How Do We Do CS on Top of Everything Else? A Coaching Cycle Approach in Elementary School

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***Abstract*—A key strategy for bringing computer science (CS) education to all students is the integration of computational thinking (CT) into core curriculum in elementary school. But teachers want to know how they can do this on top of their existing priorities. In this paper, we describe how our research-practice partnership is working to motivate, prepare, and support an elementary school to integrate equitable and inclusive computer science into core curriculum. Data were collected from teachers at a K-5 school where 65% of students are Hispanic or Latinx, 46% are English Learners, and 65% are eligible for free or reduced lunch. Data included semi-structured interviews, educators' written reflections, and observations of classroom implementation and professional development. The findings show how the school is building buy-in and capacity among teachers by using a coaching cycle led by a Teacher on Special Assignment. The cycle of preparation, implementation, and reflection demystifies CS by helping teachers design, test, and revise coherent lesson sequences that integrate CT into their lessons. Contrasting case studies are used to illustrate what teachers learned from the cycle, including the teachers' reasons for the integration, adaptations they made to promote equity, what the teachers noticed about their students engaging in CT, and their next steps. We discuss the strengths and the limitations of this approach to bringing CS for All.**

Keywords—teacher professional development; elementary school; computational thinking; equity and inclusion

I. INTRODUCTION

Computer science (CS) must be integrated into elementary school core curriculum to reach all students. However, schools already have an overwhelming set of priorities to meet the needs of their students. To ensure that CS is integrated equitably - reaching all students and supporting them to be agentic learners - we need strategies to help schools do CS on top of everything else. Teachers face time constraints and new challenges despite the growing number of tools for integrating CS and computational thinking (CT) into their lessons. For example, high school teachers describe a lack of CS content knowledge and professional development (PD), and isolation [1]. Elementary school teachers may have misconceptions about CT and not feel prepared to teach it to their students [2]. Decades of research show that teacher PD is most effective when it is long-term, embedded in teachers' jobs, and focused on particular content [3]. When PD is tied to class content and instruction, teachers see the value of using foundational concepts to support student learning and increase their knowledge of CS and CT [4]. One example is using instructional coaches to support teachers; it is most effective when it is aligned with school priorities and goals [3]. Effective coaching includes observing and providing feedback to teachers, modeling what instruction should look like, and co-teaching [5].

There is limited research on coaching in CS education, even though it is a critical infrastructure support to achieve CS for all students [6] partly because most public school teachers have no prior training in CS [4]. It is also because there are systemic inequities that contribute to the underrepresentation of female and students of color in computing [7], which reinforce stereotypes that some students are less interested in and less likely to be successful in CS [8]. Coaching introduces CS content and pedagogical content knowledge, provides scaffolding to help teachers integrate it into core subjects, and helps them create equitable and inclusive learning environments. In-class coaching can improve teachers' pedagogy and CS knowledge, and reduce isolation [6]. Specifically, co-teaching and co-planning facilitates equitable integration by helping teachers address the unique needs of their students [9].

This paper provides an example of what integration can look like in the early grades by examining a coaching model of PD developed by a Teacher on Special Assignment (TOSA). We discuss the process through which teachers developed an understanding of CT, their decisions about how to integrate it into their classes, and what that integration actually looks like. This information is critical for developing strategies to increase the readiness and capacity of teachers and staff to infuse equitable and inclusive CS into their core curriculum. We ask: What are the strengths and challenges of

using a coaching cycle to integrate CT into elementary school classrooms in equitable and inclusive ways?

II. Context

This research is situated within a research-practice partnership (RPP) focused on creating an equitable K-8 CS pathway. The school district's four elementary schools serve almost 2,000 students. One goal of the RPP is to test strategies for how CS education can increase equity in students' academic literacy. We use iterative cycles of research to inform and revise the integration of CS. In this paper, we focus on one K-5 elementary school where 46% of the 370 students are classified as English Learners. The school is using a personalized coaching cycle for in-service teachers led by Erin, the district TOSA for CS, focusing on building capacity among classroom teachers to layer foundational CT concepts in their instruction. We consider CT an analytical thinking process that includes a set of specific skills which can be used to solve problems in multiple domains (e.g., [10],[11],[12]). The school leaders have operationalized CT to focus on the concepts of decomposition, pattern recognition, and algorithms (described as sequences of instructions). Equity is conceptualized as ensuring that all students have access to learn and practice the CT concepts with the unique support that they need to be successful learners who have agency in their learning.

