USING TOULMIN'S MODEL TO DEVELOP PROSPECTIVE TEACHERS' CONCEPTIONS OF COLLECTIVE ARGUMENTATION

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As creating and critiquing arguments becomes more of a focus in mathematics classes, teachers need to develop their abilities to facilitate productive arguments. Toulmin's (1958/2003) model of argumentation has been useful in analyzing arguments in mathematics education research, raising the question whether it would assist mathematics teachers as well. In this study, we examine how using the model affected prospective secondary teachers' development of conceptions of collective argumentation. Our findings suggest that Toulmin's model facilitated appropriate understandings of what collective argumentation looks like in the mathematics classroom and provided the prospective teachers with a lens for analyzing their observations of practice. This study suggests the use of Toulmin's model in teacher education can be a promising step in helping teachers develop their conceptions of collective argumentation.

Keywords: Classroom Discourse, Teacher Education-Preservice, Instructional activities and practices

Mathematics education researchers and policymakers have called for increased student participation in argumentation in mathematics classrooms (e.g.; Foreman, Larreamendy-Joerns, Stein, & Brown, 1998; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; Yackel & Cobb, 1996). However, most prospective secondary teachers (PSTs), who continue to learn mathematics through traditional instructional practices (Stigler & Hiebert, 1999), lack the experience of engaging in argumentation in the mathematics classroom as envisioned by those calling for it. Consequently, mathematics teacher educators are tasked with developing PSTs' conceptions of what collective argumentation is and what it should look like.

A complicating factor is that the term *argument* may be interpreted in various ways in our everyday usage of the term (e.g. inquiry, persuasion, negotiation, or disagreement), with the most common interpretation involving conflicting points of view. Contrary to this popular interpretation of the term, collective argumentation in mathematics classrooms is generally characterized by a group of students and the teacher working collaboratively to establish the veracity of a claim. Given the multiple meanings of the term *argument*, it is unlikely that PSTs share a common understanding with each other or with mathematics teacher educators as to what is being asked of them regarding argumentation in the classroom.

Research suggests that facilitating mathematical discussions is difficult for teachers (e.g. Hufferd-Ackles, Fuson, & Sherin, 2004; Stein, Engle, Smith, & Hughes, 2008). Most PSTs have little experience with participating in productive mathematical discussions, and they, like experienced teachers, will likely struggle to master the nuances of facilitating these discussions. This highlights the need for mathematics teacher educators to develop more effective ways to

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support the development of PSTs' abilities to facilitate and support collective argumentation and for research to determine how PSTs learn to support and facilitate productive collective arguments. The purpose of this paper is to examine prospective secondary mathematics teachers' developing conceptions of collective argumentation as they worked through an instructional unit focused on facilitating and supporting productive classroom argumentation.

Toulmin's (1958/2003) Model of Argumentation

One model that mathematics education researchers (e.g., Hollebrands, Smith, & Conner, 2010; Krummheuer, 1995; Rasmussen & Stephan, 2008) use to describe and analyze arguments is Toulmin's (1958/2003) model of argumentation. According to Toulmin, an argument consists of claims (a statement, the truth of which is being established), data (the facts from which the claim was based), warrants (the justification for using the data to establish the claim), rebuttals (statements that call the warrant into question), qualifiers (utterances that indicate the certainty of a statement), and backings (supports for the warrant that are usually unstated and related to the academic field). Toulmin conceptualized these components as occurring in a structure as depicted in Figure 1.

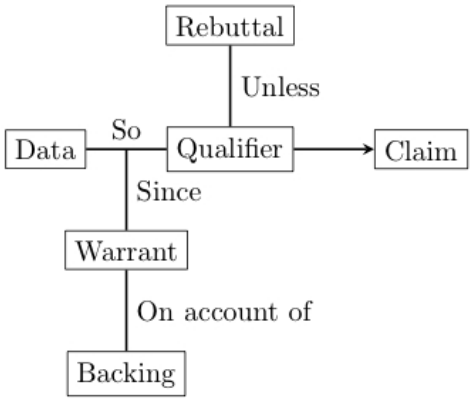

Figure 1. Toulmin's (1958/2003) Model of Argumentation

Krummheuer (1995) adapted Toulmin's (1958/2003) model to account for the social nature of collective argumentation, in which components of an argument are contributed and interpreted by a group of people. Other researchers have further modified the model to capture who (teacher, student, or both) contributed each component of the arguments (e.g. Conner, 2008) and the ways in which the teacher supports each component (e.g., Conner, Gleason, Singletary, Smith, & Wagner, 2011).

