POSSIBILITIES AND PROMISES OF USING ARGUMENTATION IN THE TEACHING OF MATHEMATICS, SCIENCE, AND CODING

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Abstract

In this paper, we examined teachers' facilitation of argumentation in teaching computer programming (or coding) and how it related to their epistemic beliefs about mathematics and science. These preliminary results showed that teachers engaged their students in both justificatory and inquiry arguments when teaching coding. This was not the case with respect to mathematics and science, in which teachers described engaging students either in justificatory or inquiry argumentation exclusively. We propose that these siloed uses of argumentation in mathematics and science relate to the teachers' epistemic beliefs about the disciplines, and their use of argumentation in coding builds on and goes beyond their experiences with argumentation in teaching mathematics and science.

Teachers' beliefs have been shown to impact their teaching practices in both mathematics and science (Bryan, 2012; Philipp, 2007), but little is known about teachers' beliefs about teaching computer programming (or coding) and how those beliefs impact instruction (Mason & Rich, 2019). Taking the perspective that teachers' beliefs are sensible systems (Leatham, 2006), we conjectured that elementary teachers' epistemic beliefs about mathematics and science may interact with the ways they take up ideas from a professional development (PD) designed to prepare them to teach students how to code with argumentation. Therefore, we examined how teachers' descriptions of their uses of argumentation in teaching mathematics and science related to their epistemic beliefs about these disciplines. We proposed that teachers could extend these uses of argumentation in mathematics and science to their coding instruction. We discovered that teachers' uses of argumentation in the teaching of coding may reflect different kinds of arguments. We argue understanding elementary teachers' epistemic beliefs may lead to possibilities and promises for preparing teachers in using argumentation to teach mathematics, science, and coding.

Background and Purpose

Due to the importance of computational thinking for 21st century life and the recent availability of block-based coding languages (e.g., Scratch), teaching coding is being emphasized in K12 education, even in elementary grades (Mason & Rich, 2019). In a review of empirical studies that investigated how K12 students learned how to code, Lye and Koh (2014) found students were often left to learn how to code through self-discovery and trial-and-error methods. However, if elementary students are left to self-discovery and trial-and-error methods, they might not develop the necessary content knowledge and practices for more advanced computer science content in later grades (Edwards, 2004). Therefore, elementary teachers have a critical role in scaffolding students' development of computer science concepts and practices, such as those within the K-12 Computer Science Framework (2016). Unfortunately, many elementary teachers lack the content and pedagogical knowledge needed to teach computer science (Ng, 2017; Rich et al., 2017; Stanton et al., 2017). However, targeted content-focused professional development shows promise in developing in-service elementary teachers' coding content knowledge (e.g., Bers et al., 2013; Leonard et al., 2018; Roberts et al., 2018).

In partnership with a school district, we engaged elementary teachers in professional development (PD) to enhance their coding content knowledge and self-efficacy to teach coding. Unique to this PD in comparison to others (see Mason & Rich, 2019), we also prepared elementary teachers to use argumentation in teaching coding, which we called the Collective Argumentation Learning and Coding (CALC) approach (Conner et al., 2021). Argumentation is currently used across STEM instruction. In science education, researchers have likened argumentation to learning scientific inquiry (Erduran & Jiménez-Aleixandre, 2008; Sampson et al., 2013). In engineering education, argumentation is related to the learning of the engineering design process, in which students justify their design solutions (Mathis et al., 2017). Learning and argumentation in mathematics education is linked with mathematical proof, reasoning, and justification (Knipping, 2008; Krummheuer, 2007; Staples et al., 2016). However, in terms of technology education, as it relates to coding, we found little research that examined argumentation with respect to learning how to code. If argumentation has been an essential disciplinary practice in the teaching and learning of other STEM disciplines individually, then it is reasonable that the CALC approach can support elementary teachers in scaffolding students' learning to code.

Our team views argumentation as a tool to support students' reasoning and logical thinking when engaging in coding activities. Through argumentation, students are expected to describe and justify their processes and solutions, which promotes a more structured approach to coding rather than the kinds of unstructured approaches (e.g., trial-and-error approach) that are commonly used by novice programmers. Elementary school teachers can have a significant impact on student attitudes toward and participation in coding (Mason & Rich, 2020). Our team believes elementary teachers should develop students' capacity to code and that this capacity should build on a structured reasoning process (i.e., argumentation).

From their review of research on professional development for teaching computer science with elementary teachers, Mason and Rich (2019) called for research that examined the impact of professional development on elementary teachers' beliefs and classroom instruction. Understanding beliefs is crucial in understanding teachers' actions in classrooms (see, e.g., Beswick, 2007; Brickhouse, 1990; Conner & Singletary, 2021; Francis, 2015; Raymond, 1997; Thompson, 1984). Understanding teachers' beliefs about knowledge construction in the disciplines of mathematics and science, that is, their epistemic beliefs, is especially important because how teachers engage students in solving problems in a discipline influences students' understanding of and abilities to interact in that discipline (Bryan, 2012; Philipp, 2007).

This paper reports preliminary results of a study that examined elementary teachers' epistemic beliefs about mathematics and science and how those epistemic beliefs related to their intentions for using argumentation with mathematics and science. This paper also gives a preliminary analysis of what kinds of arguments occurred in coding contexts and how those arguments potentially relate to teachers' intentions for argumentation in mathematics and science. The research questions for the study are:

1. What were elementary teachers' epistemic beliefs about mathematics and science?
2. What do teachers' epistemic beliefs imply about their intentions for using argumentation with respect to inquiry and justificatory arguments in mathematics and science?
3. What kinds of arguments were observed in coding contexts and how were those arguments related to teachers' intentions for argumentation in mathematics and science contexts?