III. Methods

To understand the role of the coaching cycle in CS integration, we collected multiple forms of qualitative data over three months. The data include: video recordings of Erin's Zoom meetings with classroom teachers, written notes summarizing these meetings, video recordings of the lessons being implemented, researcher observation notes taken during the lesson to capture student engagement, and responses by the classroom teachers to a questionnaire asking them to document the lessons that they completed following the coaching cycle.

Using a comparative case study approach [13], data were analyzed to understand how the coaching cycle was implemented and what teachers learned both within and across cases. Two of the authors worked separately to code the data and addressed differences together. Data analysis included an open-coding phase wherein segments of data (e.g., relevant sections of observation notes, coaching notes, lesson plans) were organized into discrete units to see what was done and learned at each stage of the cycle. Researchers worked together to triangulate the data across data sources and tell the story of each case, as well as across cases.

IV. Coaching Cycle for CT Integration

To build capacity to incorporate CT directly into existing curriculum, the principal and Erin work together to deliver monthly PD on CT to all staff and provide iterative coaching to a team of teachers chosen to be tech coaches. Erin's coaching model centers iterative cycles of observation, implementation, and one-on-one conversations. Her approach involves planning and reflective questioning, and is adapted to the needs and strengths of each teacher [14], [15]. Equity is incorporated in each phase of the cycle as Erin encourages teachers to build on students' prior knowledge and adapt the lesson to meet their students' learning needs. The outline of the cycle is as follows:

1. Pre-Observation: TOSA observes class to see how it is run and works with the classroom teacher to identify goals based on how CT can enhance a lesson to help meet the needs of different kinds of students and ensure equitable opportunities to learn among student groups.
2. Planning an integrated lesson: TOSA works with the classroom teacher to design a lesson based on the teacher's goals.
3. Modeling an integrated lesson: TOSA implements the integrated lesson planned with the classroom teacher so that they can learn through observation. After, the TOSA and classroom teacher debrief the lesson by discussing what the teacher noticed and reviewing student artifacts from the lesson. At the end of the debrief, the TOSA asks the classroom teacher to articulate new CT goals for their students and what their next steps will be for building on the content.
4. The classroom teacher designs and teaches an integrated lesson and the TOSA observes. The TOSA is available to co-design with the teacher, provide resources, review lesson plans, and offer general guidance. They have a follow-up conversation about the lesson and then the classroom teacher makes a plan to continue integrating on their own, with support from the TOSA.

V. Results

To illustrate the coaching cycle and implications for equity-oriented CS instruction, we present two cases of teachers at the school who layered CT concepts into their lessons with Erin's support. We describe the support Erin provided, the resulting lessons, what the teachers learned, and implications for next steps. All planning and lesson implementation was done online due to the COVID-19 pandemic.

A. Fiona: 3rd grade CT in ELA and SEL

Fiona is a 3rd grade teacher who Erin worked with to design three ways of including CT concepts in English Language Arts (ELA) and social and emotional learning (SEL) curriculum. At the start of the coaching cycle, Fiona's primary contributions were through generating ideas for where CT concepts might augment her existing lessons and address instructional challenges she was having. As she moved through the cycle, Fiona began to see opportunities to use CT to augment mandatory ELA lessons and connect SEL lessons to data analysis concepts the students are developing math.

1) Pre-observation: Fiona and Erin discussed the instructional challenges Fiona was having keeping her high-achieving students engaged with an online reading platform, as well as the data analysis work that all of the students were doing in math. The primary form of support that Erin provided for Fiona in this phase was to take the nascent ideas Fiona had

and turn them into a model lesson to implement in Fiona's class.

