Computation thinking in elementary classrooms: Using classroom dialogue to measure equitable participation

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***Abstract*—The increased push for access to computer science (CS) at the K-12 level has been argued as a way to broaden participation in computing. At the elementary level, computational thinking (CT) has been used as a framework for bringing CS ideas into the classroom and educating teachers about how they can integrate CT into their daily instruction. A number of these projects have made equity a central goal of their work by working in schools with diverse racial, linguistic, and economic diversity. However, we know little about whether and how teachers equitably engage students in CT during their classroom instruction–particularly during science and math lessons. In this paper, we present an approach to analyzing classroom instructional videos using the EQUIP tool (https://www.equip.ninja/). The purpose of this tool is to examine the quantity and quality of students' contributions during CT-integrated math and science lessons and how it differs based on demographic markers. We highlight this approach using classroom video observation from four teachers and discuss future work in this area.**

***Index Terms*—computational thinking, elementary classrooms, student talkm equity**

I. Introduction

In recent years, there have been widespread increases in access to computer science (CS) at the K-12 level. These increases were lead by the launch of the Advanced Placement CS Principles (AP-CSP) course where number of students taking the AP exam has increased from 43,780 in 2017 to 114,188 in 2020 (Source: https://cs4all.home.blog). At the same time, the number of test takers for AP CS-A has only seen a slight increase from 56,088 in 2017 to 65,000 in 2020. AP-CSP is designed to introduce "students to the central ideas of computer science, instilling the ideas and practices of computational thinking" (College Board, 2017, p. 1). The higher enrollment in this course suggests it may be functioning as a better entry point to CS education and that these broad conceptions of CS are more appropriate for K-12 learners. The importance of computational thinking (CT) for K-12 learners has also led to a number of efforts to bring CT practices to younger learners, including pre-K [1] and elementary students [2].

The efforts to bring computational thinking to K-12 learners have included stand-alone courses focused on coding (such as code.org's CS fundamentals) to integrating it within disciplinary subject-areas (such as english language arts, e.g. See [3], and mathematics, e.g., [2]). The majority of the work has focused on developing teacher competencies to bring CT into the classrooms and examining how teachers conceptualize CT and think about integrating it into their classrooms (See [4] and [5]). We know little about whether and how teachers engage students in computational thinking during their math and science instruction. Further, while providing access to computational thinking ideas to students is important, we need to understand how teachers engage all students in quality CT learning experiences. One way teachers engage students in learning is through classroom talk, which is important for deepening their understanding [6]. Prior work has also suggested that gender inequities exist in classroom talk with boys talking more both by the number of opportunities provided by the teacher as well as in student-student talk [7]. Given this, the purpose of this study was to examine what kinds of opportunities for talk elementary teachers provide their students to engage in CT practices and who gets those opportunities. Specifically, this study addresses the following research questions:

1) How can we describe CT participation opportunities that teachers provide during lessons and how are these opportunities distributed based on race and gender?
2) What do these CT participation opportunities in math and science lessons look like

II. Project Overview

This study is situated in a broader project that focuses on supporting elementary school teachers to integrate CT instruction into their mathematics and science lessons. Two cohorts of elementary teachers have participated in face-to-face and online professional development aimed at building their understanding of four CT practices (abstraction, decomposition, debugging, and patterns). Face-to-face professional development included time to engage in co-design of

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mathematics and science lessons for students in Grades 2-5 that integrated at least one of the four focal CT practices. Teachers implemented the lessons in their classrooms during the 2019-2020 school year (prior to the onset of the COVID-19 pandemic).

A. Code Development

Our goal was to describe elementary teachers' equitable use of CT practices during math and science lessons. To do this we used the EQUIP (Equity QUantified In Participation) observation tool (Reinholz Shah, 2018). EQUIP is a web app (https://www.equip.ninja/) meant to collect data on patterns of equity and inequity in classrooms, which can facilitate reflection on how to make classrooms more equitable spaces. EQUIP analyzes participation sequences—a string of utterances from the same student. Any time a new student contributes to the discussion, a new participation sequence begins. EQUIP allows researchers to configure different dimensions of analysis related to who gets to participate, the nature of that participation, and how different participation is distributed across students in the class. Researchers can, for example, choose dimensions such as the nature of the questions that are asked, the length of a student response, and whether and how a teacher evaluates a student response. EQUIP then aggregates the data across lessons and presents the results organized by demographic variables of interest to the researcher or teacher, which may include race, gender, bilingual status, or other social markers.

EQUIP was not, however, designed to specifically examine CT practices, so use of the tool required development of a codebook appropriate to our purpose. To develop a set of discourse dimensions related to equitable CT practices, we began with a codebook used with the EQUIP web app in a study of high school mathematics classrooms [8] and then iteratively adjusted the code book to identify our final dimensions for analysis (Table I). We retained two dimensions from the original code book. The first, Teacher Solicitation—Quality, focuses on the quality of a prompt or question posed by the teacher that initiates a students' participation with respect to the level of thinking it suggests for a response. The second, Student Talk—Quality, captures quality of a student's response.Both of these dimensions were coded based on a hierarchy from less to more cognitively rigorous. Table II further highlights the Teacher Solicitation—Quality dimension, including examples in both math and science lessons.