To our knowledge, there has been no investigation of potential links between elementary teachers' teaching of coding and their epistemic beliefs about mathematics and science. We presumed that understanding teachers' epistemic beliefs about mathematics and science and their intentions for argumentation in mathematics and science instruction might have implications for preparing teachers to teach coding with argumentation. In actuality, our preliminary analysis suggests that teachers' facilitation of argumentation in coding may expand teachers' intentions and support for argumentation in mathematics and science instruction.

Theoretical Perspective

Beliefs

Researching beliefs is inherently difficult, involving inference, because beliefs might not be consciously held (Rokeach, 1968). According to Pajares (1992), researchers must first define what a belief is in order to make sense of teachers' beliefs. We broadly follow Philipp's (2007) metaphor of beliefs as lenses used to interpret the world: Beliefs are premises or propositions about the world that an individual thinks to be true. For example, if teachers believe that argumentation occurs exclusively when two individuals engage in debate or disagreement, then they may not interpret their students' engagement in providing connected statements to support a claim (i.e., collective argumentation, see Argumentation) as an example of argumentative discourse (Conner et al., 2021). As such, we are cautious in our interpretations of teachers' beliefs and do not assume direct connections between what teachers say they believe and how we conceptualize constructs (e.g., argumentation, scientific inquiry).

While some scholars view beliefs and knowledge as indistinguishable (e.g., Beswick, 2011, 2012), we consider the relationship between beliefs and knowledge as discussed by other scholars (Furinghetti & Pehkonen, 2002; Pajares, 1992; Philipp, 2007; Thompson, 1992) to be helpful in framing our study. Beliefs and knowledge have different psychological strengths for individuals. Beliefs are personal, subjective, and not easily persuaded to change. Knowledge is social, open to rational critique, and typically easier to change than beliefs. We focus on teachers' epistemic beliefs as beliefs about the nature of knowledge or knowing, further focusing our investigation on teachers' epistemic beliefs about science as their beliefs about the nature of knowledge or knowing in science and teachers' epistemic beliefs about mathematics as their beliefs about the nature of knowledge or knowing in mathematics (see Kitchener, 2011, for elaboration of definition of epistemic beliefs). We differ from some others (e.g., Hofer &

Pintrich, 1997), by including beliefs about how one comes to learn in a discipline as part of a teacher's epistemic beliefs about that discipline.

How researchers define or conceptualize beliefs has important methodological implications for their investigation into teachers' beliefs (Leatham, 2006; Pajares, 1992). Analytically, we adopted Rokeach's (1968) definition: A belief is "any simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded by the phrase, 'I believe that…'" (1968, p. 113). Thus, we contend that we, as researchers, have to make inferences as to the nature of the "lenses" teachers use to interpret their world but that our interpretations must be supported by teachers' statements and actions in context. Defining beliefs in this way implies that teachers may not consciously hold their beliefs, and so multiple data sources across multiple contexts are needed to infer teachers' beliefs.

A common theme in the literature about teacher beliefs is the inconsistencies between teachers' espoused beliefs and their practice. Researchers' explanations for these inconsistencies vary (e.g., Eisenhart et al., 1993; Hoyles, 1992; Raymond, 1997; Tsai, 2002). We take the perspective that teachers' beliefs are complex. When initial incongruities are found between teachers' espoused beliefs and practice, we take those incongruities as evidence that more in-depth analysis is needed of teachers' descriptions and actions. To support this in-depth analysis, we follow Leatham (2006) in framing teachers' beliefs as sensible systems. According to Leatham, teachers' beliefs might appear to be contradictory to an observer, but their beliefs make sense to those teachers as part of a complex system in which some beliefs may be held in isolation from others. For example, teachers may hold isolated beliefs about argumentation in different disciplines. These beliefs are part of complex systems, are related to epistemic assumptions, and can influence how teachers expect students to engage in argumentation (Conner & Singletary, 2021).

Argumentation

Argumentation can be defined as the process of working to justify a stated claim (Jimenez-Aleixandre et al., 2000). We examined elementary teachers and students participating in *collective argumentation* or working together to establish a claim (Conner et al., 2014). An argument is the product of argumentation. To examine arguments in mathematics and science classrooms, many mathematics and science education researchers use Toulmin's (1958/2003) model (e.g., Chin & Osborne, 2010; Conner et al., 2014; Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Krummheuer, 1995, 2007; Rasmussen et al., 2015). According to Toulmin, an argument includes, at minimum, a statement (claim) that is supported with evidence (data) with justification for how the evidence supports the statement (warrant). Toulmin also explained that claims may be accompanied by statements denoting their strength (i.e., qualifiers), and warrants may be accompanied with statements detailing conditions under which it would not hold (i.e., rebuttals).

