like all students to develop new ways of enacting and understanding concepts targeted in these conversations, we recognize that this is a lofty goal for researchers or teachers. We have noted improved teacher facilitation and more productive dialectics with answer rubrics (at least for one group) from one design cycle to the next. Also, we saw that the best-intentioned student can become enveloped in a group’s ambivalence (Kelly in Group Two). Conversely, a struggling student can learn from peers by formulating current understanding (e.g., Jake in Group One), and differences in opinion among students can lead to productive disagreements and a stake in the answer rubric (Group Four).

**Implications**

This case study revealed that the role and nature of group discourse and teacher intervention affect the quality of students’ movement along a discursive trajectory from formative feedback conversations to more formal assessment activities. Our analysis illustrated ways that domain and participatory contexts can be taken up through discursive reasoning on certain problems. The varied degrees of learning were reflected both in the groups’ discourse around quiz feedback routines as well as in gains on the examination and the test.

We feel that the specific exchanges of teacher involvement in these excerpts also revealed the ways in which teacher facilitation directly impacted students’ learning as reflected in the ways that it redirected participation, adding or detracting from
discussion and co-constructed understanding. Through all of these discursive turns, a teacher’s role in the participatory context cannot be underestimated. Implications of this study can inform the design and implementation of science curricula and assessment. These insights underscore the importance of balancing the immediate goal of understanding the presented domain content with further removed goals such as grades offered by the more formal content to better foster engagement in scientific inquiry. Our observations of the teacher’s role in facilitating discourse point to the value in framing the dialectical functions of informal feedback conversations as a trajectory for arriving at more formal practises of a domain. We also hope that once students are able to successfully state and argue the rationale behind their answers they will be able to use this practise to engage in other forms of scientific discourse surrounding the examination, and eventually the test. Learning the game, *per se*, of how to act and talk *like* a scientist transcends specific curricula or assessment formats, allowing one to successfully navigate the novel terrain on either of these fronts. This work represents a small but important step in our efforts to support meaningful discourse and learning while increasing high-stakes test scores.

**Note**

1. For more information about these and other Classroom of the Future curricular materials, visit www.cotf.edu.

**References**