We then identified one EQUIP dimension we wanted to retain but modify. The original Student Talk—Length included 2+ sentences as the shortest response length. We quickly discovered that in an elementary context we needed a code to capture responses less than 1 sentence and modified accordingly (Table 1). Next, we added three dimensions to capture how teachers support a growth mindset and students as contributors to the math and science learning community. Teacher Evaluation of Student Statement focused specifically on the teacher's judgment of students' ideas (i.e., neutral, positive, negative). Similarly, Teacher Response captured whether or not the teacher acknowledged or extended the ideas presented by the student. Lastly, Teacher Talk—Use of Student's Name captured recognition of individuals as contributors. Finally, Teacher Talk—Computational Thinking and Student-Talk Computational Thinking added to capture utterances by the teacher or student containing specific CT language related to one of four CT practices (i.e., abstraction, decomposition, patterns, debugging.)

B. Pilot Data Collection

To begin testing and iteratively refining the modified EQUIP tool, we asked teachers to video record when they were integrating CT into math and/or science lessons in their classrooms. They used iPads mounted on Swivl tripods to record these lessons. We also asked teachers to provide a class list including racialized markers (Asian, Black, Latinx, White, Mixed Race) and gender markers (Boy, Girl, Nonbinary). Unfortunately, this data collection occurred in Spring 2020. The result, due to COVID, was a much smaller data set than we intended. However, we did secure videos from four teachers participants within the broader study.

Though data collection was halted, we proceeded with tool development. Our goal was to achieve 80% reliability among two coders. To do this, two raters independently coded 20% of the available video. For dimensions where agreement was less than 80%, the raters resolved disagreements through discussion and then made adjustments to the code descriptions in the codebook as necessary. They then independently coded an additional 20% of the data, which changed the overall initial agreement levels to 80%.

III. Discussion

In this paper, we presented a codebook that uses student talk and participation opportunities as one way to look at equity in classrooms where computational thinking is being implemented. The high inter-rater reliability of the coding shows the promise of EQUIP to examine participation patters in the classroom discourse. We believe that in order to prepare teachers to address equity issues in their classrooms, it is important to make them teachers aware of unintentional inequities in how they are distributing learning opportunities to their students. Using EQUIP can serve as a crucial step in this process by allowing teachers to first become aware of these inequities. The next step would be to collectively reflect on these analytics and collaborate with the teachers to design and implement changes to their teaching practice that progressively reduce inequities that were identified and how to provide opportunities for all students. In this way, we hope that the computing-based interventions are implement in a way that makes them accessible to all students.

Unfortunately, with the school shutdowns due to COVID we were unable to collect enough data to provide results at this time. We did, however, identify potential challenges in the data collection. First, teachers were asked to record lessons at their convenience. As a result, the data set is limited to what teachers chose to record in the classroom and may or

TABLE I
DISCOURSE DIMENSIONS FOR EQUIP ANALYSIS

Original EQUIP Dimensions		
Dimension	Definition	Hierarchy of Codes
Teacher Solicitation—Quality	Prompt or question posed by the teacher to initiate a students' participation	Why / How / What / Other / n-a
Student Talk—Quality	Content of student response	Why / How / What / Other / n-a
Modified Dimensions for CT Analysis		
Student Talk—Length	Amount of words in a single continuous utterance	2+ sentences / 1 sentence or less / n-a
Dimensions Added for CT Analysis		
Teacher Evaluation of Student Statement	Whether and how a teacher evaluates a student contribution	Neutral / Positive / Negative
Teacher Response	How a teacher reacts to a student's contribution in terms of acknowledging or extending the student's ideas	Asks for more / Redirects to a different student / Teacher builds on / Acknowledgement / No response
Teacher Talk—Use of Student's Name	When teacher uses the name of a student	Sequence student / Different student / Both / n-a
Teacher Talk—Computational Thinking	When the teacher uses specific CT language and narrows in on the four practices	Abstraction / Decomposition / Patterns / Debugging / n-a
Student Talk—Computational Thinking	When the *student* uses specific CT language and narrows in on the four practices	Abstraction / Decomposition / Patterns / Debugging / n-a

TABLE II
TEACHER SOLICITATION—QUALITY CODES

Code	Definition	Math Example(s)	Science Examples
What	A solicitation that calls for a student to read out part of a problem statement or recall a fact.	What did you get for an answer?	What happened when you pulled harder?
How	A solicitation that calls for students to report on the steps taken to solve a problem or the sequence of events that led to a phenomenon.	How did you get your answer?	How did that car move?
Why	A solicitation that calls for students to explain or justify the math, science, or CT behind an answer or procedure, or concept.	How do you know that answer is correct?	Why did that car move?
Other	A solicitation not related to mathematics, science, or CT, or general enough to not suggest any of the codes above.	What is happening over there? Does anyone have anything to add?	
n-a	This code is used when a student participates without being prompted by a teacher solicitation.	n-a	

may not be representative of the typical experience within a classroom. Another challenge in teachers self-selecting their lessons is ensuring enough videos across contextual factors for meaningful data analysis. For example, some teachers focused on math lessons while others focused on science lessons. Further, there was a variety of activity types including whole and small group discussions. Another challenge of the video recordings is being able to clearly identify the student speaking and what they are saying. While this is a challenge in any classroom video collection, it may be magnified due to teachers recording themselves.

Moving forward, we plan to collect a larger number of video segments, with comparable contextual factors. This will allow us to fully test the use of the EQUIP tool in identifying equitable CT instruction in math and science lessons.

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