A new perspective to help analyze argumentation in an inquiry oriented classroom

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Using argumentation to help understand how learning in a classroom occurs is a compelling and complex task. We show how education researchers can use an argumentation knowledge construction framework (Weinberger & Fischer, 2006) from research in online instruction to make sense of the learning in an inquiry oriented differential equations classroom. The long term goal is see if there are relationships among classroom participation and student outcomes. The research reported here is the first step: analyzing the discourse in terms of epistemic, social, and argumentative dimensions. The results show that the epistemic dimension can be better understood by identifying how students verbalize understanding about a problem, the conceptual space around the problem, the connections between the two and the connections to prior research. In the social dimension, we can identify if students are building on their learning partners' ideas, or using their own ideas, and or both.

Key words: inquiry, argumentation, knowledge, differential equations discourse

Discourse, argumentation, and how to codify and analyze them in collegiate mathematics is in ongoing study in Research on Undergraduate Mathematics Education. Much of the research has been about discourse in the classroom (for example: Lee et al., 2009; Mesa, 2010; Stephan & Rasmussen, 2002), teacher questioning, and other pedagogical moves in the classroom (Nicol, 1998; Moyer & Milewicz, 2002). This work has moved the field forward and provided ways for mathematics instructors to reflect on their teaching and classrooms in productive ways. However, much of this work has been more at the level of identifying the kinds of language that students and teachers use. There is still a need for research about the complex relationships between how students participate in a classroom and achievement. This is important for the growing call for improvement of undergraduate STEM Education (see [Termos, 2011] for one call).

In this report, we offer results about classroom argumentation from a different point of view. The results are part of an ongoing research project where we are hoping to relate classroom argumentation to student achievement in an active learning environment. The call for more work on connecting classrooms and student outcomes has come from several areas, and some are already reporting on it (Cazden & Beck, 2003; Singh, Granville, & Dika, 2002). Additional work has been more generally focused on "active learning" STEM classrooms (e.g., Freeman et al., 2014) and shows that there is building evidence that students that are more active in classrooms perform better on tests. For example, a recent meta-analysis about active learning in undergraduate STEM classes found that students in active learning classrooms earned higher grades (Haak, HilleRisLambers, Pitre, & Freeman, 2011).

Our larger research question is: How does students' class participation relate to student achievement? First, we are trying to more carefully define discourse and argumentation, particularly by evaluating the actual content of the verbal exchanges among students and teachers. The research question that we answer is: How can we use a framework on argumentative knowledge construction to characterize students' contributions to an inquiry-oriented (IO) undergraduate mathematics class?

Argumentation Knowledge Construction Framework

We have adopted a framework used to analyze online scripts (when students use discussion boards, etc. in an asynchronous setting). In their 2006 paper, Weinberger and Fischer offer the following theory about constructing knowledge by argumentation:

> Argumentative knowledge construction (AKC) is based on the assumption that learners engage in discourse activities and that *the frequency of these discourse activities is related to knowledge acquisition.* Learners construct arguments in interaction with their learning partners in order to acquire knowledge about argumentation as well as knowledge of the content under consideration (Andriessen, Baker, & Suthers, 2003). This *definition of argumentative knowledge construction includes that discourse activities on multiple process dimensions may facilitate knowledge acquisition*. Analyzing and facilitating argumentative knowledge construction on multiple process dimensions may extend and refine our understanding of what kind of student discourse contributes to individual knowledge acquisition (van Boxtel & Roelofs, 2001). (p. 73, italics added)

This conception of knowledge acquisition and how it is part of discourse activities resonates with the notion that learning is a social activity (Wenger & Lave, 1991) and that classrooms are where learning may take place (Yackel & Cobb, 1996). It shows a different perspective, in that it discusses knowledge acquisition, something that is very difficult to identify and measure.

The original framework consists of four dimensions: participation, social mode, epistemic, and argument. The participation dimension is two-fold; quantity of participation describes whether learners participate at all, while heterogeneity of participation describes whether they participate equally. For the social modes of co-construction, highly related to knowledge acquisition, characterizes to what extent learners make reference to contributions of other learners in class. The epistemic dimension goes beyond the participation dimension which confirms quantity; it examines the content of learners' contributions by considering how learners work on the task at hand. Lastly, the argument dimension holds the notion that learners encounter difficult problems, and must balance arguments and counterarguments to ultimately find solutions to problems. For the purpose of this analysis, we excluded the first dimension as we felt that we can include that as we inspect the coding of the other three; participation will be evident and the number of talk turns was the most important aspect of our work.

A few additional modifications arose during analysis (See Table 1). The term 'learning partner' is used to describe anyone in the classroom participating in the development of the mathematics, including the instructor.