We have used these modifications of Toulmin's (1958/2003) model in research to analyze argumentation in mathematics classrooms (Conner et al., 2011). In this work, the model provided useful information about how teachers facilitate and support arguments, and the roles of the teacher and students in these arguments. Our findings would not have been accessible without the use of the model. In light of the recent emphasis on argumentation in the classroom (e.g. National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), we conjectured that PSTs might find the model useful for analyzing and reflecting on instructional practice. The research questions that guided our study were:

- How do PSTs interpret the components of Toulmin's model of argumentation?

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- To which aspects of mathematics classrooms do PSTs attend when using Toulmin's model as a lens for observing?

Methodology

To answer these questions, we conducted a study in a secondary mathematics methods course in which one of the units focused on collective argumentation. In this section, we describe the participants, course, data collection, and analysis methods.

Participants

The participants in this study were 11 PSTs who were enrolled in a 15-week secondary mathematics education methods course taught by one of the authors. The PSTs were in their final semester of coursework prior to a semester-long student teaching experience and had previously or concurrently fulfilled requirements including at least six advanced mathematics courses and two courses focused on high school mathematics content. The methods course was focused on pedagogical topics such as choosing and implementing high cognitive demand tasks, assessment, equity, and questioning. The PSTs were enrolled in a concurrent field experience course, in which they were assigned in pairs to local classrooms to observe and interact with the teachers and students. They were assigned weekly written reflections of their observations of these topics during their field experiences.

Argumentation Unit

The topic of argumentation was scheduled to be taught for one and a half class periods in the methods course and part of a class period in the field experience class (approximately three hours total). Given the potential complexity of collective arguments and the limited amount of time assigned to argumentation in the secondary methods course, we decided to introduce only the core components (data, claim, warrant) of Toulmin's (1958/2003) model of argumentation. We believed that this limited introduction would provide an overview of the most important and common elements of argumentation. We decided to have another author act as a guest instructor for the unit because the guest instructor was more knowledgeable about facilitating argumentation and using Toulmin's model as a means to analyze arguments.

On the first day of the unit, the instructor introduced argumentation by having the students watch a video in which two individuals defined what an argument is and what it is not. After a short discussion about the definition of argument, the instructor introduced the modified Toulmin's (1958/2003) model for argumentation, created a diagram of an argument, and then had the PSTs create diagrams of arguments found in transcripts and videos of mathematics classroom. At the conclusion of class, the instructor gave an assignment in which the PSTs were asked to watch a video clip of a mathematics classroom, to identify and diagram episodes of argumentation, and to bring their diagrams to the next class session.

In the next class meeting, the PSTs presented their argument diagrams and discussed the similarities and differences among them, particularly noting the contents of each component and who contributed them. For their weekly field experience reflection, the PSTs were asked in pairs to identify and diagram at least two classroom arguments, identifying the claims, data, and warrants in each and to describe episodes of argumentation that they believed were effective and ineffective, as well as their reasons for each choice. On the final day of the unit, the PSTs reflected on and shared their observations from their field experience.

Data Collection and Analysis

We videotaped and transcribed the three relevant classroom sessions. We collected the PSTs' notes from each day and the assignment that they completed. We analyzed the data using the constant comparative and grounded theory methods, as outlined by Corbin and Strauss (2008), in

order to capture individual interpretations. Through axial coding, we identified categories, which suggested a thematic framework on the use of Toulmin's (1958/2003) model of argumentation in the PSTs' development of a conception of collective argumentation.

Findings

The PSTs developed conceptions of what an argument is and made certain observations about teachers and students using Toulmin's (1958/2003) model of argumentation. These observations lent themselves to the PSTs conjecturing about characteristics of effective and ineffective arguments. Below we describe their conceptions of argumentation and how they evolved using Toulmin's diagrams. We then describe the PSTs' conceptions of the model components and how attention to these components served as a lens for analyzing collective argumentation. Finally, we describe how this analysis of collective argumentation framed the PSTs' descriptions of effective and ineffective collective argumentation.

