The Instructor's Role in Promoting Student Argumentation in an Inquiry-Oriented Classroom

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Abstract

Four class sessions in inquiry-oriented differential equations were analyzed to understand the role of the instructor in supporting student argumentation. Three coding schemes were developed to identify arguments, characterize instructor utterances, and connect instructor talk to argumentation goals in inquiry-oriented instruction. Results show that students generated the majority of arguments tendered in the four class sessions. The instructor used questions to generate student arguments more than other types of instructional utterances (e.g., revoicing, telling). Nearly half of the instructor's utterances were aligned with argumentation goals. More detailed examples of student-generated arguments in the class sessions are being constructed to illustrate the flow and function of different goal alignment routines to understand what it is that the instructor did during class to promote student argumentation.

Keywords: Inquiry, Teaching, Active learning, Case study

Mounting research evidence points to the benefits of active learning in improving student outcomes in undergraduate STEM courses compared to more traditionally taught courses (e.g., Freeman et al., 2014; Kogan & Laursen 2014; Larsen, Johnson, & Bartlo, 2013; Rasmussen & Kwon, 2007). Recently, professional societies explicitly recognize the need for faculty to increase their use of active learning to improve student success (Saxe & Braddy, 2015). But to what extent do mathematics departments across the country value active learning and actually use various active learning strategies? In a recently completed census survey of all mathematics departments that offer a graduate degree in mathematics, researchers found that 44% of departments report that active learning is very important in their Precalculus through Calculus 2 courses but only 15% say their program is very successful in implementing active learning (Apkarian & Kirin, 2017). Moreover, recent comprehensive literature reviews (Larsen, Marrongelle, Bressoud, & Graham, 2017; Rasmussen & Wawro, 2017) reveal that very few studies provide detailed analyses of what instructors actually do to create and sustain active learning classrooms. All of this points to the need for in depth case studies of how instructors successfully implement active learning in undergraduate mathematics classes. The research reported here begins to address this pressing, national need.

The analysis presented here focuses on a specific active learning classroom, in particular an inquiry-oriented differential equations class. We define inquiry in terms of three principles: student deep engagement in mathematics, peer to peer interaction, and instructor interest in and use of student thinking (Rasmussen, Marrongelle, Kwon, & Hodge, in press; Rasmussen & Wawro, 2017). This definition of inquiry follows from over a decade of work in creating and investigating active learning classrooms in undergraduate classrooms (Rasmussen & Kwon, 2007; Rasmussen & Marrongelle, 2006) and parallel framing of the inquiry based learning movement (Laursen, Hassi, Kogan, Hunter, & Weston, 2015). At the intersection of deep engagement in mathematics and peer to peer interaction is argumentation, where argumentation refers to classroom discussion featuring significant mathematics, conjectures, reasoning to support conjectures, and students making sense of others' reasoning. In keeping with this focus, we chose for our analysis four days in an inquiry-oriented differential equations class because on these four days students made considerable progress on debating what graphs of solutions to a system of two linear homogeneous differential equations in the phase plane look like and on justifying their conclusions. In other words, argumentation was a distinguishing feature of this class and hence provides an opportunity to unpack the role of the instructor in initiating and supporting student debate. In particular, we address the following research questions:

1. To what extent did the instructor and students contribute to arguments and what was the nature of their respective contributions?
2. What did the instructor do to promote student argumentation?

Background

The role of student argumentation in mathematics classrooms has a long history in mathematics education reform, both at the K-12 and post-secondary levels. For example, in the late 1980's Cobb and colleagues investigated how classroom argumentation supported student learning and intellectual autonomy in elementary school classrooms. They argued that classroom argumentation provides "opportunities for children to articulate and reflect on their own and others' mathematical activities" (Cobb, Yackel, & Wood, 1989, p. 126). These researchers also examined the role of the teacher in supporting student argumentation, leading in part to the articulation of social and sociomathematical norms (Yackel & Cobb, 1996) and how teachers initiate and sustain productive discursive norms that support argumentation (Wood, Cobb, & Yackel, 1990). This work was later extended to the university setting with further articulation of the role of the instructor (Yackel, Rasmussen, & King, 2000; Rasmussen, Yackel, & King, 2003). Part of this extensive literature has also included the elaboration and extension of particular social norms for argumentation in terms of four broader goals for inquiry-oriented instruction and specific teacher prompts that can function to realize these goals. The four argumentation goals are: (1) getting students to share their thinking, (2) helping students to orient to and engage in others' thinking, (3) helping students deepen their thinking, and (4) building on and extending student ideas (Rasmussen, 2015; Rasmussen, Marrongelle, Kwon, & Hodge, in press).

