Developing Pedagogical Practices That Support Disciplinary Practices When Integrating Computer Science Into Elementary School Curriculum

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Abstract: There is a growing movement seeking to promote Computer Science (CS) and Computational Thinking (CT) across K-8 education. While advantageous for supporting student learning through engaging in complex and interdisciplinary learning, integrating CS/CT into the elementary school curriculum can pose curricular and pedagogical challenges. For one, teachers themselves must understand the concepts and disciplinary practices associated with CS/CT and the other content areas being integrated, as well as develop a related pedagogical repertoire. This study addresses how two 3rd grade teachers made sense of the intersection of disciplinary practices and pedagogical practices to support student learning. We present preliminary findings from a Research-Practice Partnership that worked with elementary teachers to integrate aspects of CS/CT practice into existing content areas. We identified two main disciplinary activities that drove their curriculum design and pedagogical practices: (1) the importance of productive frustration and failure; and (2) the importance of precision.

Introduction and rationale

There is a growing movement that calls for promoting Computer Science (CS) and Computational Thinking (CT) across K-12 education, including in the elementary grades (Rich, et al., 2019). Proponents of CSforAll favor an approach that seeks to integrate CS/CT into PreK-8 instructional materials and pedagogical approaches (Rich, Belikov, Yoshikawa, & Perkins, 2018). This type of integration will be advantageous in supporting students to engage in more complex and interdisciplinary learning and problem-solving. Nevertheless, integrating CS/CT into current primary learning environments could pose noteworthy curricular and pedagogical challenges that the field needs to anticipate and understand. Specifically, designing interdisciplinary learning experiences must consider how CS/CT concepts and disciplinary practices will be integrated into and with the concepts and practices of other content areas. Moreover, in order for these curricular efforts to be successful, teachers themselves must understand the concepts and disciplinary practices associated with CS/CT and the other content areas being integrated, as well as develop a pedagogical repertoire that will support student learning. Building on Lampert's (2010) work, we recognize the multidimensional nature of pedagogical practice, comprising educators' visions and commitments, as well as instructional strategies they develop and/or adopt to relate to students, meet their needs, and support their learning. More research is needed to understand how teachers make sense of the intersection of disciplinary practices and the pedagogical practices they rely on, particularly in curriculum that integrates CS/CT. This study addresses this topic through the following research question: *How do elementary-grade teachers make sense of the intersection of disciplinary practices and pedagogical practices to support student learning?*

Here we present preliminary findings from a Research-Practice Partnership that worked with third grade teachers to integrate aspects of computer science practice (e.g., creating algorithms, writing code, debugging programs) into disciplinary learning (English, Math, and/or Science). Participating teachers were tasked with considering the disciplinary practices of computer science in relation to the disciplinary practices of a chosen content area, and to consider the pedagogical practices that will support interdisciplinary learning. By analyzing lesson plans from a focal teacher dyad and interviews with one of those teachers, we were able to identify two main disciplinary activities that drove their curriculum design and pedagogical practices: (1) the importance of productive frustration and failure; and (2) the importance of precision. We conclude that there is an inherent tension created when teachers work to implement interdisciplinary curricula that requires them to not only understand the disciplinary practices of the various content areas, but also to create pedagogical strategies to support integrated student learning, especially curricula and pedagogies other teachers will leverage.

Conceptual framework

Our work and design are grounded in a situated learning perspective (Lave & Wenger, 1991), understanding that school-based disciplinary learning is deeply intertwined with the pedagogical strategies that teachers employ to support learning. In STEM education, a situated learning perspective expresses itself in creating learning opportunities for students to learn through engaging in disciplinary practices (Manz, 2015). Specifically, Ford and Forman (2006) developed a situated framework for conceptualizing learning through engaging in disciplinary practices that includes three elements: social aspects, material aspects, and roles. Social aspects refer to constituent members of the community of practice, material aspects refer to elements that constitute the basis of authority in the debates within the discipline, and roles to the modes of interaction a community member can embody (e.g., constructor of knowledge, critiquer of knowledge). We build on this work to understand the kinds of disciplinary work the curriculum our participating teachers designed asks of their elementary-aged students.

Additionally, key to our situative perspective is locating teaching and teacher learning in specific sociocultural contexts (Putnam & Borko, 2000). As teachers develop and implement learning activities, they draw on multiple resources, including assumptions about who their students are and how they learn, existing pedagogical strategies, curriculum materials, and standards (Stein & Coburn, 2008) that support their learning. Moreover, working in groups is a powerful mechanism for teachers to develop and negotiate pedagogical tools, pedagogical practices, and even identities (Kazemi & Franke, 2004). Therefore, we are interested in how teachers discuss their design decisions and pedagogical commitments to understand in greater depth how they were conceptualizing the different disciplinary practices they were negotiating as they were developing learning activities that integrated CS/CT into different content areas.

