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Collective Argumentation Learning and Coding (CALC)

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Dr. Foutz, a professor in the College of Engineering, is a Josiah Meigs Distinguished Teaching Professors, the university's highest recognition for excellence in instruction at the undergraduate and graduate levels. Dr. Foutz has active projects in the general area of engineering education, including Humanistic studies into engineering education to enhance service learning, Identifying faculty-based specifications for improving instruction and enhancing student success in STEM disciplines and Developing a Collective Argumentation Framework for infusing computer programming into elementary school mathematics. • Teaching Technology to Elementary Students While Teaching Design to Engineering Majors • Connecting and Aligning Teaching, Assessment, and Project-Based Understanding for Learners in the 21st Century: Teachers Empowering All Math and Science Students • Integrating Mathematics, Science and Engineering in Middle Grades • Development of a Instructional Manual for Incorporating Engineering and Technology into Georgia's Elementary Science Program • Bridges for Engineering Education

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AnnaMarie Conner is a professor of mathematics education at the University of Georgia. Her work research is classroom-based and longitudinal, crossing boundaries between instruction in university courses and classroom teaching in school districts. She investigates teachers' beliefs and identity construction during teacher education and how teachers learn to support collective argumentation in mathematics classes. These two lines of research come together in findings describing how teachers' beliefs impact their classroom practice with respect to collective argumentation. Dr. Conner's work investigates the complex connections between teacher education, teacher characteristics, and teacher practice. She is currently collaborating with secondary mathematics teachers in supporting mathematical arguments as well as investigating how elementary teachers navigate infusing argumentation into integrative STEM instruction.

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I earned my B.A. in mathematics, secondary education, and theology from the University of Saint Thomas in Houston, Texas and my Masters in mathematics education from the University of Dayton in Dayton, Ohio. I taught high school mathematics in Cincinnati, Ohio before coming to the University of Georgia to complete my Ph.D. in mathematics education. My research focuses on teacher preparation programs and how we assess teachers' feelings of preparedness.

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This project investigates the potential of the Collective Argumentation Learning and Coding (CALC) concept for integrating the teaching of computer coding and other computer science content into the standard practices already used to teach different elementary (grades 3-5) curriculum content. Elementary school teachers significantly influence student motivation to engage in coding and are being asked to provide increased instruction on coding. Unfortunately, few practicing teachers have academic backgrounds in computer coding. This project aims to identify the knowledge needed to transform the CALC concept into a learning practice in which young, novice programmers use the argumentation framework to develop coding sequences. Why? School administrators and other stakeholders often express that teaching coding is a distraction to teaching content related to state tests (e.g., mathematics, science) [1]. Suppose computer coding is an integral part of teaching mathematics and science subject areas. In that case, the concerns that coding is a distraction might decline, and administrative support for teaching coding might increase. We believe this work should be done at the elementary school level, better preparing more students and underrepresented groups for STEM subjects taught in the upper grades.

Feurzeig [2] provides an overview of the studies assessing the integration of coding into K-12 mathematical and science curricula. Efforts [3], [4], [5] have provided approaches that allow novice coders to learn the concepts of coding sequencing. Other efforts [6] offer practices that help students use coding to learn mathematics subjects and analyze data in scientific inquiry. However, many of these efforts do not engage students in coding activities with structured, reflective learning strategies that research [7] suggests young learners need. Our concept for integrating coding into the elementary school curriculum is grounded on the framework of Collective Argumentation and is called Collective Argumentation Learning and Coding (CALC).