At the university level, research is just beginning to provide in depth portraits of what inquiry-oriented instruction actually looks like and what instructors do on a daily basis to promote argumentation. For example, one of the studies that examined effective instructional practices in differential equations focused on the instructor-student interaction patterns that facilitated students' reinvention of a bifurcation diagram (Rasmussen, Zandieh, & Wawro, 2009). These researchers identified three instructor "brokering" moves that forged connections between the different small groups, the classroom community as a whole, and conventional terminology and notations of the broader mathematical community. This work resonates with the fourth argumentation goal, building on and extending student ideas. In other work examining instructor-student interactions that contributed to significant student progress in creating, interpreting, and using phase portraits, Kwon et al. (2008) identified and illustrated four functions of instructor revoicing (O'Connor & Michaels, 1993). In this analysis, revoicing was shown to function in multiple ways in support of argumentation - as a binder of ideas among students, as a springboard for new ideas, for ownership of ideas, and as a means for socialization into the discipline of mathematics. These functions resonate with argumentation goals two and three.

In inquiry-oriented classrooms instructors need to decide when and how to insert information, formalize students' informal ideas, and make connections to related mathematics in the midst of students exploring ideas and doing mathematics. Doing so requires a blend of mathematical expertise, pedagogical knowledge, and pedagogical content knowledge. In a case study of two mathematicians implementing an inquiry-oriented differential equations curriculum, Rasmussen and Marrongelle (2006) identified two different ways that inquiry-oriented instructors connected to student thinking while moving the mathematical agenda forward – transformational records and generative alternatives. Transformational records are defined as notations, diagrams, or other graphical representations that are initially used to record student thinking and that are later used by students to solve new problems. Generative alternatives are defined to be alternate symbolic expressions or graphical representations that a teacher uses to foster particular social norms for explanation and that generate student justifications for the validity of these alternatives. Johnson (2013) illustrates other ways that instructors can build on and extend student thinking. In particular, Johnson identified a variety of ways in which two abstract algebra instructors interpreted student ideas, analyzed and evaluated these ideas, and made connections between students' ideas and conventional mathematics.

In more recent work, Kuster, Johnson, Keene, and Andrews-Larson (in press) specify four components of inquiry-oriented instruction: generating student ways of reasoning, building on student contributions, developing a shared understanding, and connecting to standard mathematical language and notation. Each of these components, which connects well with the four goals for argumentation, are further refined by specifying practices that support each component. These components and practices are culled from the K-16 literature and their own work supporting and studying inquiry-oriented teaching in abstract algebra, linear algebra, and differential equations. As this emerging body of research focused on the work of inquiry-oriented instruction suggests, the work of instructors in inquiry-oriented classrooms goes well beyond the typical teaching preparation that mathematicians receive. In depth case studies of such work, as one in this report, can offer useful practical and theoretical accounts of practice.

Methodology

Data for this analysis comes from four class sessions in an inquiry oriented differential equations class. These sessions were part of an eight-week classroom teaching experiment. Data sources consisted of video recordings of whole class and small group discussions, researcher field notes, and copies of student work. We began the data analysis by making complete transcripts of all whole class discussions from the four classroom sessions.We engaged in three passes of coding. In the first pass, we conducted a Toulmin analysis of all whole class discussion. In the second and third passes, all instructor utterances were coded for the nature of the instructor utterance. The second pass focused on the type of utterance (referred to as talk move) and the third pass focused on the alignment of the utterance with the four argumentation goals. Details on each of these passes follows. We are currently coordinating these three passes to develop a detailed, empirically grounded portrait of how this instructor promoted student argumentation. This preliminary report therefore focuses on results related to the first research question.

Toulmin coding: In his seminal work, Toulmin (1969) created a model to describe the structure and function of an argument. The core of an argument consists of three parts: data, claim, and warrant. In any argumentation, the speaker makes a claim and presents evidence or data to support that claim. Typically, the data consist of facts that lead to the conclusion that is made. In order to clarify what the data has to do with the conclusion, a person might also present a warrant that serves as a kind of bridge between the data and the conclusion. Often, warrants remain implied by the speaker and are elaborations that connect or show the implications of the data to the conclusion (Rasmussen & Stephan, 2008). Backings, when offered, provide legitimacy for the core of the argument (that is, the data-claim-warrant).

Videotaped data of the four class sessions and transcripts were reviewed by a group of eight mathematics education researchers and initial arguments identified according to Toulmin's model of argumentation. In particular, elements of claim, data, and warrant needed to be identified and present to be considered an argument. Identification of the arguments was done for a portion of the video data as a whole group. The remainder of the video data was coded in smaller groups. The groups would reconvene as a whole in order to review problematic data or interesting episodes. The collaborative coding process enabled shared interpretations of the codes and decreased instances of interpretations not grounded in the video data. Authorship of an argument was determined by who offered the justification (i.e., data, warrant or backing). Authorship could be attributed to the instructor, a student, or jointly constructed by the instructor and students.

