

Uncovering Teachers' Pedagogical Reasoning in Science Discussions

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Abstract: We report on research in progress that examines how teachers reason about and make pedagogical decisions in the context of science discussions. We developed and administered a high-fidelity multimedia survey instrument populated with segments of class discussions and open-ended questions to expose 1) teachers' reasoning about student thinking in science discussions and 2) what pedagogical moves they would make in light of their reasoning to advance the discussion. The findings show distinct qualitative differences in the way novice and more experienced teachers *see* dialogic and conceptual processes in science discussions. They help to identify places where teachers may need support in developing their pedagogical reasoning in science discussion.

Keywords: pedagogical reasoning, science education, classroom discourse

Introduction

Growing evidence shows that when teachers lead students in argumentation (i.e., collaborative problem-solving discussions that externalize student thinking and reasoning), students benefit with steep increases in learning (c.f., Resnick et al., 2015). However, it is rare to find teachers using discursive pedagogy in K-12 science education, despite growing value placed on the role of argumentation for science learning from both research and government initiatives such as the Next Generation Science Standards (McNeill & Pimentel, 2010; NGSS, 2013). Several teacher development interventions on dialogic pedagogy in science have shown that it can take several years before it is possible to see significant changes in the ways teachers use talk to foster conceptual learning in science (Clarke et al., 2013; Osborne et al., 2013). This raises a critical question: why is it challenging for teachers to appropriate dialogic pedagogy to support students' science learning?

In this paper we report on the first phase of a design study to examine teachers' pedagogical reasoning in whole-class science discussions, with the goal of developing targeted support to bridge the gap between teachers' cognition and classroom practice.

Theoretical framework

Recognizing the critical role that teachers play in orchestrating science discussions and the difficulty in doing so, there has been growing interest in teacher professional development as a means by which to make argumentation in science widespread practice (Osborne, 2015). Several studies have focused teacher training on how to elicit specific features of argumentation (e.g., claims, warrants, probing for evidence) to make student reasoning public in order to develop students' conceptual understanding and skills in argumentation (Clarke et al., 2013; Osborne et al., 2013). These studies show that teachers can gain a theoretical understanding of scientific argumentation and 'talk moves' through training, but the uptake of these moves in classroom instruction has been modest. Several studies have found that science teachers have difficulty analyzing written and oral representations of student reasoning and knowing how to respond to them in productive ways, even within the context of professional development (McNeill & Knight, 2013; Levine et al., 2009). In subsequent work, McNeill and colleagues rigorously developed and tested an instrument to assess teachers' pedagogical content knowledge (PCK) of science argumentation (teachers' knowledge of student thinking in science and knowledge of instructional strategies in science argumentation). After piloting and refining their instrument with 103 middle school science teachers, they concluded that teachers' PCK of science argumentation consists of two core abilities - the ability to evaluate and support students in justifying their claims, and the ability to evaluate and support students' transactive reasoning in argumentation (McNeill et al., 2015).

Building on this work, we argue that in order to develop approaches that narrow the gap between a) teachers' theoretical knowledge about facilitating science argumentation and b) their practical action in the classroom, there is a need to understand *how* teachers reason about what happens in science discussions, and precisely *how* their decision making in facilitating discussions is tethered to that reasoning.

In this paper we report on the first phase of a design study on pedagogical reasoning and action in whole-class science discussions in complex social settings. By pedagogical reasoning, we refer to the sense-making processes that teachers are constantly engaged in while facilitating argumentation in class, such as reasoning about student ideas, enacting instructional goals, calling to task their pedagogical repertoire to make instructional decisions in light of their sense-making, and finally, taking action. Following Shulman, (1987), we conceptualize pedagogical reasoning as a facet of the larger construct of teacher cognition, PCK. In this study we focus on understanding the nature of pedagogical reasoning in science discussions to inform the development of an educational technology designed to support teachers in learning how to productively facilitate science argumentation.

The goal of this study was to examine teachers' pedagogical reasoning and decision making (hereafter referred to as *action*) in biology classroom discussions. The questions guiding this study were: 1) *what is the nature of teachers' pedagogical reasoning about science discussions?* and, 2) *what is the relationship between teachers' reasoning about discussions and (intended) actions?* Building on McNeill and colleagues (2015), we developed, piloted, refined, and administered an instrument designed to elicit teachers' tacit reasoning in class discussions by focusing specifically on moments in biology discussion that require a pedagogical action on the part of the teacher. However, in contrast to previous work, a core design principle for our instrument was to preserve the rich, often messy complexity of real classroom interaction data in our instrument. Since teachers have competing demands on their attention during teaching (Levine et al., 2009), our interest was in understanding the nature of teachers' reasoning when the complexity of those interactions were preserved.

