Building Elementary Computer Science Educators' Capacity:

A Workshop to Improve Content and Pedagogical Knowledge

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Computer science education, including computational thinking, provides students with increasingly valuable knowledge and skills to possess within the US job market, in which current projections indicate a rapid 22% increase in technology employment opportunities from 2020-2030 (Bureau of Labor Statistics, 2022). With the dual goals of meeting the growing need for computer science professionals and seeking to better prepare their students to be competitive in this market, many states are beginning to require computer science (CS) within their standard curricula. While many districts already provide these educational opportunities at the high school level, there is a growing need for instruction in elementary and middle school settings. Research has shown that teaching these concepts at an earlier age leads to long-lasting effects including a reduction in internalized gender-based stereotypes (Sullivan & Bers, 2019) and helps address issues around inclusion and equity (El-Hamamsy et al., 2023). With current research and demand in mind, New Jersey introduced Computer Science Student Learning Standards (hereafter, the "CS Standards") for K-12 students citing the need for equitable access to "...rigorous computer science and design thinking education."

The CS Standards not only seek to promote increased learning in CS, but also are designed to move the state towards more equitable educational practices within computer science education (CSE), effectively increasing participation and providing equal access to this content knowledge for all students. Currently, the state has observed disparities among CS participation for certain groups of students, including those that identify as female, students of color, students with learning disabilities, and students who speak English as a second language (Santo et al., 2019). Underscoring this problem, a report released in 2021 showed that while 88% of New Jersey high school students attend a school that offers CS, only 7.1% were enrolled in a foundational CS course (Hendrickson et al., 2021). Throughout the state, gender disparities within CS are also prevalent, with only 28% of female-identifying students enrolled in CS courses. Hispanic and Latinx students within the state are 2x less likely to enroll in CS courses than their White and Asian peers, and Black students are 1.6x less likely to do so (Hendrickson et al., 2021).

While the CS Standards hold great promise in strengthening and expanding the CS pipeline by holding education systems accountable for bringing rigorous CSE to all students, their ratification meant that many schools across the state needed to implement CS instruction for the first time, which is particularly impactful on elementary schools. Alongside the logistic challenges involved in dedicating the required instructional time and resources was the immediate need to equip individual educators with the content knowledge and pedagogical strategies to ultimately ensure the success of CSE implementation.

It's important to note that the CS Standards were not a replacement set of learning objectives, but rather an addition to standards from previous years. Conscious of time constraints and the volume of curricula already in place, many schools considered alternatives to classroom instruction to meet the CS Standards, such as through integration with library media or computer and technology literacy programs. This has profound implications on the teacher preparation needed: media specialists and technology teachers must be included in professional learning opportunities, and pedagogical discussions cannot assume that those administering computer science instruction meet with students on a regular basis or for sustained periods of time. This article details the design, implementation, and implications of a professional