Talk move coding: A coding scheme was then developed as we observed video and simultaneously highlighted the teacher's discourse in the transcripts. We broke what the instructor said into identifiable utterances that served a different function. An utterance is not a conventional unit, like the sentence, but a unit nonetheless in the sense that it is marked out in the boundaries of speech (Bakhtin, 1986). We refined and revised our coding scheme of teacher utterances based on review of the literature (e.g., Forman et al, 1998; Krussel, Edwards, & Springer, 2004; Lobato et al, 2005; Mehan, 1979) and multiple passes through our data. The final coding scheme consisted of four main codes: revoicing, questioning/requesting, telling, and managing. Each of these main codes had four subcodes. Full descriptions of the codes can be found in (Rasmussen, Marrongelle, & Kwon, 2009). We used problematic or especially interesting episodes to sharpen and refine the coding scheme and a collaborative, iterative process to share and defend interpretations of the video and corresponding transcripts. In addition, we explained our coding scheme to a mathematics education graduate student who then independently coded all transcripts, resulting in over 80% agreement.

Goal alignment coding. Recall that the four argumentation goals for inquiry-oriented instruction are: (1) getting students to share their thinking, (2) helping students to orient to and engage in others' thinking, (3) helping students deepen their thinking, and (4) building on and extending student ideas. In this pass through the data, we aligned the instructor's discourse with these four goals for inquiry-oriented instruction. We did not attempt to make judgements about the thinking or rationale of the instructor; rather, we attempted to align the instructor's speech with how the speech functioned in furthering argumentation in the classroom. Three mathematics education researchers coded the data independently, and discussed differences to reach 100% coding agreement.

Sample Results

We begin with a top level view of who was responsible for arguments and the nature of the instructor's contributions. As shown in Table 2, the students (Student) gave 35 of the 52 of the arguments (67%), with another 7 of the 52 arguments (13%) being co-constructed between students and the instructor (S&I). Clearly the instructor was not the primary source of justifications for argumentations tendered.

Day	**Student**	**Instructor**	**S&I**	**Total**
4/18	6	3	0	9
4/20	5	3	4	12
4/22	2	2	0	4
4/25	22	2	3	27
Total	**35**	**10**	**7**	**52**

Table 2. Number of arguments given in whole class discussions

To gain insight into what else he was doing we also examined the instructor's utterances for frequency at which he used revoicing (R), telling (T), Questioning/requesting (Q), and Managing (M). As shown in Table 3, the instructor used questioning more than the other types of utterances (approximately 37% of his utterances) over the four days. The other utterances types – revoicing, telling, and managing – were about equally represented (approximately 20% each). The full analysis will look more closely at the role these utterances in the production of arguments, but preliminary analysis points to the key role of questioning/requesting and revoicing (which comprise nearly 60% of the utterances.

Day	R	T	Q	M	Total
4/18	16 (25.4)	12 (19)	23 (36.5)	12 (19)	63
4/20	8 (25)	8 (25)	8 (25)	8 (25)	32
4/22	6 (20)	8 (26.7)	12 (40)	4 (13.3)	30
4/25	20 (20)	20 (20)	44 (44)	16 (16)	100
Total	**50 (22.2)**	**48 (21.3)**	**84 (37.3)**	**40 (17.8)**	**225**

Table 3: Total number of instructor utterances per day

Further insight into the function of the instructor utterances is revealed by examining how each utterance relates to the four argumentation goals. Recall that the four argumentation goals are: (1) getting students to share their thinking, (2) helping students to orient to and engage in others' thinking, (3) helping students deepen their thinking, and (4) building on and extending student ideas. Table 4 shows the frequency of utterances that aligned with each of the four goals, as well as the number of utterances that were not aligned with any of the four argumentation goals.

Day	G1	G2	G3	G4	No G	Total	G/Tot
4/18	13	6	7	7	33	66	50%
4/20	1	5	2	4	17	29	41%
4/22	4	1	3	1	20	29	31%
4/25	21	12	7	8	56	104	46%
Total	**39**	**24**	**19**	**20**	**126**	**228**	**45%**

Table 4: Alignment of instructor utterances with argumentation goals

There were a total of 102 total utterances that were argumentation goal-aligned. Approximately 38% of these were aligned with goal 1, getting students to share their thinking. This makes sense because this is the first step for students to explicate their reasoning. The percentage of goals 2-4 were fairly equally distributed, ranging from 19% to 23.5%.

By providing detailed examples of student-generated arguments from initiation to conclusion, we will illustrate the flow and function of different goal alignment routines to understand what it is that the instructor did during class to promote student argumentation, moving beyond simply coding for questions or revoicing. In one such detailed example we will discuss how the teacher, making use of a generative alternative (Rasmussen & Marrongelle, 2008), supports three student arguments about solutions to a system of differential equations. This rich example provides a prototype for how instructors can enact this particular global strategy for promoting student argumentation. We anticipate identifying other prototypes in the full report.

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