Results from Rice University WeTeach_CS: A Computer Science Teaching Collaborative Serving Teachers with Different Needs through Variety of Pathways

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Abstract: Computer science (CS) is one of the school subjects that gained a great attention recently, yet it faces challenges such as teacher shortages and huge variability in teachers' professional preparation. These challenges make PD efforts even more critical to develop in-service teachers to effectively teach CS topics. This paper presents results from Rice University School Mathematics Project's WeTeach_CS program, a CS teaching collaborative that provided 20 CS teachers with an innovative professional development. The innovation comes from the four different pathways to serve diverse needs of the teachers in the best way possible and each pathway having several components spread out to several months rather than being one-time, one-shot. The paper will describe each pathway in detail to set an example for other professional development programs. The overarching goal of the program was to develop the self-efficacy and pedagogical content knowledge, which as research shows are integral to successful CS teaching. This study focused on teachers' self-efficacy for CS, CS teaching, and computational thinking, and technological, pedagogical, and content knowledge (TPACK). Data collection means include pre- and post-surveys, teacher reflections, and teach interviews. The results are promising in that the collaborative improved teachers in all these areas. The paper also describes the different pathways in detail to provide an example of a successful CS teaching collaborative.

Introduction

National reports and calls have pushed the computer science (CS) to the forefronts of K-12 education initiatives. Bureau of Labor Statistics (2015) projects that there will 4.4 million computer and information technology jobs in the U.S. by 2024 making these fields among the fastest growing. Underrepresentation of certain populations in CS, particularly ethnically minority persons, has been an urgent issue. Reasons for underrepresentation of these populations include the lack of opportunities for ethnic-minority students to enroll in CS high school courses (Goode, 2007). As all schools attempt to respond to the increasing demand for CS courses and including CS and computational thinking in their curriculum, they face with a critical shortage of teachers. In the state of Texas, about 25% of high schools offer a CS course (Texas Education Agency, 2016). Particularly, in high-poverty urban schools, these challenges become even more prominent. Therefore, it is important to train and develop CS teachers who are qualified to effectively teach diverse populations of students and attract them to CS related fields. An effective way of addressing this issue is to establish partnerships among institutions of higher education and secondary schools that will provide high quality and sustained professional development (PD) focused on the education of CS teachers. Such training should continuously stimulate teachers' intellectual growth and upgrade teachers' knowledge and skills through activities that are grounded in scientifically based research and aligned with local, state, and national CS education standards. This paper presents an innovative collaborative PD program how this program impacted teachers' self-efficacy for CS, self-efficacy for CS teaching, self-efficacy for computational thinking, and technological, pedagogical, and content knowledge (TPACK) in CS.

Literature

CS professional development

Providing effective professional development has great potential to reform computer science teachers' practices (Barr & Stephenson, 2011). Research has identified several core and structural features of effective PD that positively influence teachers' beliefs, knowledge and skills, and in turn, their teaching practices (Garet, Porter, Desimone, Birman, & Yoon, 2001). Three core features of effective professional development include: enhancing teachers' content knowledge, integrating the PD content with teachers' daily experiences in the classroom to align with local/state standards, and creating an environment that facilitates active, hands-on learning opportunities for teachers (Desimone, 2009; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). For these core features to have a positive and sustainable effect on instruction, the duration of the PD (long and spread out across time) and the collective participation among teachers from the same schools or school districts are among other critical factors (Garet et al., 2001). In addition, given that teacher learning is dynamic and occurs over time, establishing a long-term and effective relationship among teachers and between teachers and professional development facilitators is a key premise of effective professional development (Goode, Margolis, & Chapman, 2014). This would mean, instead one-time, one-shot programs, a culture of ongoing learning community with a lot of reflection is needed to develop teacher in a sustainable way (Garet et al., 2001). These critical features of effective professional has great potential to improve, particularly, teachers' self-efficacy and TPACK (Voogt, Fisser, Roblin, Tondeur, & van Braak, 2012; Wang et al., 2004). Thus, this study focuses on whether the quality of a professional development program that embodied the aforementioned critical characteristics of effective teacher development programs would positively influence CS teaching self-efficacy and TPACK.

Self-efficacy

Self-efficacy is defined as "a judgment of one's capability to accomplish a certain level of performance" (Bandura, 1986, p. 391). Within the teaching discipline, teachers' self-efficacy may be defined as the extent to which teachers believe they can successfully execute teaching-related tasks within a particular context (Tschannen-Moran & Hoy, 2001). Teachers' self-efficacy beliefs about the subject matter and its teaching have been linked to their instructional approaches and their students' motivation and achievement (Anderson, Greene, & Loewen, 1988; Clark et al., 2014; Desimone, 2009; Stipek et al., 2001). Researchers proposed that teachers' self-efficacy is influenced by factors including personal experiences, vicarious experiences, and physiological indicators (Tschannen-Moran & Hoy, 2001). Proxies for these sources of teachers' self-efficacy include teaching experience, educational background in the subject matter taught, and professional development experiences (Stevens et al., 2013; Swackhamer, Koellner, Basile, & Kimbrough, 2009).