Argumentation involves logical reasoning. In K-12 education, students in the argumentation process typically make a claim (a statement that something is true), use evidence (e.g., data, principles)to support that claim, and connect the claim and evidence with logical reasoning. A review [8] of the literature on argumentation in the nation's K-12 engineering education provides evidence that teachers likely recognize that engineering endeavors require discussion and debate. Collective argumentation [9] is when a group co-constructs an argument, often involving one member challenging another's claim with each defending their reasoning. Collective argumentation supports a deep-level understanding of content and promotes learning in multiple disciplines. The CALC concept discussed herein is intended for students to learn computer coding using more formal or structured practices, similar to ways of reasoning in mathematics and science education. If successfully designed, the CALC concept should help the teacher

1. trace the growth of the student's understanding and misunderstanding of ideas about coding as they form,
2. facilitate students' use of evidence, not opinion, to select a solution among the multiple possible ways of structuring a coding sequence, and
3. help each student realize they, as well others, are legitimate participants in developing, assessing, and implementing a coding idea (e.g., coding of a robot).

CALC's success will encourage students to use a structured approach to coding rather than the trial-and-error approach commonly used by novices. CALC will provide teachers with a practice common to mathematics and science instruction, increasing the probability that coding becomes a regular part of classroom instruction. As a practice commonly used in today's K-12 curricula, principals and other administrators will likely provide more support for the learning of computer coding if it is an integral part of mathematics and science learning.

CALC goes beyond treating a coding lesson as an informal learning activity where young novice coders tinker with a coding sequence to find out what works or does not work. CALC also goes beyond collaborative learning tactics such as paired programming. The concept of CALC is to provide a formal support structure that allows the student to create, critique, and compare arguments, leading to more efficient coding decisions. CALC will build students' capacity to function effectively in an increasingly technological and information-heavy world.

The structure of the CALC concept consists of three elements, 1) Coding Content, 2) Choice of Task, and 3) Teacher Support for Argumentation. This project focused on the research question: How do elementary school teachers use the CALC approach to support their students' *coding, mathematics, and science content and practices?* The knowledge presented herein involves teacher support for argumentation and its role in the success of the proposed CALC concept.

Methods

The research team consisted of three faculty researchers and eight graduate students. The faculty represented expertise in mathematics education, science education, and engineering. The Ph.D. graduate students were from the Department of Mathematics, Science, and Social Studies Education.

Two cohorts of elementary school teachers from one school district took a course focused on the CALC concept. One cohort consisted of 14 teachers, with nine teaching grades 3, 4, and 5; five of the 14 were specialists who taught all grades. This cohort completed the course in the spring semester of 2018. The second cohort consisted of 17 teachers with 15 teaching grades 3, 4, and 5. Two teachers were STEM specialists who taught across these grades. This cohort completed the course in the spring semester of 2019.

The research team followed ten of these teachers as the teachers implemented the CALC concept. Implementation occurred in the fall semester after the teacher completed the CALC course. Each teacher chose and designed the lessons involving CALC. So, the lessons included coding within mathematics, science, literacy, and social studies topics. Members of the research team visited each of the ten teachers two to three times during the semester and recorded how the teachers implemented the CALC concept in these different lessons. The data collected included video and audio recordings of the teachers and students engaging in the lesson.

After data collection, the research team viewed each recording and identified episodes of collective argumentation. For 9 of the ten teachers, episodes from at least three lessons were identified. For one teacher, episodes were identified from only two lessons. Verbatim transcripts of the identified episodes of argumentation, enhanced with gestures and pictures, were made. The following paragraph outlines the procedure for identifying an episode.

A sub-group of the team reviewed a teacher's transcripts and videos and identified each episode where the teacher engaged the whole class, a single student, or a small group of students (typically 2-4 students) in collective argumentation. The sub-group presented their identified episodes to the team. If the entire team agreed that an episode involved collective argumentation, then that episode was analyzed further. Multiple sub-groups were formed, so no team member reviewed all videos until the team meeting. A random process was used to identify at least 10 minutes of episodes where the teacher engaged students in collective argumentation. Then, the team analyzed these episodes for teacher supportive actions (described below). So, not all episodes were analyzed. After the final selection, ninety-five argumentation episodes across the lessons of ten teachers engaging small groups of students were analyzed for teacher supportive actions. Episodes involving the whole class were analyzed; however, this presentation primarily focuses on small group arguments.