Crosswhite (1996) contended justificatory arguments (Toulmin, 1958/2003), in which a decided-upon truth is defended, and inquiry arguments (Meiland, 1989), in which a new truth is being established, all serve to persuade. Crosswhite further distinguished between an audience outside the argument (justificatory arguments) and an audience of self or peer group within the argument (inquiry arguments). Crosswhite's (1996) distinction between justificatory and inquiry arguments aligns with many definitions of argumentation in STEM disciplines. In mathematics education, Krummheuer (1995) defines argumentation as "the intentional explication of the reasoning of a solution during its development or after it" (p. 231). Krummheuer's definition allows for both inquiry and justificatory arguments. In science education, justificatory arguments occur when a speaker seeks to persuade the audience of the validity of a scientific explanation. Inquiry arguments occur when "different perspectives are being examined and the purpose is to reach agreement on acceptable claims or courses of action," which can occur within an individual or a group (Driver et al., 2000, p. 291).

In this paper, we investigated how teachers' epistemic beliefs about mathematics and science related to their intentions for using of inquiry and justificatory arguments in mathematics and science. In addition, we examined how teachers' support for argumentation in coding contexts related to their intentions for argumentation in mathematics and science.

Methods and Data

Context and Participants

The context of this study is a PD designed to support elementary teachers to teach coding using argumentation and incorporating coding into regular mathematics and science instruction. Two cohorts of elementary school teachers (32 teachers total) from a rural school district in the southeastern United States participated in the study. In Phase 1, teachers participated in a hybrid format course, with four face-to-face meetings and additional online instruction. In Phase 2, we followed 10 teachers from the course into their classrooms to support their design and implementation of lessons and observed how they engaged students in argumentation.

Data Sources

Phase 1 data sources (for epistemic beliefs) included video recordings of two semi-structured interviews (Interviews 1 and 2) with each teacher and of the fourth in-person meeting of the course (Video Club), in which teachers discussed argumentation and shared a self-recorded video of their facilitation of argumentation. In Interview 1, teachers described their experiences with and perspectives on coding, a recent mathematics or science lesson, and their choices of similes for most/least like a mathematics and science teacher. In Interview 2, teachers described a recent mathematics or science lesson and how they would engage their students in coding activities designed by the research team. Phase 2 data (argumentation enactment) included video recordings of 2-4 lessons from each of the 10 participating teachers' classroom.

Data Analysis

All data were transcribed and imported into Transana Version 3.3 (Woods, 2020), which is a video analysis software. To analyze teachers' epistemic beliefs, we reduced the data to instances when participants' talk included utterances about mathematics or science. We developed initial codes by iteratively comparing instances and met as a team to document similarities and distinctions between teachers' utterances (Glaser & Strauss, 1967). Disagreements were discussed until consensus was reached. After initial coding, we generated reports of codes across data sources and created analytic memos about the teachers' epistemic beliefs. These memos were compared and discussed until consensus was reached. We also explicitly searched for disconfirming evidence of these epistemic beliefs as part of the process of reaching consensus.

To analyze how teachers supported classroom-based argumentation, the team watched video recordings of lessons and reached consensus on identified episodes of argumentation focused on mathematics, science, or coding. From those identified, we randomly selected episodes to choose approximately 5 minutes of small-group arguments and 10 minutes of whole-class arguments for each teacher. We recreated 95 arguments using expanded Toulmin (1958/2003) diagrams (as described in Conner, 2008; See Figure 1). We documented students' and teachers' activity in each argument. Teachers' contributions to an argument component (e.g., claim) or supportive actions prompting or responding to an argument component were outlined in a solid red line. Students' contributions to an argument were outlined in a dashed blue line. Argument components that were jointly contributed by a teacher and student(s) together were outlined in a hybrid dotted-dashed purple line. Sometimes warrants were not explicitly stated by students or the teacher and so we inferred the warrant from the context of the argument in the classroom community. We described our inference for these implicit warrants in a surrounding cloud. Using the argument diagrams as data, we then coded the arguments with our initial codes of justificatory or inquiry argument (as previously defined in Argumentation).

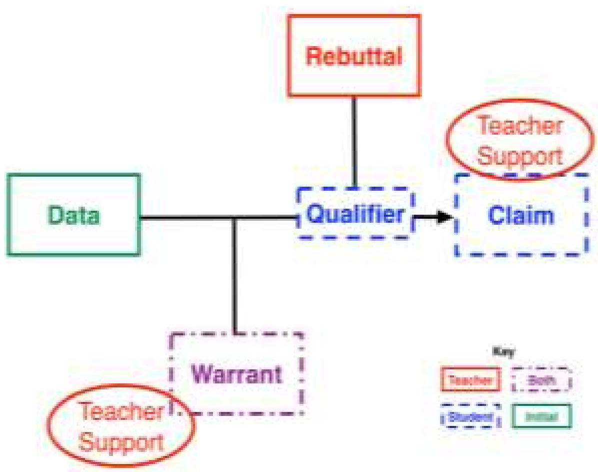

Figure 1. *Expanded Toulmin (1958/2003) diagram model (Conner, 2008)*

Results

Teachers' Epistemic Beliefs and Argumentation in Mathematics and Science

Teachers' self-reports of argumentation and our analysis of arguments in their mathematics and science lessons share common elements with their epistemic beliefs about mathematics and science. Fay[1] explained, "As similar and as much as we like to smoosh [mathematics and science] together, and they often are parallel, there are so many differences in

[1] All names are pseudonyms.

what they do and their purpose" (Int1). Teachers perceived differences in how results are established in mathematics and science.