Table 1

AKC Framework, adapted from Weinberger and Fischer (2006)

Dimension	Categories of Discourse by Learning Partners	Brief Description
Social Mode	Externalization (EXT)	Articulating thoughts to the group

	Elicitation (ELI)	Questioning the learning partner or provoking a reaction from the learning partner
	Quick consensus building (QCB)	Accepting the contributions of the learning partners in order to move on with the task
	Integration-oriented consensus building (IOCB)	Taking over, integrating and applying the perspectives of the learning partner
	Conflict-oriented consensus building (COCB)	Disagreeing, modifying or replacing the perspectives of the learning partners
Argumentation	Argument (ARG)	Statement put forward in favor of a specific proposition
	Counterargument (COU)	An argument opposing a preceding argument, favoring an opposite proposition
	Integration (reply [RPY])	Statement that aims to balance and to advance a preceding argument and counterargument
	Non-argumentative moves (NAR)	Questions, coordinating moves, and meta-statements on Argumentation
Epistemic	Construction of problem space (CPS)	Learners relate case information to case information within the problem space with the aim to foster understanding of the problem
	Construction of conceptual space (CCS)	Learners relate theoretical concepts with each other and explain theoretical principles to foster understanding of a theory
	Construction of adequate relations between conceptual and problem space (CAR+)	Applying the relevant theoretical concepts adequately to solve a problem. Learners relate theoretical concepts to case information.
	Construction of inadequate relations between conceptual and problem space (CAR-)	Applying theoretical concepts inadequately to the case problem. Learners may select the wrong concepts or may not apply the concepts according to the principles of the given theory
	Construction of adequate relations between prior knowledge and problem space (CRP+)	Applying concepts adequately that stem from prior knowledge rather than the new theoretical concepts that are to be learned
	Construction of inadequate relations between prior knowledge and problem space (CRP-)	Applying concepts inadequately that stem from prior knowledge rather than the new theoretical concepts that are to be learned
	Non-epistemic activities (NEA)	Digressing off-topic

Methods

Setting and Participants

This study took place during an IO differential equations course for teachers working to earn a master's degree in Mathematics Education. The course was held in the summer at a large southeastern university. Twenty-one students participated in the course, which was taught by a professor experienced in teaching inquiry mathematics courses. The student population was comprised of students seeking a master's degree in Mathematics and Mathematics Education and doctoral students in Mathematics Education. Some of the students had previously taken undergraduate differential equations; however, such coursework was not a prerequisite for the course and the majority of the students indicated that they were starting with minimal or no knowledge of differential equations.

The course met three times a week for two and a half hours in a classroom designed for group work. The classroom had tables where the students sat in assigned groups which were changed at least once a week. The class was taught using the tenets of (IO) instruction (Rasmussen & Kwon, 2007). This meant that students worked on research-based tasks to reinvent the mathematics of the course. The students inquired into the mathematics, working in cycles of small group and whole group discussion spaces. The mathematics involved using differential equations to model real world situations, and understanding the analytical, qualitative, and numerical methods to solve. The students took a pretest and posttest to assess conceptual understanding of the material. Additionally, there were weekly conceptual and procedural homework assignments and two exams.

Data Collection

Each class session was video recorded by a researcher with two cameras, one in the back and another on the side near the front of the room. For this report, we chose one hour of whole-class discussion from four class sessions that occurred before the midterm exam, three in the early part of the course and one the day before the midterm. In order to capture a representative glimpse of the contributions made by the learning partners, we randomly selected one of the 15-minute time moments in the class to use as our beginning time. From that time period, the next full hour of whole-class discussion was transcribed for coding. The transcriptions were divided into talk turns; we define *talk turns* as a single utterance made by any of the learning partners. The instructor's talk was not transcribed verbatim, but all other talk was.

Data Analysis

Two members of the research team coded each talk turn using the transcripts of whole-class discussions by using the descriptors from the framework. With the exception of the professor under the epistemic dimension (as the instructor was assumed to not be constructing new mathematical conceptions), each learning partner's talk turns were coded for epistemic, social, and argument dimensions according to the framework identified above. If the two researchers' codes were not in agreement, the third researcher gave the talk turn its final code, breaking the tie or providing a new code. In order to establish reasonable agreement between the two coders a trial coding was conducted for one of the class sessions. Originally, the two coders had poor agreement (see Table 2 for July 5, Argumentative). As a result, the three researchers spent 10 hours discussing coding discrepancies, clarifying language that was not used the same in another research field and modifying when it did not seem to be appropriate for whole class in-person discussions.