Conceptions of Argumentation

Although the initial activity of the unit was focused on dispelling the perception that argumentation implied contradiction, many of the PSTs still perceived collective argumentation as involving disagreements between students. For example, Megan (all names are pseudonyms) posited that collective argumentation happened "when the whole group is actively participating in the argument. So you have different sides and people getting together behind certain, like different ideas." One PST exhibited an interpretation of argumentation that was more aligned with what is usually found in mathematics classrooms: "Maybe [argumentation is] an opinion you could justify" (Lauren). However, the majority of PSTs interpreted collective argumentation as involving controversy, though perhaps undertaken in a respectful manner: "It's not like a personalized kind of thing where you're arguing against the person, but you're just arguing against I guess the viewpoint and you're not being demeaning or just flat out saying they're wrong" (Mitch). It was only after exposure to Toulmin's (1958/2003) model that the PSTs came to an understanding that collective argumentation occurs any time a claim is supported by evidence. For example, at the end of the unit, Mitch and Jared wrote that arguments occur "whenever a claim is made … and [there is] reasoning or warrant behind the claim."

Learning Toulmin's Model of Argumentation

The PSTs' conceptions of argumentation shifted as they learned more about the components of Toulmin's (1958/2003) model and began using the model to create diagrams of collective arguments. Their understandings of the components were evidenced in their explicit statements and the choices they made when producing their diagrams.

Most PSTs treated claims as a *single assertion* or a series of assertions that did not contradict each other, reflecting their emerging understanding that collective argumentation does not require opposing points of view. The majority of the PSTs' diagrams revealed this understanding of claims except for two cases when PSTs diagrammed a *description* of an argument as a claim. In these cases, the claim took the form of a summary. For example, Megan's diagram of an argument from her field placement stated the claim as, "Two students disagree on what the correct answer is."

The PSTs envisioned data as encompassing information that was *explicit* or *implicit* to the student. Explicit data referred to information that was introduced orally or visually and therefore was identifiable by an outside observer. For example, in a transcript that was used during the first day of the unit, the classroom teacher stated that the measure of angle A was 20 degrees. All of the PSTs identified this given information as data. Implicit data included information that the PSTs assumed the students must have held internally in order to participate in the argument. For

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example, in an argumentation episode in which students used the properties of vertical and supplementary angles to find angle measures, the PSTs identified "knowledge of the existence of vertical and supplementary angles" as data because, they claimed, without such knowledge the students could not have appealed to their properties.

The PSTs perceived warrants in two different forms. In one form, they saw the warrant as having its foundation in *external mathematical authority*. In these cases, warrants consisted of rules or formulas, calculations, or definitions. For example, Emily described a student's warrant as "the sum of the measure of the angles of a triangle is 180," which was a previously established theorem in the class. The PSTs suggested that warrants of this form could ostensibly be successfully applied even if the student providing the warrant did not fully comprehend the reasoning behind it. In the other form, the PSTs saw the warrant as having its foundation in *sense making*. In these cases, warrants consisted of student reasoning, previous knowledge, or explanations. For example, in describing a warrant, Billy stated, "the student's reasoning was that we want 180 on the inside." The PSTs suggested that warrants of this form reflected and revealed student understanding.

Analyzing Classroom Discussions Through the Lens of Toulmin's Diagrams

The PSTs made a number of observations within the context of diagramming collective arguments that reflect what they noticed when observing the classroom through the lens of Toulmin's (1958/2003) model of argumentation. We categorized their observations as focused on collective argumentation, teacher practice, or students.

Collective argumentation. The PSTs made comments that reflected their developing opinions about collective argumentation itself. One area of noticing was when the students or teacher used *inadequate mathematical terminology*. For example, Sarah observed, "[the students and teacher] should say the measure of the angles, not the angles are." The PSTs also attended to *who contributed* (teacher, student, or both) each of the components, including who contributed to arguments in a general sense (e.g. there was a lot of (or little) student participation). They also noticed *patterns of warrants* that were used throughout their observation period, such as a heavy reliance on rules or formulas for warrants. Finally, the PSTs observed that argumentation is *inherent to instruction*. Mitch and Jared wrote, "teaching is full of argumentation even though teachers and students might not realize it."