Methods

Our instrument consists of hi-fidelity multimedia scenarios constructed from whole-class discussions previously collected as part of a large-scale longitudinal study on Accountable Talk® biology discussions (Clarke et al., 2013; 2015). Since teaching science through scientific argumentation means situating opportunities for argumentation within particular scientific problems (Brown et al., 1989), our scenarios were constructed with segments of discussion bounded within a single lesson in the BSCS biology curriculum – Punnett Squares. To select discussion segments, we reduced the dataset to lessons on Punnett Squares, then used theoretical sampling to reduce the dataset further to segments where students disagreed on the content. We predicted that these sections of lessons would be a hotbed for academically productive talk, as previous research has shown that disagreement yields other productive dialogic interaction (e.g., explanations, elaboration and transactive reasoning) (Howe, 2010). We selected seven such moments as they presented opportunities for teachers' pedagogical reasoning and action, such as: sequences of disagreement between students, expressions of misconceptions, and moments where challenges were issued by the instructor or fellow students.

We developed seven video scenarios to embed in the instrument using the audio recordings from the original dataset and enhanced them with a scenario framing that situates the activities within the flow of the discussions, real-time transcription of the audio during playback (for speaker management), and board representations of the Punnett Squares being discussed (for deictic management). We then developed a set of open-ended questions for each scenario to expose 1) teachers' reasoning about the scenario in terms of students' thinking and its emergence in discussion, 2) evidence teachers could identify to support their interpretation of student thinking, and 3) what they would do next to advance the discussion; e.g., "What do you think is Amir's current level of understanding? What is your evidence?". To further situate teachers reasoning about these scenarios, we imposed a set of instructional goals that fit the lesson for teachers to operate on in their explanations of their reasoning about student thinking and what actions they would take in light of that reasoning. Goal 1 was for students to reason probabilistically about genetic inheritance using Punnett Squares as a tool to calculate probability, and Goal 2 was for students to provide evidence of their reasoning. In this we sought to better understand how teachers were making sense of action in science discussions in terms of proximal and distal goals (proximal = managing moment-to-moment dialogic processes; distal = leveraging dialogic processes towards achieving a conceptual end). All speakers had pseudonyms and we elided any names present in the audio. Audio was not otherwise modified.

We then conducted two design and evaluation cycles of the instrument, and we report on the findings from iteration 2 in the rest of this paper. Teachers were recruited via an email flyer distributed through teacher leaders in two urban high schools that serve diverse populations of students in the United States, and received \$40. Six science teachers responded to the survey (two first year teachers (novices), two 3rd year teachers (mid-level), and two teachers with greater than five years (experienced)). We instrumented several qualitative analyses in order to address our research questions. First, we developed a 5-point scoring rubric to score responses in terms of the extent to which responses diagnosed an opportunity for pedagogical action, and the rationale for the action they proposed (e.g., identifies a misconception vs. identifies which student has a misconception and what that

misconception is). Responses were scored by two raters, with a “very good” interrater reliability score ($\kappa=.88$) calculated on the first two segments. Any disagreements were then discussed. We then used these codes to explore the data with respect to teachers’ level of expertise to examine qualitatively how their reasoning was elaborated on. We report findings below.

Findings

Our analyses produced several key findings. First, with respect to diagnosing decision-points in discussion, experienced teachers were able to successfully diagnose points where a pedagogical decision was required despite the purposely preserved “noise” of the scenarios, scoring a median of 3 (on a scale of 0-4) across scenarios and never below a 2. In addition, although our scenario questions were purposefully open-ended, both experienced teachers identified the same decision-points that our research team had identified when selecting the segments as likely candidates for pedagogical reasoning scenarios. Moreover, one segment was included in the set because it contained only evidence that students were accurately applying and reasoning about the solution. We reasoned this would provide a crucible for examining how teachers reason about conceptual accuracy in discussion in the process of building a larger explanation of genetic inheritance (i.e., do teachers make connections to previous concepts, move on to new concepts, etc.). Experienced teachers’ responses to this scenario showed that they were able to correctly identify the conceptual accuracy of students’ responses. Overall, experienced teachers explicated both their reasoning about the dialogic processes of discussion (e.g., disagreements, challenges, clarifications) and the conceptual processes of the discussion (e.g., the relationship between the proposed genotype and the expressed phenotype).