Epistemic Beliefs. Teachers discussed mathematics as "black and white" with correct answers but also expressed that students could use multiple strategies to arrive at the answer. "In math, there is a right and wrong, but there is [sic] a lot of ways to get there." (Katy, Int1[2]). These strategies involve a lot of steps (Katy, Int1) and might require guidance from the teacher (Bill, Int1). However, the teachers believed it was important that students understand these steps and the "why" behind their correct answers (Sarah, VC; Annie, Int1). These beliefs aligned with their descriptions of arguments in which students defend their answers by explaining their various steps and strategies as illustrated in Figure 2 (Crosswhite's justificatory arguments).

In contrast, teachers viewed science as lacking definite answers, more exploratory and open than math (Alice, Int1). All answers could be acceptable as long as students present a valid argument to support their claims (Malia, Int1). In science, teachers described students as driven by wonder about natural phenomena that leads them to "get curious and they come with ideas" (Beth, Int1). Students arrive at their conclusions by engaging in hands-on inquiry-based learning and experiments in which they "figure things out on their own" (Lauren, Int1). These beliefs aligned with the teachers' descriptions of arguments in which students create and test hypotheses, as illustrated in Figure 3, or search for explanations of phenomena (Crosswhite's inquiry arguments).

Intentions for Argumentation in Mathematics and Science. Teachers discussed argumentation in teaching mathematics and science in ways that aligned primarily with only one kind of persuasive argumentation: argumentation as justification in mathematics and

[2] We use Int1, Int2 or VC to indicate the source of the data as Interview 1, Interview 2, or Video Club.

argumentation as inquiry in science. In mathematics, teachers regarded argumentation as an opportunity for students to explain their problem-solving strategies (Gloria, Int2; Bill, Int2). Teachers also reported that their students engaging in argumentation when they “explain why this math works and these numbers [are] in this process” (Maureen, Int2). That is, teachers described argumentation in mathematics as students justifying their completed work with the “why” behind the formulas they used.

In science**,** teachers reported using argumentation in the “inquiry model” (Lauren, Int1); students engaged in argumentation when they created and tested hypotheses (Jessica, Int2) and developed explanations for how and why things happened (Gloria, Int2). Teachers also described their students engaging in argumentation when students discussed ways to approach an experiment and convinced group members that a proposed strategy would work (Bill, Int2).

Examples of Argumentation in Mathematics and Science Lessons. To make sense of teachers’ actions along with their statements about their intentions towards argumentation, we present one representative argument form a mathematics lesson and another argument from a science lesson. In the mathematics argumentation episode (see Figure 2), students were asked to determine if Carmella would have enough space for all of her 4,410 cards in 6 albums with each album holding 500 cards (See part (a) of a problem statement in Data 1 in Figure 2). After working independently, the teacher (Katy) called students back as a whole class to share and justify their already decided upon answers. In this justificatory argument, a student provided the claim that Carmella would not have enough space for her baseball cards (see Claim 6 in Figure 2). Katy asked, “Why not?” (see teacher support on Data/Claim 4 in Figure 2). Using previous calculations as warrants (see implicit warrants in Figure 2), a student claimed “[the albums hold] 3,000 [cards]” and “she has 4,310 cards total” (see Data/Claim 3 and Data/Claim 4 in Figure 2).

From those claims, the student concluded that "she has 1,310 cards over the limit" (see Warrant/Claim 5 in Figure 2) and thus does not have enough space for all of her cards. This justificatory argument illustrates a student defending his claim that Carmella would not have enough albums to his peers.