Table 2

Inter-rater reliability by class date and dimension

Day	Epistemic	Social	Argumentative
July 2	80.58%	77.70%	68.35%
July 3	76.22%	78.32%	60.14%
July 5	73.65%	67.70%	48.60%
July 16	81.63%	89.12%	80.95%

As shown above, the interrater reliability increased dramatically after the hours of discussion. The days were coded in the following order: July 5, July 3, July 2, July 16. After the coding, all the ties were broken and analysis began.

Results

We present the results of our coding, relationships among the codes that can be identified statistically, and a discussion of our experience with the framework and its utility for codifying argumentation in a classroom setting. Table 3 depicts the compilation of all codes given to all talk turns from students only. The 8 in the top section of the table indicates that 8 student talk turns were coded with the chain, CPS-ELI-NAR, indicating that students were asking authentic questions about the problem space 8 times during the 4 hours of whole-class discussion. Notable values include the 26 talk turns coded with CAR+ and IOC in the epistemic and social dimensions. These codes indicate that students made adequate connections between the problem and concept spaces while building from previous students' thoughts. These talk turns made up roughly 46% of the turns coded CAR+. Another notable value is the 102 talk turns coded as blank in all three dimensions. These talk turns make up nearly a quarter of student contributions, and illustrate the times in which students displayed Quick Consensus Building. Comments such as, "Right," or, "I agree," were exemplars of quick consensus building.

Table 3
Number of each code sequence for student contributions

	CPS	CCS	CAR-	CAR+	CRP-	CRP+	NEA	(blank)	Grand Total
ELI									
ARG	2	1	1					1	5
COU	1	1			1	2			5
NAR	8	5	1	1	1			18	34
RPY	2	4		1				2	9
(blank)								1	1
ELI Total	**13**	**11**	**2**	**2**	**2**	**2**		**22**	**54**
IOC									
ARG	4	3		3		2			12
COU	5			3	1				9
NAR								1	1
RPY	14	7	1	20		2		3	47
IOC Total	**23**	**10**	**1**	**26**	**1**	**4**		**4**	**69**
COC									
ARG								1	1
COU	7	6	1	4				1	19
NAR								1	1
RPY	5	2	1			1		1	10
COC Total	**12**	**8**	**2**	**4**		**1**		**4**	**31**
(blank)									
ARG	34	10	2	9		1		2	58
COU	11	6	2	4		1		1	25
NAR	6				1		1	9	17
RPY	33	13	2	12		4		12	76
(blank)	7						6	78	91
(blank) Total	**91**	**29**	**6**	**25**	**1**	**6**	**7**	**102**	**267**
Grand Total	**139**	**58**	**11**	**57**	**4**	**13**	**7**	**132**	**421**

To further display student contributions to discourse, we provide Figures 1 and 2. These figures display the number of talk turns by each student (pseudonyms) that were assigned each code from the Epistemic and Social dimensions (respectively). In Figure 1, it can be seen that many of the contributions by students were focused on constructing the problem space. However, for students with more than 20 talk turns, a bulk of their contributions made adequate connections from concepts to problems. Excitedly, inaccurate connections from prior knowledge or between concept and problem spaces were student contributions that occurred least often.

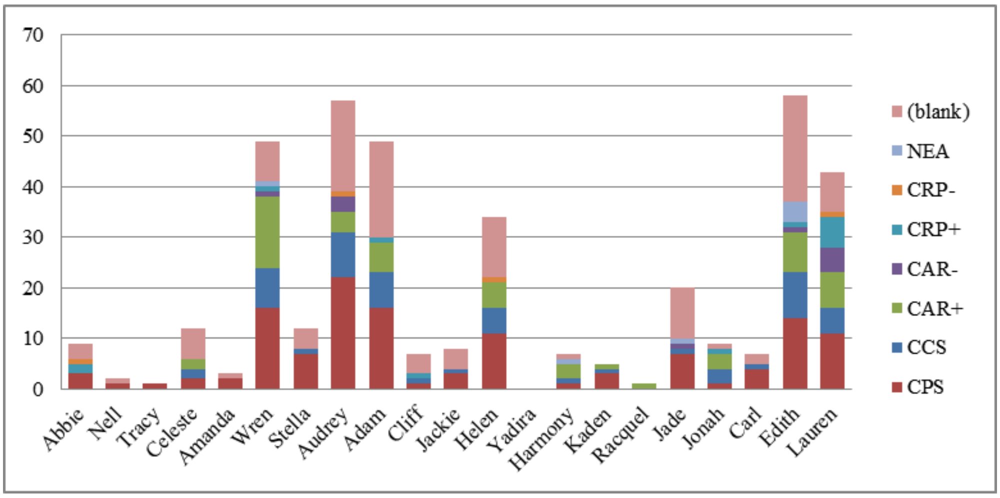

Figure 1. Epistemic codes by students.

