Design Considerations for A Middle School Computer Science Pedagogical Content Knowledge Instrument

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Abstract: K-12 Computer Science (CS) education is developing rapidly but still lacks a comprehensive measure for CS teachers' pedagogical content knowledge (PCK). We respond to this need by describing the design of a CS-PCK instrument for 'Algorithms and Programming' that measures three broad constructs: (a) teachers' understanding of standards and standards-alignment, (b) teachers' formative assessment practices, and (c) teachers' self-efficacy for teaching and assessing CS.

Introduction and significance of the work

Various theoretical and empirical studies have emphasized the significance of teachers' pedagogical content knowledge (PCK) in determining the quality of instruction and student learning. PCK is defined as teachers' ability to integrate their knowledge of content and pedagogy to guide, "ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1987 p. 9). In K-12 Computer Science (CS) education, the dramatic increase in recent years in the number of CS course offerings and thus the need for qualified CS teachers highlights the need for research on promoting teachers' CS PCK. Early research in CS education focused primarily on developing curricula and software that lower the barriers to computing and inspire student interest, and less on the pedagogy for K-12 CS education. In order to promote and improve CS PCK, it is critical to have an accurate and comprehensive way to measure it that can inform the design of teacher professional development (PD) aimed at improving CS PCK.

The CS PCK literature is currently limited and has mostly been informed by work conducted in other disciplines such as science and math education because key elements of PCK are similar across disciplines. Research in these fields has suggested that teachers have distinct PCK for different topics, resulting in PCK being measured with topic-specific instruments rather than subject-specific ones (Hill et al., 2008). Also, some studies have measured teacher PCK using labor-intensive qualitative methods such as analyzing teachers' lesson plans, and interviewing and observing teachers (e.g., Park & Chen, 2012). Topic-specific instruments and labor-intensive methods have made it challenging to scale measurement of PCK. In CS, one well-known PCK instrument is that by Yadav and Berges (2019) in which teachers are presented with vignettes describing student programming challenges and are asked to select strategies they would use to identify and/or address the challenges. While less labor-intensive and more amenable to scaling, this instrument does not include various common PCK components such as teacher knowledge of CS standards, ability to analyze CS curricula, and formative assessment practices which are aspects of PCK highlighted in the CS teacher standards (what teachers should know and be able to do) outlined by the Computer Science Teachers Association (CSTA, 2020). Further, this PCK instrument does not include measures of teacher efficacy and attitudes as suggested by the literature (Park & Chen, 2012).

To address the abovementioned issues, we developed a CS PCK instrument aligned with the topic of middle school 'Algorithms and Programming' that assesses teachers' knowledge of CS standards and standards-alignment, formative assessment literacy and practices, and self-efficacy for teaching and assessing CS. While not completely comprehensive, our instrument will allow for the measurement of many different aspects of CS PCK within one CS content area and may serve as a model for others developing additional CS PCK instruments.

CS-PCK Instrument design and development

We aligned our instrument with the 'Algorithms and programming' content area and a set of skills and abilities outlined by the CS teacher standards. We expect the instrument to take teachers 30-40 minutes to complete.

Component 1: Knowledge of standards and standards-alignment of CS activities

An important aspect of PCK is a deep understanding of disciplinary standards and ways in which students can engage with standards. It includes an understanding that each standard is a broad statement that can be further decomposed into a set of fine-grained learning targets. This component of our instrument targets teachers' understanding of CS standards (CSTA, 2017) and ability to identify what standard(s) and what aspects of standards a given CS activity is targeting. We developed 3 multiple-choice PCK tasks that provide an example of a CS curricular activity or a CS assessment task and ask teachers to select aligned standards and/or learning targets.

Component 2: Formative assessment literacy and practices

This component of our PCK instrument targets teachers' formative assessment practices, in particular teachers' ability to (i) select appropriate formative assessment tasks to elicit evidence for (or against) particular student challenges, (ii) design rubrics to evaluate and interpret student responses to CS activities, (iii) predict outputs of student-generated correct and incorrect code, (iv) interpret student work and identify potential student challenges and causes for student errors, and (v) determine appropriate follow-up strategies based on student performance.

We developed a set of 8 PCK tasks involving a combination of selected and constructed responses. As an example, for one PCK task, we present a CS programming task and ask teachers to evaluate three student responses for both correctness and level of sophistication. In another task, we assess teachers' ability to select appropriate formative assessments by presenting a few tasks and having teachers select which student challenges they would be able to identify using the tasks. A third type of PCK task asks teachers to outline aspects of student responses to include in a rubric for a given CS activity. This will provide information on how well teachers are able to identify critical aspects of student work and recognize the importance of rubrics that go beyond correct/incorrect scoring of student responses. Another category of PCK tasks assess teachers' ability to interpret student work and diagnose student challenges on programming concepts. While it is important for teachers to be able to interpret student work, it is also critical that they know what to do with the information, especially if they have diagnosed student challenges. To address this aspect of teacher PCK, we developed three tasks that assess teachers' knowledge of instructional strategies. Each task starts with a vignette describing an instructional activity and targets a specific programming challenge. Teachers need to diagnose the student challenge and then select from a list of pedagogical approaches to indicate which approach(es) they would use to address the challenge.

Component 3: Self-efficacy for Teaching Algorithms and Programming

To create a measure of CS teacher self-efficacy for teaching algorithms and programming concepts and using formative assessments, we selected and adapted existing items from validated surveys that measure teachers' self-efficacy for teaching CS and using formative assessments. An example item for teaching self-efficacy is "I understand the algorithms and programming concepts well enough to be effective in teaching them to my students." For using formative assessment, an example item is "I understand how to diagnose students' understanding of algorithms and programming concepts in all stages of instruction." A total of eight 5-point Likert-type items with four for each sub-component constitute this component of our PCK instrument.

Next steps and future directions

This PCK instrument is part of a larger project to promote middle school CS teachers' PCK by supporting their understanding of CS standards and ability to use formative assessments related to these standards. Next steps on this project include piloting the PCK instrument for validation purposes, analyzing teacher responses to the tasks, and using the instrument as a pre-post-measure of how the project intervention is affecting CS teachers' PCK.

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