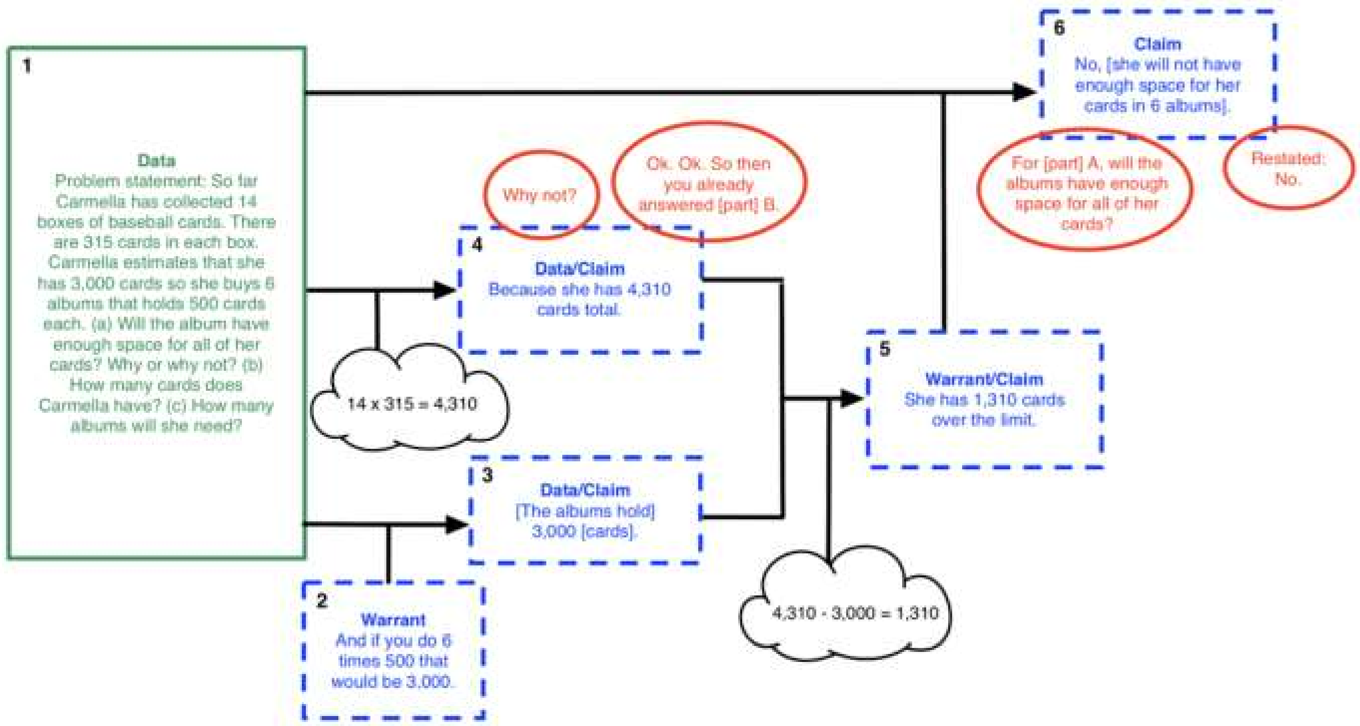

Figure 2. *Justificatory argument during a mathematics lesson*

As a part of a science lesson on simple machines (e.g., lever or wheel-and-axel), students worked in small groups to design and build Rube Goldberg machines (i.e., machines designed to complete a simple task through a chain reaction of events). In this episode (see Figure 3), a small group of students designed a Rube Goldberg machine to turn off the classroom lights (see Data 1 in Figure 3). However, as they were building their machine, they ran into a design challenge in keeping a string on the light switch so that a robot could pull the string and turn off the lights (see Data 2 in Figure 3). This design challenge led to an inquiry argument in which students were trying to persuade their peers in the group of potential design solutions for the machine.

At the request of the teacher (see teacher support on Data/Claim 4 in Figure 3), one student suggested that they should move the robot's starting position (see Data/Claim 4 in Figure 3) and have the robot travel perpendicular to the wall on which the light switch is located (see Claim 6 in Figure 4). The student reasoned that the string attached to the robot would pull the string in the correct direction (see Warrants 3 and 5 in Figure 3). The teacher prompted the rest of the group to consider this change (see teacher support on Rebuttal 7 in Figure 3). Two students expressed objections. The first student conveyed concern that the robot would now run into other furniture (see Rebuttal 7 in Figure 3), while the second student anticipated that this change would cause the robot to pull the string off the light switch (see Rebuttal/Data 8 in Figure 3). This inquiry argument illustrates how students sought to persuade each other of a new design solution that would meet an unanticipated design challenge.