Students are presenting their thinking about the genotypes of the cats and attempting to support their thinking with explanation of how their genotypes fit the parent cats...Phil was able to see past Aamir's solution to how it could be possible for the orange parent cat could be heterozygous. At no time however did any students express their thinking in probabilities or by referencing evidence beyond the explanation of what they could see. (T1: Experienced)

We found that novices, however, did not explicate their reasoning about segments beyond the general description that students were participating in discussion. These teachers scored a median/mode of 1 (described interaction in general terms), as in T5: “*In this segment there is a small group discussion on inheritance.*”

Mid-level teachers also scored a median of 3, but scores ranged from 1-4. At times they described the interaction rotely, as in T4: “*The teacher gives a prompt. Then one student responds with his answer and explanation. The next student gives his answer and explanation. The teacher then cues the other group members to speak. They agree.*” In the same scenario, T3 identified a specific pedagogical issue: “*The two responding students have obviously different levels of understand[ing], and the class doesn't see the difference.*” In other scenarios, T4 was equally able to articulate such a response. Their expertise at recognizing pedagogical issues appears to be emergent, which may explain their ability to explicate reasoning more substantively at some times but not others.

With respect to pedagogical actions in light of their reasoning, experienced teachers frequently took into account the current state of the class discussion and tied their next steps directly to the problem that they believed was happening, e.g., T2: “*I feel like the students are missing the recessive phenotype and I would want to pull the class back to examining the phenotypes of the adults again.*” Novices, however, generally indicated that they would either continue the current trajectory (e.g., T6: “*I would continue the activity by have the students draw out the Punnett square and discuss what they found*”), or they suggested that they would switch to something else entirely (e.g., T5: “*I would just make sure that the problems are on the board to give them a visual reason to believe it as well.*”). In addition, for every single scenario, novice responses indicated that they believed the distal goals were being met, and their proposed follow-up actions made no connection to these goals. Distal goals were introduced at the beginning of the survey, and again in each scenario accompanying question probes about whether the goals had been met within the segment. Instead, their responses focused on proximal aspects of the interaction and only in very general terms.

Third, with respect to the content, novices provided evidence of lack of understanding of the science content being discussed within scenarios (e.g., excerpts below).

Phil was probably at a slightly lower level of understanding because he believed that the color of the litter was by chance or luck which is a possibility but when there is only heterozygous allele there is no way for there to be any other color other than dark orange. (T6: Novice)

Phil probably has an advanced level of understanding since he was able to see that there was more than one answer and [the] probabilities. (T2: Experienced)

We interpret these differences by experience level as fundamental differences in how teachers *see* the interactions in science discussions.

Conclusions and implications

While the sample size is small, the dataset from this instrument is rich, and the findings indicate there are distinct qualitative differences in the way novice and more experienced teachers *see* dialogic and conceptual processes in science discussions. Mid-level and experienced teachers show greater specificity in their diagnoses of scenarios and rationales for intended actions in light of problems they identify. In addition, mid-level and experienced teachers demonstrated an adeptness to weed through the ‘noise’ of classroom discussions and attend to student thinking. Novice teachers were not able to identify moments where there were conceptual impasses in discussion that merit the intervention of the teacher, and the strategies that they propose for moving discussions forward are general rather than content driven. However, we caution the conclusion that novices lack pedagogical reasoning or PCK. We think these findings provide evidence that novice teachers’ reasoning attends primarily to surface features of classroom interaction. Thus, these findings raise the question of the extent to which novices’ decision making is tethered to substantive features of class discussions.

These findings help to identify places where teachers may need support in developing their pedagogical reasoning in science discussions. In addition, they show that dexterity with dialogic processes may not be the only, or most pressing challenge for teachers’ use of dialogic pedagogy. Rather, issues may lie in teachers’ understanding of the content, and thus interfere with their ability to assess students’ evidence and claims (proximal goals) and then efficiently use these processes towards achieving a conceptual end (distal goals).

This study contributes to growing scholarship in the learning sciences on teacher learning processes. We provide insight into teachers’ reasoning processes engaged in the midst of dialogic discussions in science, and thus some of the challenges of facilitating dynamic discourse processes. In future work, we seek to leverage insights from this instrument to develop an adaptive educational technology to support teachers’ learning.

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Acknowledgments

This work was conducted with the support of NSF-CISE-IIS #1464204 and the IES, U.S. Department of Education grant R305B090023. We would also like to thank Lauren B. Resnick for her support for this project.