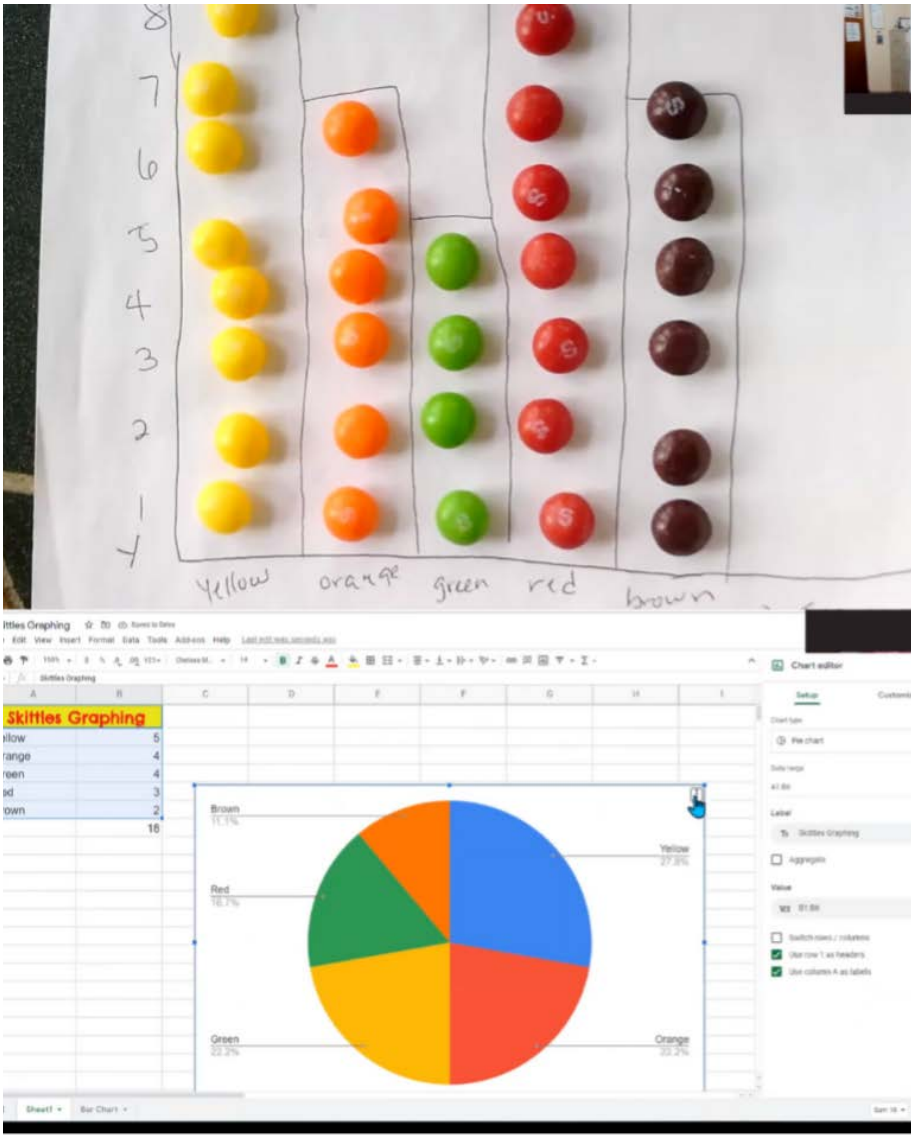

Figure 1. In the Graphing with Skittles® model lesson, bar graphs were first created on paper (top), then used to create a spreadsheet with various types of graphs (bottom).

learning workshop aimed at meeting these assessed needs to build the capacity of elementary educators in New Jersey to fully realize the promise of the CS Standards.

Workshop Design

The goal of any professional development (PD) event for educators should be an increase in content knowledge and/or pedagogical practices that can be leveraged to improve the effectiveness of classroom teaching and ultimately impact student learning. However, recent research within the field of cognitive science on *teacher* learning loss indicates that unless mitigated by certain tactics, learning loss can happen quite rapidly, thus never translating into any actual benefit for students (Liu & Phelps, 2019). Research has shown that to minimize this decay rate, a PD session should include content that is both directly applicable and can be applied in a practice setting as quickly as possible (Liu & Phelps, 2019). This combination of actionable instruction and direct practice improves chances of knowledge retention and helps ensure that concepts explored during PD sessions will be adopted as a routine part of practice. Drawing on this literature, to facilitate the translation of CSE concepts directly to instruction, we collaborated with workshop instructors to develop professional learning that would ensure long-term retention through short-term implementation.

Best practices in professional development include an intentional focus on content and associated pedagogical strategies and examples, opportunities for active learning through participation in model lessons, dedicated spaces for purposeful, semi-structured collaboration, and ample opportunities for reflection (Darling-Hammond, 2017). The design of the workshop was heavily influenced by these aspects of quality PD. Ultimately, the "K-5 Computer Science Standards Workshop" (hereafter, the "Standards Workshop") was delivered virtually over two days. Each of the CS Standard domains were explored separately: for each domain, educators learned key terminology, examined a selection of standards in detail, and participated in a model lesson, an important way to support active learning and retention. Materials needed for participating in lessons (and to subsequently implement them) were mailed to participants prior to the workshop. This active learning took place for the first half of each day, while afternoons were dedicated to collaboratively reflecting on the material and co-creating and modifying lessons in semi-structured breakout groups. This collaboration and reflection were integral to the design of the workshop. Specifically, structuring each workshop session in this manner was intended to improve the chances of content retention by allowing new content and pedagogical skills to be applied immediately after instruction (Liu & Phelps, 2019).

Data Collection and Reflections

A total of 21 educators attended the Standards Workshop, and all but two completed a pre-survey (a 90% response rate). Of the 19 individuals who completed a pre-survey, 16 completed a post-survey (an 84% follow-through rate). The pre-survey included 20 questions representing a mix of Likert, multiple choice, and open-ended items that addressed (a) participant backgrounds and demographic information, (b) perceptions of self-efficacy in delivering CSE, (c) confidence with and mastery of CS content knowledge, and (d) perceptions of CS as a discipline. The post-survey included 27 questions, additionally exploring how well the Standards Workshop addressed topics they had hoped to learn. Participants were given 20 minutes at the start and end of the workshop to complete surveys. Pre- and post-survey responses were linked using last name, which was then removed from the dataset before analyses; participants were aware that responses were confidential.