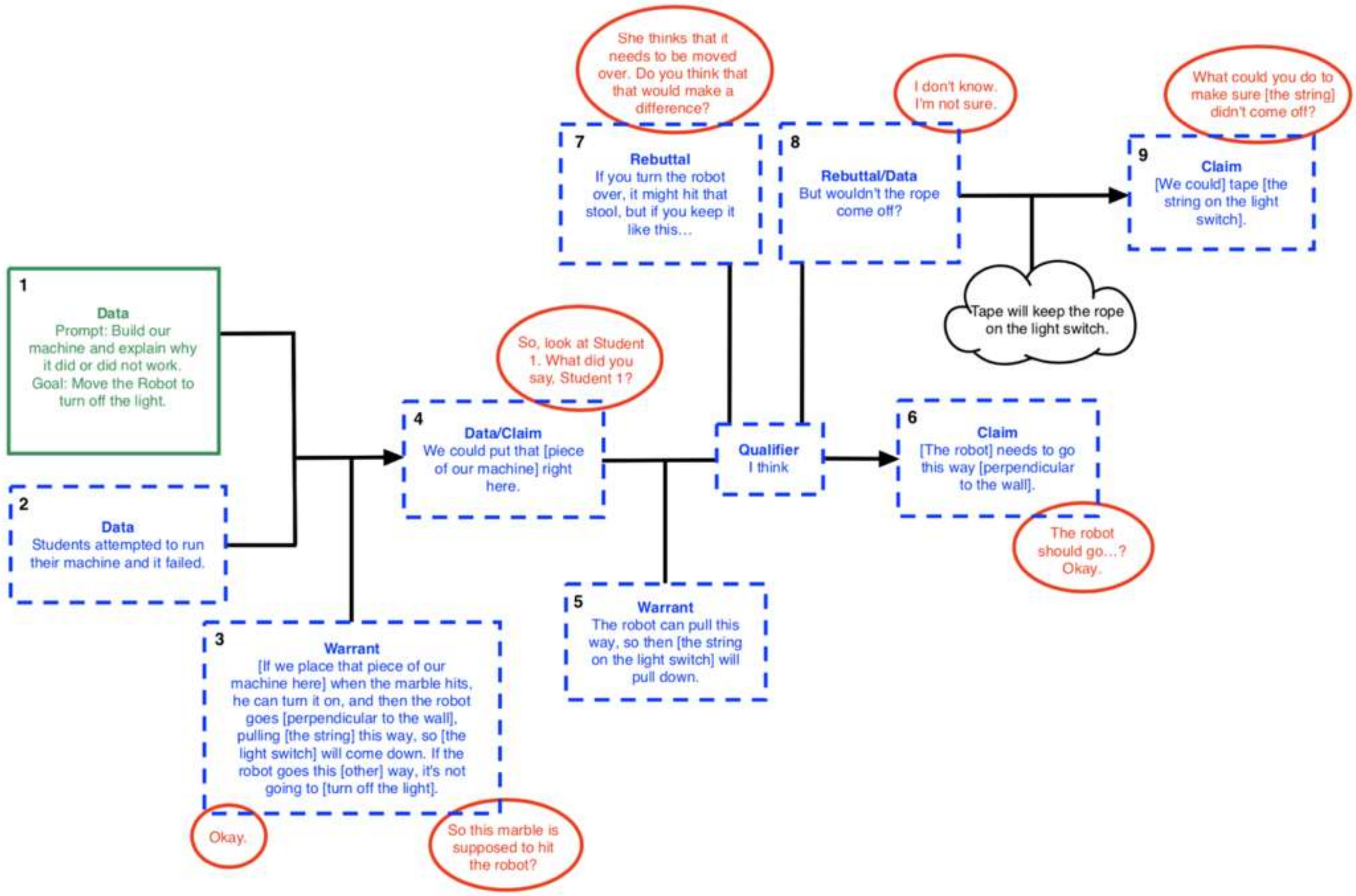

Figure 3. *Inquiry argument during a science lesson*

Kinds of Arguments in Coding Contexts and Their Relation to Teachers' Intentions

Students' coding-focused arguments included both justificatory arguments to defend their choice of particular coding structures or adjustment of coding variables (e.g., delay time) to others and inquiry arguments to consider possible solution strategies and make predictions. This differed from how teachers described mathematics-focused and science-focused arguments, which each tended to center on one kind of argument. To illustrate the range of coding-focused arguments, we present two sequential arguments from a fourth-grade teacher's lesson. The teacher, Bill, tasked students with coding a robot to trace the letter R (see Figures 4 and 5; actions summarized from transcript for clarity).

In the first coding argument (see Figure 4), students made a justificatory argument to defend their decision to use a repetition structure (i.e., repeat block). Bill selected and asked a student volunteer to explain why she used a repeat block (see teacher support on Warrant 3 in Figure 4). The student said she used the repeat block to make the robot travel from A to B (see Claim 4 in Figure 4) "because you had to go four blocks up" (see Warrant 3 in Figure 4). Bill questioned why one would use a repeat block in this instance (see Rebuttal/Data 5 in Figure 4). A second student elaborated, "You use repeat. [The robot] goes four blocks" (see Claim 7 in Figure 4). "You just do one block and [the robot] will just repeat that block" (see Warrant 6 in Figure 4).

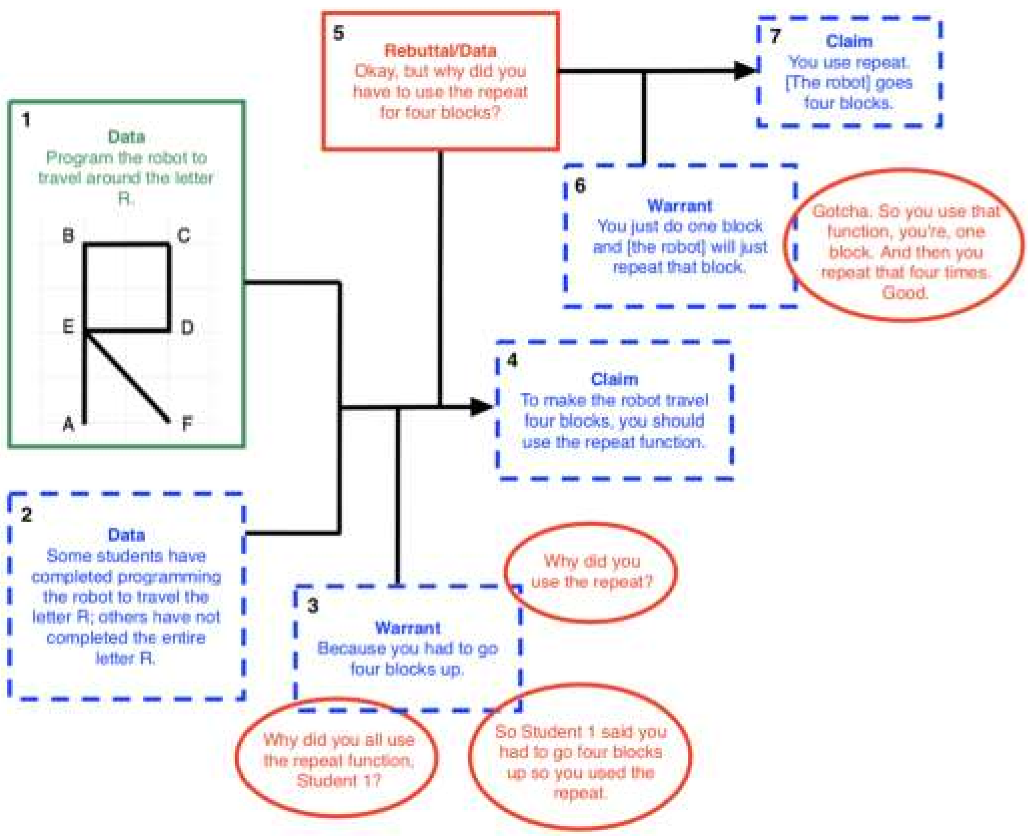

Figure 4. *Justificatory Argument in a Coding Lesson*

Similar to how teachers described justificatory arguments in mathematics as explaining a problem-solving strategy or providing a rationale for using a mathematical formula, this coding-focused argument illustrates how teachers engaged their students in justifying their choice of coding blocks. In the mathematics-focused argument described earlier (see Figure 2), the students reported out and justified their previously determined solutions to the class. Similarly, in the first coding-focused argument, students justified the use of the repeat block after having already programmed the robot to travel around the letter R.