Teacher practice. The PSTs remarked on a number of aspects related to teacher practice while using Toulmin's (1958/2003) model. They noticed the *questions* the teacher asked to support the argument, particularly the general nature of the question asked and the results they achieved. The PSTs also noted *patterns* of practice that came to light in their analysis of classroom observations. For example, Emily noted that the teacher in her field placement, "basically gave them (the students) answers for everything."

A large number of PSTs' observations concerned the *shortcomings* of the teacher or *potential improvements* to the teacher's practice. For example, PSTs observed that the teacher did not require justification for claims, gave students little to no opportunity to contribute to collective arguments, or accepted or encouraged inadequate warrants. The PSTs also suggested a number of ways that the teachers they observed could have improved their ability to facilitate arguments. Emily noted, "I was thinking it wouldn't be that hard to make [the argument] effective if you just changed who's giving what answers." Contemplating an improved environment for collective argumentation, Sarah ventured, "Maybe the teacher would ask why instead of telling them why."

Students. PSTs made comments that reflected things they noticed about students when they attended to the argumentation model. Since they had determined that implicit elements act as

data, the PSTs occasionally noted the *prerequisite knowledge* that the students needed in order to participate in or follow the argument. They also identified *weaknesses in components* contributed by students, such as warrants that did not fully justify or were irrelevant to the claim. The PSTs made general comments related to *student thinking* that attention to the argument components revealed. For example, noting the heavy use of drawings in an argument, Harry postulated that students were thinking "visually." Other PSTs used their argument diagrams as a launching point for considering aspects of the mathematical argument that students did not understand. For example, after diagramming an episode of argumentation in their observed field experience, Billy and Megan wrote, "the student did not understand that … the inverse operation of logarithms is exponentiation (sic)." Lastly, the PSTs sometimes noted that *connections* were being formed between topics.

Descriptions of Effective and Ineffective Arguments

The PSTs incorporated what they noticed in collective arguments to inform their opinions about what constitutes effective or ineffective arguments. As part of their field experience reflection, the paired PSTs were asked to identify an effective and an ineffective argument from their observations and explain their choices.

Effective arguments. Mitch and Jared referenced arguments concerning the behavior of absolute value functions and observed that the warrants took the form of analogies of the behavior of quadratic functions. They argued that effective arguments make explicit *connections* between topics in this way. Other PSTs identified effective arguments as those that either contained or lent themselves to *multiple perspectives*. Lauren and Iris argued that a specific argument was effective because it would "allow other students in the class to see different methods [other than their own] for solving the problem." Additionally, Emily and Sarah argued that one of the things that made their identified argument effective was that it was *relevant* to the students in that it was "similar to questions that would appear on the midterm." Another characteristic of effective arguments identified by PSTs was a high level of *student participation*. In particular, many of the PSTs characterized effective arguments as those in which students contributed most of the components, particularly the claims and warrants. Additionally, the PSTs felt *explicit warrants* were a characteristic of effective arguments. During a discussion, Megan offered, "Maybe that's a characteristic of a good argument. Or a clear argument. When the warrant is clarified and really explicit. It's explicitly stated. The other students who aren't really participating in the argument at least see what's going on."

Ineffective arguments. Megan and Billy were dismayed by an argument they observed, in which a student used the product rule of logarithms to warrant her claim that $\log(x^2) = 2\log(x)$, because the teacher had disagreed with the student's warrant. The teacher asserted, "The exponent rule was the rule to use." After noting that the student's warrant could have easily been justified, Megan and Billy characterized the argument as ineffective because the teacher allowed *one method only* and did not allow for alternative perspectives. This characteristic of ineffective arguments closely mirrored Lauren and Iris' depiction of ineffective arguments as relying on *memorized warrants*, that is, warrants that were rules or formulas lacking conceptual bases. Mitch and Jared also focused on the role of the warrant, citing *inadequate warrants* as a property of ineffective arguments, objecting to an argument in which the warrant accepted by the teacher and students did "not give a full understanding as to why that is the answer." Emily and Sarah added the characteristics of *low student participation* and a *rushed atmosphere*: "Students were not given time to look at the questions or try for themselves before the teacher began going over the answer…. [She] did not 'recruit' students to join the argument."

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Discussion

Researchers and policymakers have called for increased argumentation in mathematics classrooms, yet few PSTs have experienced collective argumentation in the mathematics classroom in the form envisioned by researchers. Because facilitating classroom discussions is difficult even for experienced teachers, we can expect PSTs to face challenges in developing their abilities to support collective argumentation. A necessary first step is to help PSTs develop an appropriate vision of what collective argumentation is and to provide them the means for analyzing their observations to determine factors that contribute to effective or ineffective arguments.