2) Planning an integrated lesson: Erin drafted a guided reading lesson based on pattern recognition and decomposition. She shared the draft with Fiona who provided feedback. Erin's goal for drafting the lesson first and then eliciting feedback was to show how easy it was to bring CT concepts into the lesson rather than focusing on the process of lesson planning itself.

3) Modeling an integrated lesson: In a 30-minute guided reading lesson, students used the settings of the books they were reading as a context for exploring in Google Maps. Students discussed their books in breakout rooms and then contributed pins to a Google Map shared by the whole class showing where their books were set. At the end of the lesson, students completed reflection questions about what they had learned. CT was present in the lesson through a short discussion about breaking down long reading assignments into chunks (decomposition) and recognizing patterns in their reading over time (pattern recognition.)

Erin led the entire lesson while Fiona observed and took notes on the pedagogical moves that Erin made. After the lesson, they met to discuss Fiona's observations. Together, Erin and Fiona reviewed the students' responses to the reflection questions and found evidence of the students not understanding the questions Erin had included about pattern matching and decomposition. Other than that, however, Fiona's noticings mostly revolved around the students' ELA knowledge (e.g., confusion about the concept of a setting). In the debrief conversation, she leaned on her knowledge of ELA to describe her goals for future lessons. Through gentle probes, Erin helped draw out her thinking on CT and focus the conversation on actionable next steps.

4) Classroom teacher designs a lesson: Fiona started with a lesson that Erin had made available in a set of CT activities designed to support SEL. Fiona, Erin, and the other 3rd grade teacher at the school corresponded over email to figure out what would best meet student needs and build on their prior knowledge. They decided on data analysis of bar charts because the students were already working with graphs in math class. For the lesson, students were sent a set of gummy worms to their homes. Based on the colors of a gummy that they chose, they filled out slides answering different questions about themselves. Then Fiona tallied up the number of different combinations of colors and made a bar chart. She showed it to the class and solicited observations about the bar chart. Two students made observations about which bar was largest. However, further conversation was halted by technical difficulties with the online platform they were using to view the graphs.

After the lesson, Fiona reported that the lesson was effective: "students were motivated and participated (maybe because it involved gummy worms) but also recognized some of the data graphs and could bring in previous knowledge and continue." She also observed that the students were building on their prior knowledge of graphs: "We'd been practicing analyzing graphs in math talks and students pointed out what was familiar and what they remembered about those lessons." For her next steps integrating CS, Fiona plans to make the process of close reading explicit through introducing it as a sequence of steps to go through to analyze a text.

B. Drew: Layering CS in 2nd Grade Science

Drew is a 2nd grade teacher who Erin coached to use CT as a way to make science lessons more interactive. Earlier in the year he led a lesson on data analysis where his students had measured their feet with and without shoes and created graphs to show the data they collected. Through participating in the coaching cycle, Drew began to think more creatively about how he was teaching science during distance learning and see the potential for further CT integration.

1) Pre-observation: In their initial conversation, Erin and Drew discussed how his students were doing and identified science or ELA as potential areas for integration. Overall, Drew reported that attendance and engagement were high among his students, but that he was struggling to teach virtual science lessons.

2) Planning an integrated lesson: Erin created three potential activities for Drew's class based on the science content that he was covering - habitats. She explained how they would work, and asked for Drew's feedback on what he thought would work best for his students. Drew was receptive to all three activities and assured Erin that his students would be able to do all three without being overwhelmed. Although the teacher was open to having the lesson be a fun extra activity that wasn't tied to a learning objective, Erin emphasized the CT concepts that would be covered in the lesson and described how she would connect the lesson to the actions of real world scientists.

3) Modeling an integrated lesson. Erin led the class in the three activities with Drew observing and assisting with classroom management as needed. All of the students except those who received special services were present. In the first activity, students matched pictures of animals to pictures of their habitats. Next, students matched pictures of habitats before and after an animal had modified them. Lastly, students created a sequence of directions using arrow symbols to get a bee through a pollination path on a grid and test their "code" by drawing lines on the grid to trace the path. Activities 1 and 2 were based on the CT concept of pattern recognition (e.g., what clues did the students see in the pictures of habitats that indicated where a particular animal would have been), while activity 3 helped students get started writing simple algorithms.