Analysis of Teacher Support

The ninety-five collective argumentation episodes were analyzed using expanded Toulmin [10] diagrams. Briefly, an argument consists of a combination of

- claims (a statement that the student believes is valid),
- data (statements that provide evidence of the validity of the claim),
- warrants (statements that connect the data to the claim),
- rebuttals (statements that dispute the validity of the claim) and
- qualifiers (statement about the certainty surrounding the claim).

The teacher supportive actions used during each episode were added to the diagrams following the processes described in Conner [11]. Examples of teacher supportive actions include but are not limited to 1) asking a question to initiate a student's input to the argument, 2) the teacher directly providing input to the argument, and 3) the teacher responding to a student's input to the argument. Conner [12] provides details of the entire analysis process; a brief description follows. The diagram components were transferred into a spreadsheet, where each argument was placed in a row. Each argument's claim and warrant were placed in a column. The teacher support was entered within cells of the argument. If multiple teacher support actions were within an argument, then extra rows were established for the argument with each of these supportive actions in its row. After all argument episodes and teacher support were entered into the spreadsheet, each team member grouped each teacher support action. The team then discussed each grouping until a consensus was reached, similar to that outlined above.

The team analyzed the actions the ten teachers took when supporting their students during an engagement involving CALC. Not all of these actions involved asking a question, a supportive action commonly reported in the literature. Each identified supportive action was placed in the following groups,

- Requesting a factual answer,
- Requesting an idea,
- Requesting a method,
- Requesting elaboration,
- Requesting evaluation,
- Directing -the teacher focuses students' attention,
- Promoting- the teacher supports students to (continue to) explore a problem or solution
- Informing- the teacher provides information to the students
- Repeating-the teacher repeats what a student contributes, and
- Evaluating-the teacher has the student consider an action.

For example, if the teacher requests that a student explain a coding structure before that code is activated, the action would be grouped under Requesting elaboration. During the student’s explanation, the student would be asked to justify the idea behind the coding structure, and assess the success of the code before it is implemented.

Results and Discussion

The research literature (e.g., [13], [14]) provides evidence that teachers must be active facilitators when engaged in instructional strategies that promote student discourse (such as collective argumentation), and teacher support during this facilitation is a critical element for engaging students in discourse for learning content. The literature [12], [15], [16], [17], [18] also provides evidence that teacher support impacts the extent to which an argumentation framework builds students’ knowledge of mathematics and science.

Teacher supportive action during CALC implementation has to be transferable across the learning of mathematics, science, and computer coding. Currently, the team's work has shown that the student action initiated by teacher support differs within mathematics, science, and computer science education. For example, in a mathematics lesson, a Request for an idea can result in students identifying a pattern, making an analogy based on existing knowledge, assessing the analogy, or making a mathematical-based prediction. That is, the students engage in conjecture as described in mathematics education [19]. Also, the teacher support of “Requesting a method” typically calls for the student to implement an operation that may or may not be dependent on a conjecture of some kind. The meanings of the words used to describe these two kinds of teacher support differ in designing code, the primary purpose of computer science operations. Design is a process where a concept for solving a problem evolves as the approach for implementing that concept is developed [20], [21]. So, possibly, the supportive actions of Requesting an idea and Requesting a method may be blended.

One challenge currently being explored by the project team is determining if there is a way to describe patterns in how teachers support argumentation across disciplines. Knowledge of such patterns can expand the teacher support framework already applied to mathematics arguments to supportive actions across disciplines within the CALC concept. Studies [22], [23], [24], [25] examining the relationship of teacher questioning with students’ levels of thinking suggest that understanding this pattern can expand the impact of teacher-student interaction. Suppose our research team finds and understands a pattern of teacher supportive action during the implementation of the CALC concept. In that case, knowledge of this pattern can help transition the concept that results in computer coding becoming regular classroom content.

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