In the second coding argument (see Figure 5), students made an inquiry argument in response to Bill's request for another place to use repeat (see Data 2 in Figure 5). Students proposed similar but slightly different uses of the repeat block: "You could use [the repeat] on the angles" (see Claim 7 in Figure 5) and "you could repeat where we go [straight] and then turn" (see Claim 4 in Figure 5). Each student's use of "could" indicates they had not yet tried it, and Bill's reiteration "I don't think anybody did that" (see teacher support on Claim 4 in Figure 5) suggests this was an inquiry, rather than justificatory, argument because students were not defending an already determined coding structure.

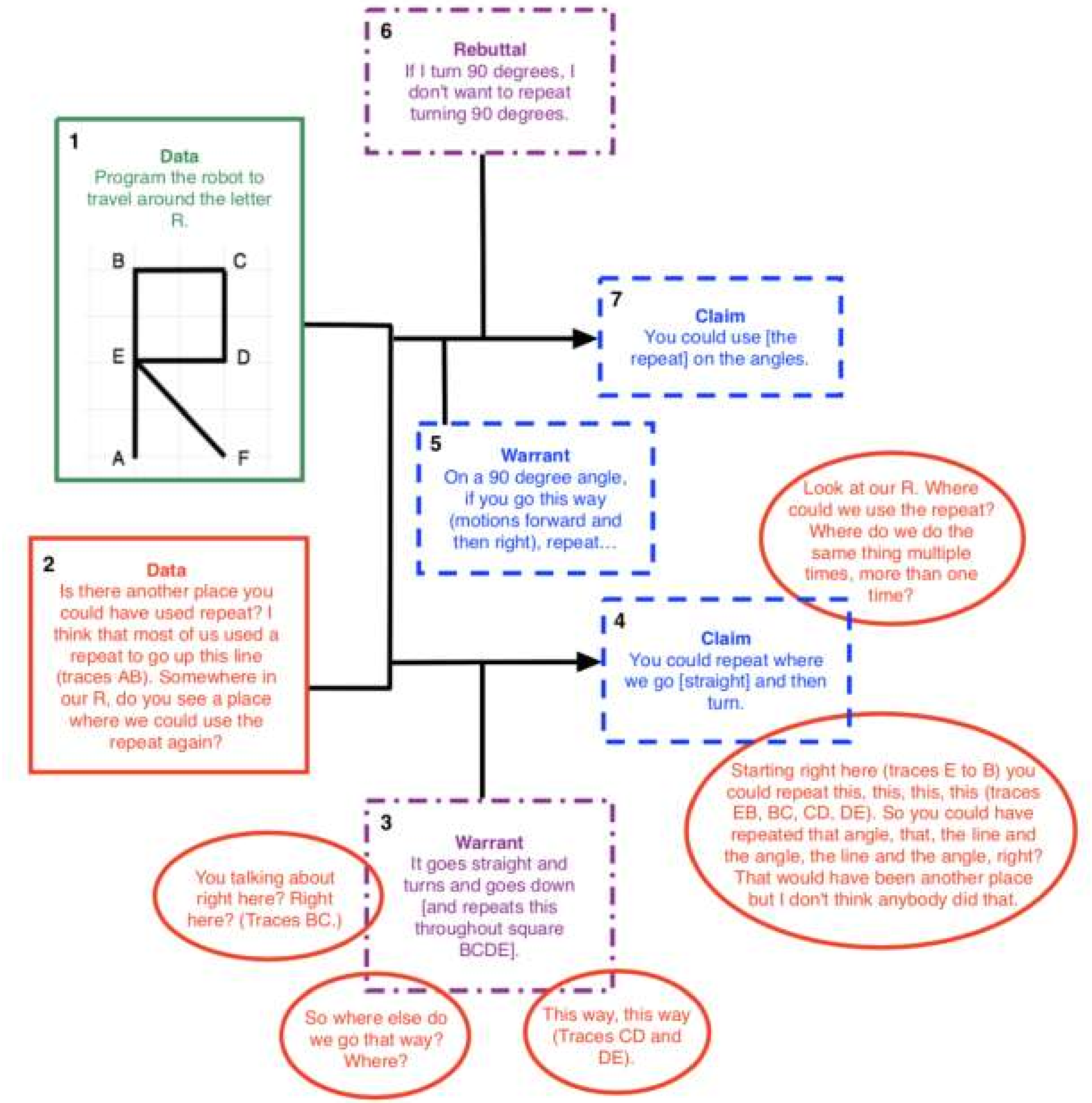

Figure 5. *Inquiry Argument in a Coding Lesson*

Similar to how teachers described inquiry arguments in science as lacking definite answers and exploratory, this coding-focused argument illustrates how teachers engaged their students in discovering other ways to use the repeat block. In the science-focused argument described earlier (see Figure 3), a student suggested that changing the robot's direction of travel would solve the design challenge of turning the lights off. Members of the group explored and rebutted this suggestion by bringing forth implications (e.g., robot might hit the stool) not yet considered by the student that suggested the modified design. Similarly, in the second coding-focused argument, students explored two other applications of the repeat block that they had not yet considered. The reasoning for one application of the repeat block was rebutted due to not considering the condition that the robot needed to also move forward in-between turns.