After the lesson, Erin went through a list of debrief questions with Drew to discuss what he had noticed in the lesson and implications for next steps to prompt Drew's thinking about how to continue building the students CT knowledge and his pedagogical approach. Drew was impressed by how capable the students were at creating the algorithm for the bee pollination cycle. He also noted that the lessons tied nicely to the content that the students had already

been learning, and that engagement and comprehension were high among the students. Watching the students solve step by step problems gave him more confidence to try exploration-based activities. Seeing how CS activities could be used to augment the lessons and make them more interactive got him thinking about ways that he could continue building on the students' foundational CS knowledge. Moving forward, he stated that his goal would be for the students to solve more difficult problems with algorithms. He was also inspired to think of ways that the pattern recognition lessons could be modified to substitute data collection activities in place of the physical data collection that they would normally do.

4) Classroom teacher designs a lesson: Drew planned the next lesson on his own and solicited feedback from Erin. He took the structure of the bee pollination activity and modified it for a lesson to review the rock cycle. Erin provided minor feedback, such as reminding him to have students define "algorithm" so that they practice recalling the word, and reviewing with the students how computers need precise instructions. Otherwise Drew designed and implemented on his own. In the lesson, students reviewed the processes that formed igneous, sedimentary, and metamorphic rocks and applied their understanding to create a rock cycle algorithm using pictorial representations of the rocks and processes (e.g., volcano, weather, pressure). Drew chose to set up the lesson this way because asking students to only manipulate pictures was developmentally appropriate. After the lesson, Drew reported: "I think the lesson was fairly effective. It was "hands-on" and engaging. I think it gave the students the opportunity to apply what they had learned in science to an active problem. It could have been more clearly linked to developing an algorithm, however." As before, Drew planned to continue integrating CS into his science lessons to make them more engaging.

VI. Discussion

The cases we presented here show the start of capacity building for in-service teachers using a coaching model. Further research is needed to understand and document the emergent coaching strategies and pedagogical questions that arise during the process, as well as how to address the inherent limitations of this model of PD. Through the coaching cycle, Erin demystified CT for Fiona and Drew by modeling sample lessons modified from their existing curriculum, discussed their observations, and supported them to design their own lessons layered with CT concepts. In Fiona's case, she saw potential for a CT activity to engage her students in mandatory ELA lessons. For Drew, CT activities were a welcome change from the way he had been teaching science and renewed his engagement with the curriculum.

However, the depth of engagement with the CT concepts at hand differed between Fiona's and Drew's lessons, and raises implications for equity. In both cases, the teachers built on students' prior content knowledge (e.g., habitats, rock cycle, math talks) or personal experience (e.g., gummy worms, bees). However, not all students in Drew's class were present for Erin's model lesson, pointing to the need for the design of CT integration to take into account the constraints placed on the curriculum by special services. In Fiona's case, both lessons could have been enhanced by going one step further in connecting the activities to CT. For example, having the students construct the bar graphs cooperatively would have reinforced their data analysis skills and allowed Fiona to concretize the connection. The guided reading lesson introduced the students to a Google Maps feature, providing them a new digital literacy skill, but stopped short of engaging them in thinking about the components that would be needed to create the platform. Additionally, the activities were designed to engage high-achieving readers which raises concerns about future access to CT for struggling readers.

The cases also point to the need to support teachers on how to differentiate CT and digital literacy, especially for teachers learning CT one step ahead of their students. Previous research has shown that at first, teachers do not distinguish CS from math or digital literacy [16], [17] and that taking a broad view of CT by grounding the definition of CT in teachers' lessons increases teacher buy-in for CS integration [4], [18]. With further development, the coaching cycle could address this issue. A limitation of the current model is that it relies on a single TOSA to embed in multiple grade levels and is driven by teachers' immediate needs. The goal of modeling one-off lessons that fit into the teachers' current lesson plans shows the teachers what CT would look like in practice. However, taking it to the next step of ensuring that the CT concepts are integrated meaningfully and not disconnected from the rest of the lesson sequences requires additional work at the school level to develop a collective understanding of when, where, and how in the curriculum to incorporate CT.

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