Methods

The work presented here is derived from the first year of a four-year grant funded CS4All Researcher-Practitioner Partnership (RPP; Coburn, Penuel, Geil, 2013). The project focuses on supporting elementary school teachers in a larger urban district to introduce computer science across K-5 through integrating Computer Science/Computational Thinking (CS/CT) into subject areas. Engaged in collaborative Design-Based Implementation Research (DBIR; Penuel, Fishman, Cheng, & Sabelli, 2011), teachers work in dyads to design, enact, assess, and refine curricula that their colleagues in the district would then implement and revise. In the first year, the project has collected data from multiple streams of a representative subset of 16 participating teachers (eight K and eight 3rd grade teachers) and their students. We focus our initial analyses on two iterations of a curricular unit that a 3rd grade teacher dyad designed - Lewis and Jennifer (pseudonyms). The dyads designed an integrated curriculum, which they then implemented, revised based on their experience and feedback from colleagues, and passed on to another dyad to iterate on Interview 1 was conducted right after the second implementation in year 1. Interview 2 was conducted right before a third dyad implemented the unit.

We chose Lewis as our initial case because of his extensive experience of being a professional hydro-geologist and deep understanding of disciplinary practice in science and engineering. Our analyses of the lesson plans and teacher interviews have been qualitative in nature (Miles, Huberman & Saldaña, 2014). We focused on moments in the interviews when Lewis spoke explicitly about coordinating aspects of different disciplines when designing curriculum and implementing learning activities (e.g., the interplay between algorithms and specificity in the engineering design process), his own disciplinary expertise, and instances related to the teacher's pedagogical decisions to support student learning based on key elements of disciplinary practice.

Preliminary findings

The unit Lewis and Jennifer designed focused on writing instructions for building an engineering structure (a 3D model), emphasizing the need for precision in writing algorithms. The design team mapped their CT-based lessons into the grade three technology and engineering standards (engineering design), as well as the English Language Arts standards (procedural writing). An important cross-cutting concept in this unit is precision, expressed in computer science as precision in algorithms, in engineering design as precision in the development of blueprints and structures, and in English Language Arts as precision in the writing of instructions. In this integrated lesson, students were asked to plan and build a two-story tower that held a certain weight for 15 seconds, based on the written and drawn instructions of another group in the class. From our analysis of Lewis's interviews, we inductively generated two kinds of disciplinary activity that drive the curricular materials the dyad designed to support learning: (1) the importance of productive frustration and failure; and (2) the importance of precision.

Productive frustration and failure

As a scientist and engineer, Lewis's knowledge in disciplinary practice led to the inclusion of and insisting on productive frustration and failure as pedagogical practices. Lewis identified himself as career switcher: "I'm a second-year teacher. I switched careers. I originally worked as a hydro-geologist and professional wetland scientist for about, say, 13 years or so at a large engineering firm." (interview 1 032019). Lewis's professional science experience seems to have had an impact on his view of how students should learn, including having the experience of productive frustration and failure. In discussing the unit he co-designed, Lewis remarked: “We want them [the students] to get frustrated in our lesson…but we want the frustration to be productive and to have them realize like, ‘Oh, man. I can't work with this. I guess it really is important to be specific because this is unworkable’.” (interview 1 032019)

Lewis goes on to discuss the importance of failure when learning and, in particular, how it relates to learning:

> Behind my board there, if you move it over, I have a big thing about failure. It's a quote I like. It says, “Ever tried, ever failed? No matter, try again, fail again, but fail better.” I'm trying to tell everybody, the kids, like, “It's all about failure. You have to keep failing because then you learn. If you don't, everything gets reinforced that what you did was right.” That was one of the things that, from my engineering days... "Nothing fails like success." (interview 1 032019).

While Lewis believed in the importance of failure to learning in their science classrooms, Lewis noticed that not all of the 3rd grade design team teachers shared this view. This difference in views created tension for him and his partner in considering how to revise their unit. However, they ultimately decided not to edit the potential for frustration and failure out of their unit, because it is an important aspect of disciplinary practice. Lewis reflected on the feedback the dyad received from colleagues who piloted their lesson during the second iteration.