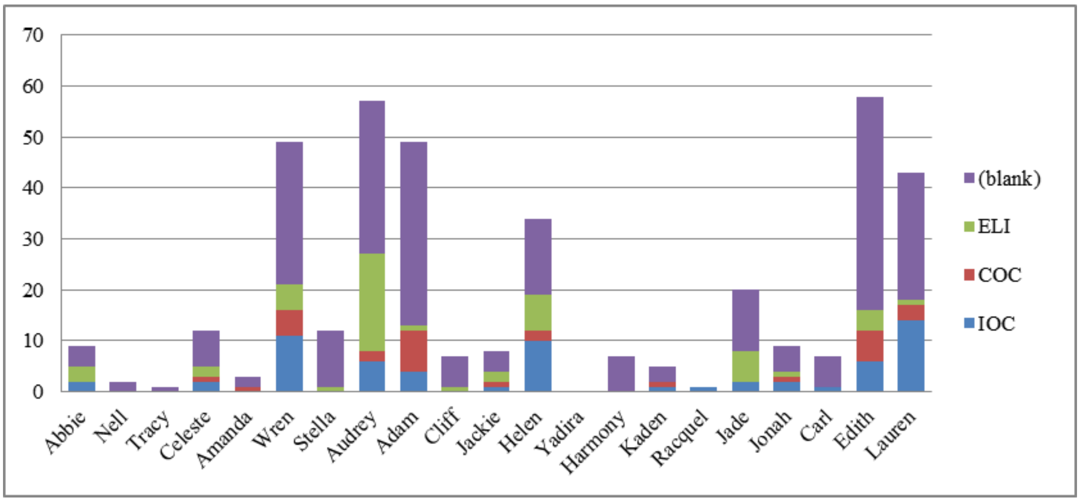

Figure 2. Social codes by students.

Together, Figure 2 and Table 3 respectively illustrate the frequency and source of the blanks from the social dimension. From a social standpoint, we noticed that the more vocal students had an abundance of IOC and COC. In contrast, the less vocal students had most of the blanks for these categories with the social dimension. All students but one (Racquel) had blanks for their talk turn codes, which may indicate quick consensus building, a code we decided to not consider in analysis. Students were either constructing the problem space, quick consensus building, or externalizing a thought – without providing much to the argument. The framework for argumentative knowledge construction used here was originally used on scripts from asynchronous online discussions. However, we found the framework very useful as the dimensions of epistemic, argument, and social were highly evident in active and more traditional classrooms (Weinberger & Fischer, 2006). Following are some issues we found.

First, the coding is exceptionally time consuming. After transcription, for the 6 hours we coded, the two coders spent approximately 42 hours coding and another 10 hours breaking the ties. We also spent 12 hours meeting to refine, modify, and agree on descriptions of the codes. We believe the results are accurate and useful, but considering just the coding, not the preparation work, this means that each hour of class took about 16 hours to complete the coding only, a significant time commitment.

Secondly, we had to make modifications to the knowledge framework in some key (good) ways. We were able to watch the class videos and see nuances that were not present during the original framework development. There were many places where graphs and tables were being discussed, and it was sometimes hard to interpret the words, but we felt that the videos were an important resource for this. We also had samples of student work to help analyze their knowledge construction on the research-based tasks implemented in the course.

Third, we found that thinking in terms of problem space, conceptual space, and prior knowledge was a very helpful way to determine how students were developing their ideas in terms of the epistemic dimension. We have seen other work in this area (Sfard, 1998), but this seems particularly effective with understanding the actual construction of knowledge. Connected to this, thinking about the way students either express their own thinking and/or build on others in a social dimension helped us see how this actually occurs in an (IO) environment. The argument dimension was the least useful at this point; it appeared to be the most difficult to code and find agreement. Ultimately, we saw few connections. Future work might involve only considering the epistemic and social dimension.

Conclusion

In summary, this framework is a new valuable tool that can help us understand knowledge acquisition of students in all mathematics classrooms, not just at the undergraduate level. The educational community outside of mathematics education can provide new and effective ways to do research. The framework allows us to identify when students are building on each other's knowledge and bring in their own ideas. It also helps show when students are thinking about a given problem, the conceptual space behind it, and previous knowledge used to solve the problem. Although time consuming, we propose this as an effective tool to analyze knowledge development in an active learning classroom. The next step is to take this information and see how it connects to student outcomes in terms of homework, projects, tests, etc. By thinking about how our students participate in a more focused way, we can provide instructors with ways to think about implementing and improving inquiry and other active learning situations.

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