Additionally, throughout the Standards Workshop, participants were periodically asked to reflect on material using a shared, collaborative document. Educators reflected after the discussion and model lesson of each standard domain on their understanding of those concepts, at the conclusion of the workshop overall, and were also asked to contribute to an evolving "gots and needs" document, where participants provided takeaways that they "got" from the workshop as well as information or resources they still "need." Their responses were collected and analyzed qualitatively through an abbreviated process of axial and selective coding (Williams & Moser, 2019) given the relatively small sample size.

Figure 2. In the Cup Stacking Algorithms model lesson, participants designed a series of instructions using only arrows and basic symbols to arrange plastic cups into target configurations. This was first done as a group, then in breakout rooms.

Workshop Highlights

The two-day Standards Workshop required a robust agenda to cover, in some level of detail, each of the five domains of the CS Standards. The following highlights were selected to represent the most well-received pieces of the workshop as well as those that can be easily replicated or implemented in other settings by educators or PD providers.

MODEL LESSON, DATA AND ANALYSIS

Attending educators participated in the "Graphing with Skittles®" lesson led by the Standards Workshop facilitators. In this lesson, educators created bar graphs (see Figure 1) that show the distribution of Skittles® colors from a pack. At first, the Skittles® were physically arranged on a piece of paper by color. Then, a bar graph was drawn around them using colored markers. Afterwards, participants created a spreadsheet and graph using Google Sheets (In New Jersey, most schools use the G-Suite for education; however, this lesson can be directly replicated using other spreadsheet software with few, if any, modifications) and explored features including axes labels, chart titles, and cosmetic features. Afterwards, the group reflected on what CS Standards the lesson covered, including "collect, organize, and display data" and "identify and describe patterns in data visualizations."

COLLABORATIVE PLANNING

For the last few hours of each day, participants worked in breakout rooms to talk through the material presented during the day, discuss relevant experiences, resources, and ideas, and mobilize this information by co-creating additional lesson plans, instructional resources, or revising existing materials. An important aspect of this time, as seen with other collaborative groups (i.e., researcher-practitioner partnerships in education (Blitz et al., 2021)), was the sharing of resources—and more importantly, how they were used. Popular items discussed included

YouTube videos geared towards elementary-age students that explain concepts in CS and CT, Code.org lesson plans (especially those that include a teachers' guide), and digital tools like the G-Suite, Pear Deck, and Wakelet.

INDEPENDENT "QUEST"

Between the two workshop dates, participants were encouraged to participate in an independent "quest" that involved exploring one of the discussed standards in greater detail (or, looking ahead to a standard to be discussed at the second workshop date) and pulling together ideas or resources on teaching that standard in elementary classes or specials. This work was compiled in a shared drive that was made available to all participants (and remained active following the workshop). After the workshop, educators were offered the opportunity to further develop their lesson ideas and record a video modelling the lesson and explaining how it can be implemented and modified in classes.

MODEL LESSON, ALGORITHMS AND PROGRAMMING

Participants explored the idea of an algorithm by thinking about processes in their own lives and decomposing them into smaller, concise steps. Afterwards, participants completed an activity in pairs where they described in simple steps how to create various shapes out of stacked cups (see Figure 2). Participants would then share their instructions with others to see how well their directions could be interpreted and whether those reading the instructions were able to create the target structure. Following the activity, participants debriefed on how this lesson could be used in elementary classes, what modifications could be made to the lesson to differentiate and scaffold instruction, and what conversations might be necessary to highlight aspects of computational thinking that this activity encompasses.

Survey Results, Educator Takeaways

All but one of the Standards Workshop attendees identified as female (95%). The majority (74%) identified as white, 11% identified as Black, 5% as Hispanic, and 11% as AAPI. Most participants were seasoned educators, with an average of 12 years of total teaching experience and an average of 9 years teaching at their current grade level. Participants had varied educational backgrounds, with 16% indicating they had earned at least an undergraduate major in the arts, 16% in computer science, 74% in education, 16% in math, and 21% in history. Roughly half (58%) reported holding a Master's or Doctoral degree (all in education). Most attendees had taken at least one CS class at the university level: 42% reported taking one or two courses, 11% reported taking between three and five courses, and 26% reported taking more than five courses. Of particular interest to this workshop, 21% of the attendees were classroom teachers, 32% were media specialists, and 47% reported teaching a weekly special.