> The second pilot of our lesson, they [the teachers] were frustrated, because not all their kids could have built it. But, that's part of it. So, Jennifer and I are kind of like, that was something that we are kind of holding firm on, because whenever she teaches science, I teach science, whenever we have an engineering challenge and it fails. That's fine. (interview 2 052419)

Lewis and Jennifer resolved the tension created by feedback from their colleagues by deciding to “hold firm” on their original design, despite the fact that some students would likely fail to create a working structure. However, they did make certain changes to the written presentation of the unit to emphasize for other teachers the idea that students may experience productive frustration and failure. The changes were made in the teacher and student activities section and the assessment section of the individual lesson templates. For example, in lesson four, under teacher activity, the following new guidance is provided: “If the structure fails, and time allows have the students improve the structure so you can retest it. It is okay if the structure never works. Continue to encourage the students to work through the design and redesign.” Also, in lesson one, in the assessment section, the focal dyad advised other teachers that “Students may struggle with using precise phrasing of directions.”

Importance of precision

Lewis valued precision as a critical concept and disciplinary practice of engineering, which undergirded the dyad’s decision to highlight precision in their interdisciplinary CS lessons. The concept of precision was introduced in the first iteration of the unit as an activity where students were meant to follow verbal instructions (first imprecise, then precise) in creating a drawing. The difference in precision was meant to result in different drawings (variable or uniform) from the students. However, this outcome was not realized. Indeed, the students produced variable drawings in both trials (imprecise and precise instructions). With feedback from other teachers who implemented the lesson, the design dyad developed a different approach to introducing the concept of precision. The new activity was a common unplugged robotics one in which the students work to move the teacher around the room, by means of precise verbal instructions for physical movement. Lewis remarked on this activity: “And if they [verbal instructions] weren’t specific enough, the teacher would walk into the wall or bump into chairs and that sort of thing.” (interview 2 052419). A variation of this new activity was to have the children provide the teacher with verbal instructions for drawing a house on the blackboard (e.g., drawing a triangle on top of a square).

After this introductory activity, students were asked to write precise directions to draw a two-story tower, and the term algorithm was introduced and iteratively deployed by the teacher. With feedback from another dyad who implemented the unit, Lewis and Jennifer decided to add a word bank that included shapes to the unit so that students would use specific language in their directions to build a two-story tower. The focal dyad added these elements to focus the unit more clearly on precision in writing directions. In our interviews with Lewis, he expounded on the importance of precision in computer science, as he stated: “The computational thinking, the big part of it is building the algorithm, understanding what an algorithm is, understanding that precise directions need to be included within an algorithm.” (interview 2 052419).

Discussion and implications

We surmise that Lewis's experiences as a professional hydro-geological engineer drove his interpretations of the interplay between pedagogy, materials, and disciplinary practices and discipline-based learning goals within the integrated CT unit they created. From a situated perspective, Lewis drew on his knowledge of engineering practices to support pedagogical decisions he and Jennifer made in the creation and implementation of the unit. The integrated unit the focal dyad designed revolves around the cross-cutting concept of precision. The students who enacted the unit had difficulty in writing precise instructions, and they experienced both frustration and failure. Lewis saw these experiences as valuable for learning in an engineering context. However, pedagogical practices that are derived from disciplinary practices (allowing children to feel frustrated and to fail with an engineering task), may not be widely understood or shared by teachers who lack a similar disciplinary background, as was the case in this study. Therefore, one of the redesign challenges the focal dyad faced was considering how to address other teachers' concerns about the high potential of student failure embedded in the activity.

Lewis and Jennifer chose to address this concern not by changing the actual activity, but by changing how they framed the unit for other teachers, including the mode of address used in the template. Whereas in the first iteration of the unit, "student struggle and failure" is not referred to at all, in the second iteration, it is. Moreover, the mode of address shifts from guidance regarding the activities of the teacher and students, to some form of mentoring regarding the acceptability of particular activity outcomes. This is seen specifically in the comment "It is okay if the structure never works," which was written into the activities section of lesson four of the revised unit. This change in the mode of address shifted the focal teachers' role within the context of the design-based work. The written instantiation of their redesigned unit serves not only as a curricular guide, but also as a tool for teaching about discipline specific parameters and expectations to other teachers (e.g., in engineering activities it is okay to fail, and, in fact, failure promotes learning in engineering).

The change in the mode of address also points to the inherent tension created when teachers work to implement interdisciplinary curricula that requires them to not only understand the disciplinary practices of the various content areas, but also to create pedagogical strategies to support integrated student learning. This is a problem of particular concern for those involved in CSforAll, as it is unlikely that computer science will become a stand-alone discipline in elementary school any time soon. Therefore, an important direction for future research relates to deeper inquiry into the conditions that would support elementary teachers' pedagogical and disciplinary learning as they undertake interdisciplinary integration of computer science concepts in the curriculum.

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