Using the lens and the language of Toulmin's (1958/2003) model, the PSTs in this study made observations related to students, teacher practice, and collective argumentation, which informed their conceptions of effective and ineffective arguments. In developing their conceptions about what constitutes an effective collective argument, the PSTs gained valuable insights from the observations they made using the lens of the argumentation components (see figure 2). Researchers in mathematics education have yet to clearly describe the elements of effective, or productive, collective argumentation, which suggests the complexity of the endeavor; therefore, it is important for PSTs to begin developing a personal conception that will inform their future practice. By identifying characteristics of discourse they desire in their future classrooms, the PSTs will be better situated to negotiate the classroom and sociomathematical norms (Yackel & Cobb, 1996) that foster their vision. Because practicing teachers also find facilitating classroom discussions difficult, Toulmin's model may similarly impact their conceptions of collective argumentation in ways that will help them improve their practice.

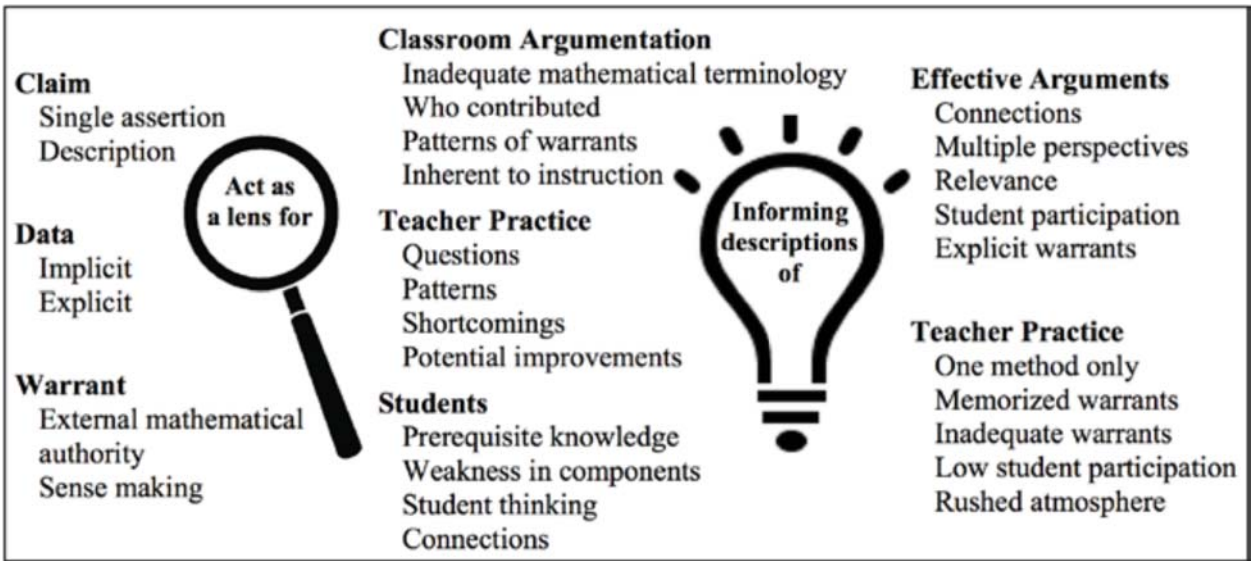

Figure 2. Development of Conceptions of Argumentation

Recent mathematics education research identifies specific ways that PSTs support collective argumentation (Conner, Singletary, Smith, Wagner, & Francisco, 2012), which may help mathematics teacher educators foster instructional practices that lead to effective arguments. Future research can explore the ways in which PSTs use Toulmin's (1958/2003) model of argumentation to develop their skills in facilitating and supporting collective argumentation. It

can also determine whether a more thorough introduction of Toulmin's model, such as including rebuttals, counterclaims, sub-arguments, and qualifiers, contributes to PSTs' understandings of argumentation in a meaningful way. Advances in research in these areas will increase our ability to effectively instruct PSTs in the techniques of collective argumentation. In the meantime, this investigation into the possibilities afforded by introducing PSTs to the basic components of Toulmin's model suggests that it is a promising first step in developing their conceptions of argumentation.

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