Before the workshop, educators reflected on how prepared they felt in various aspects of delivering CSE instruction. Attendees felt most prepared to (a) ensure that every student participates in CSE learning activities (74% of respondents indicated they felt "prepared" or "very prepared"); (b) teach students the relevance of CS in their daily lives (74%), and (c) foster group interactions during learning activities (79%). Attendees reported the lowest levels of preparation in addressing diversity, equity, inclusion, and accessibility (DEIA) in their CS instruction; specifically, attendees felt least prepared to teach CS to students with physical or learning disabilities (with mean scores of 2.21 and 2.37 on a 4-point scale, respectively) and to engage students from traditionally underrepresented demographic groups with CSE-related concepts (2.83).

Participants were asked to rank their perceived challenges to implementing CSE at their schools prior to attending the workshop. The greatest challenges that emerged were lack of teacher subject knowledge (which received a mean response of 2.05 on a 3-point scale, placing it just above a "moderate" challenge), a lack of curriculum resources (mean score 2.0), and rapidly changing technology (2.0). At the end of the workshop, educators' perceptions of key challenges had shifted: the challenges that participants perceived as having the highest severity included organizational challenges at the school and district level (commonly, an overloaded curriculum) with a mean score of 2.34. Other key challenges reported after the workshop included a lack of understanding about which pedagogical methods work best to deliver CSE (mean 1.88) and a lack of educator subject area knowledge (mean 1.83).

We believe that the persistence of a lack of teacher content-area knowledge as a key challenge in delivering quality CSE at the elementary level points to a central barrier to the implementation of CSE across K-12. As CSE is an emerging field, and even more so in elementary spaces, educators often do not have formal training in CS concepts themselves or how they are best delivered in classroom settings. In this regard, the workshop also yielded promising news: in the post-survey, participants were asked to rate, in addition to the severity of challenges, how difficult specific challenges would be to overcome; teacher content knowledge, although it has high severity (2.34), was viewed as one of the easier challenges to address, with a mean response of 1.36 (on a corresponding 3-point scale). Educators

viewed organizational challenges as the most difficult to overcome, with a mean response of 2.78.

Thus, an important implication of this workshop is the call for long-run integration of CS concepts into pre-service teacher preparation, but more immediately, the need for professional learning opportunities to bring these concepts to existing educators, especially in spaces where CSE is new. Fortunately, all but one participant indicated they were planning to attend additional professional learning opportunities related to CSE, and educators shared some of the things they will be looking for in future PD opportunities:

- "More about coding, design thinking, and maker activities to present… [the] CS realm."
- "Additional support and resources to implement the new standards."
- "Experienced teachers that have been teaching CS like the current presenters."
- "Practical resources," "more specific lessons," and "lesson planning advice."

Implications and Concluding Remarks

With computer science and computational thinking concepts being brought to elementary spaces with greater frequency, professional learning providers, policymakers, and advocacy groups have a window of opportunity to influence the ways that CSE becomes implemented before it is codified in routine practice. This, considered alongside schools' strategies of grouping CSE with the library or other specials, suggests it is imperative that *all* educational stakeholders have access to high-quality professional learning opportunities that will prepare them to quickly and effectively integrate CS and CT concepts into their instruction, not only classroom teachers.

> "As a growing body of research points towards the centrality of computer science (CS) to a well-rounded education, systems nationwide are working to make CS an integrated component of curricula articulated across K-12."

This report detailed guiding principles used in the development of a virtual workshop to meet this need, highlighted particularly engaging or novel aspects of its implementation, and shared perspectives and outcomes gleaned from participating educators. Importantly, the design of the workshop was able to leverage traditionally understood best practices in teacher preparation in a non-traditional format. In experimenting with structural aspects of the learning experience (its virtual format on a weekend during the school year, holding sessions on non-consecutive days, re-imagining the agenda to include interactive components like model lessons, etc.), the authors believe they have created an adaptable learning experience that was well-received by those in attendance, and one that accomplished its goals.

Findings and reflections offer and re-affirm several important lessons. First, PD must afford educators the opportunity to mobilize the information they learned, which can happen during the session itself (or even between sessions) through both the delivery of new material (i.e., model lessons) or collaborative debriefing afterwards. Second, to truly build educational capacity, learning opportunities must be tailored to the specific circumstances and needs of attending educators, which may involve challenging assumptions about who should be attending. Finally, this workshop was a reminder that CSE is an emerging field, and educators might not yet be aware of all it encompasses; thus, providing both new knowledge and pointing educators to curated resources to continue to learn are both important. Findings offer direction for future research, including the differential outcomes of this (and other) format of professional learning, the validity and reliability of reflection data and self-reported efficacy and content knowledge beliefs, and educators' attitudes towards CSE.

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