These two coding arguments illustrate how teachers engaged their students in both defending their solutions to problems and exploring potential courses of actions in coding-focused arguments. Some coding-focused arguments seemed similar to the justificatory arguments found in mathematics lessons and other coding-focused arguments seemed similar to the inquiry arguments found in science lessons.

Discussion

The elementary teachers in this study took part in a PD opportunity to develop their coding content knowledge and their support for argumentation in mathematics, science, and coding contexts. By considering the teachers' beliefs as sensible systems (Leatham, 2006), we found consistencies between teachers' epistemic beliefs about mathematics and science and their intentions for using argumentation in mathematics and science. These consistencies were found in not only teachers' statements about their intentions for using argumentation but also in their support for argumentation as evident in the expanded Toulmin models.

These elementary teachers believed there to be differences in how results or knowledge are established in mathematics and science. For instance, teachers described mathematics as being "black-and-white" while science was "exploratory" for students. In mathematics, teachers believed students built their understanding by defending their answer. In science, teachers believed students' curiosity led to new ideas to build students' scientific knowledge. These epistemic beliefs were consistent with teachers' intentions for argumentation across the two disciplines. Teachers described using argumentation in mathematics that aligned with justificatory arguments, in which students were to provide logical reasoning for why their already-found-answer was indeed true to others in the class. In comparison, teachers described using argumentation in science in ways that aligned with inquiry arguments, in which students collaboratively built on each other's ideas to reach consensus about a claim or hypothesis.

In our early-stage analysis of arguments in mathematics and science contexts, we have found that some of the arguments and teachers' support for argumentation appeared consistent with their epistemic beliefs and intentions for argumentation. For instance, teachers would sometimes request students to present their methods to the class and provide some guidance such as requesting elaboration from the student or repeating the student's statement to the class in some mathematics contexts (see Figure 2). On the other hand, teachers would sometimes request ideas from students or request students to evaluate another student's ideas in some science contexts (see Figure 3). As our analysis continues, we anticipate finding more consistencies between teachers' support for argumentation in mathematics and science contexts and their epistemic beliefs about the subjects. Inconsistencies that appear will provide opportunities for us to deepen our understandings of teachers' use of argumentation and their sensible belief systems. Future and more enriched findings may offer practical implications for professional development, such as ways to extend teachers' intentions for argumentation in mathematics, science, and coding.

When we analyzed Toulmin models of arguments in coding contexts, we observed both justificatory and inquiry arguments. Evidence of these two kinds of arguments illustrated how these elementary teachers engaged their students in both defending their solutions to problems and exploring potential courses of actions in coding-focused arguments. These justificatory and inquiry arguments in coding contexts in many ways mirrored the justificatory arguments in mathematics contexts and inquiry arguments in science contexts. We argue that teachers' intentions for argumentation in coding extends from their experiences with argumentation in teaching mathematics and science. We also presume teachers' intentions for argumentation in coding may also expand their intentions and support for argumentation in mathematics and science instruction. For instance, teachers may consider how to support argumentation in mathematics that align with inquiry intentions in similar ways they were able to move between supporting justificatory and inquiry arguments when teaching coding.

Conclusion and Significance

Previous research has suggested that students and teachers engage primarily in unstructured approaches (e.g., trial and error) when learning to code (Fessakis, Gouli, & Mavroudi, 2013; Kim et al., 2015). This study considered the possibility of argumentation as a structured approach to support teachers to teach coding. The PD integrated coding content knowledge with the CALC approach and was unlike other PDs described in the literature (see Mason & Rich, 2019). Our findings indicated that elementary teachers, after participating in PD, did engage students in more logic-based and structured approaches. Professional developers seeking to design PD with teachers on teaching coding with argumentation may consider the possibility of the CALC approach for their context or potentially adapting features from other successful PDs on argumentation in mathematics and science.

Furthermore, how these teachers engaged students in argumentation after the PD is promising. We initially intended the PD to improve coding instruction by linking it to argumentation in mathematics and science. However, we found that teachers were adept in how they supported argumentation in coding contexts. We found teachers engaged students in both justificatory and inquiry arguments when learning how to code. Teaching coding with argumentation may actually provide insights into improving argumentation in mathematics and science instruction, particularly if teachers' epistemic beliefs allow for such changes.

Our findings also contribute to the field by extending elementary teachers' epistemic beliefs as sensible systems into computer science education. In their literature review about PDs preparing elementary teachers to teach computing, coding, and computational thinking, Mason and Rich (2019) found only two studies (Rich et al, 2017; Roberts et al., 2018) that directly addressed teachers' beliefs. As a result, Mason and Rich recommended for more research that addresses teachers' beliefs in context. Our study contributes to this recommendation by making sense of teachers' epistemic beliefs as sensible systems. In particular, we examined potential relations between teachers' epistemic beliefs in mathematics and science and their facilitation of argumentation in coding contexts. The findings suggest that teachers' support for argumentation in coding contexts may go beyond their epistemic beliefs in mathematics and science. We encourage the field to continue considering other interactions in elementary teachers' sensible beliefs systems in the context of teaching coding.

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