Teachers' Technological Pedagogical Content Knowledge (TPACK)

TPACK is a theoretical framework that addresses teachers' knowledge of effective technology use during their instruction (Mishra & Koehler, 2006). TPACK framework proposes that in addition to the importance of teachers' content-specific knowledge and pedagogical knowledge for effective teaching, teachers should also gain knowledge of how to integrate technology in their instruction (Thompson & Mishra, 2007). Although technology integration seems trivial for CS content, it is not always the case that teachers effectively use technology to teach CS. TPACK framework identifies three technology-specific knowledge dimensions: technological content knowledge (TCK; the knowledge of how technology can provide new representations of specific content), technological pedagogical knowledge (TPK; the knowledge of how different technologies can be utilized for teaching), and technological pedagogical content knowledge (TPCK; the knowledge necessary for teachers to integrate technology into their teaching of a specific content area). It is important to understand to what extent professional development and teacher education programs impact TPACK so that more effective programs can be developed to serve the needs of teachers, schools, and the community (Mishra & Koehler, 2006; Schmidt et al., 2009).

The Rice University School Mathematics Project (RUSMP) WeTeach_CS Collaborative

The goals of the RUSMP WeTeach_CS Collaborative was to (1) increase CS content and pedagogical knowledge of teacher participants, and (2) to provide support for teacher participants as they embark on teaching the first CS course on their respective campuses. The Collaborative was facilitated by Rice University School Mathematics Project (RUSMP), a mathematics education and STEM education and research center located a diverse metropolitan area (Houston, TX, United States). Funding for the six-month program was provided from WeTeach_CS, a state grant program organized through the University of Texas at Austin (UT-Austin), a flagship state university. A total of 29 programs across the state received funding through the program. WeTeach_CS funding received from the state was leveraged with funds received from Code.org, a national non-profit organization dedicated to improving computer science education in the states.

Twenty teachers, 18 middle school and 2 high school, participated in the Collaborative. Originally, it was expected that all participants would be from the largest school district in the city, however three teachers originally recruited for the program declined their positions and were replaced; two by teachers in suburban districts and one by a teacher in a private school. Participants in the program each received a stipend of $1600 and over $600 in materials.

Teachers in the collaborative were required to complete 60 hours of professional development during the grant period. All collaborative participants participated in a one-week conference sponsored by Code.org and attended three evening meetings throughout the grant period. During the evening meetings, the participants had the opportunity to get hands-on experience with coding including programming the movement of miniature vehicles. Participants then selected one of three pathways that best met their professional needs. Participants in Pathway 1 were actively pursuing Computer Science certification. Teachers (N=5) in this pathway attended face-to-face institutes that focused on preparation for the rigorous state certification examinations as well as smaller tutorial sessions. Participants who successfully obtained CS 8-12 certification received an additional stipend provided by the Center for STEM Education at UT-Austin via state and corporate/foundation funding. Pathway 2 participants (N=6) attended a statewide computer science conference and then shared what they learned at the conference with their fellow participants at one of the evening meetings. Teachers in Pathway 3 (N=4) selected online courses and were to complete these courses at their own pace.

Finally, some teachers in Pathway 3 were not able to successfully complete their online courses and needed to attend face-to-face workshops instead, which basically became kind of a combination of Pathway 1 and Pathway 3. Originally not intended but emerged as customizing to the needs of teachers, this Pathway 4 had five teachers. Ultimately all 20 participants completed their required 60 hours.

Methods

The effectiveness of the RUSMP WeTeach_CS Collaborative was studied through pre- and post-surveys as well as post-interviews. The pre-survey was administered through Qualtrics (an online survey development and administration platform) in the first month of the program in February. The post-survey was administered in the last month of the program in July after all teachers completed their required 60-hour work. Pre- and post-survey items related to CS teaching and pedagogical content knowledge were modified and adapted from the following five main instruments that are valid and reliable: CS self-efficacy (8 items; Kolar, Carberry, & Amresh, 2013); CS teaching self-efficacy (instructional strategies; 4 items; Klassen et al., 2009); CS teaching self-efficacy (general; 12 items; Enochs, Smith, & Huinker, 2000); computational thinking self-efficacy (6 items; Angeli et al., 2016); and TPACK (14 items; Schmidt et al. (2009).

In addition, the pre-survey included teachers' academic preparation, prior experience in CS and CS teaching, expectations for the program. The post-survey also included open-ended questions to evaluate each component of RUSMP WeTeach_CS program. Additionally, one teacher per pathway was randomly selected for a post-program phone interview to evaluate the different components of the program beyond the program. The interviews were transcribed and qualitatively analyzed to explore the effectiveness of the RUSMP WeTeach_CS Collaborative.

Results

We investigated the impact that the Collaborative had on CS teachers' self-efficacy and knowledge. More specifically, utilizing a self-reported pre-and post-survey design, we measured teachers' self-efficacy in computer science (CS), computational thinking, CS teaching (general), and CS teaching (instructional strategies) as well as CS content knowledge, CS pedagogical content knowledge, and CS technological pedagogical content knowledge (using TPACK framework). The changes in all of these areas from pre- to post-survey (repeated-measures *t*-test) were all positive and significant except for one construct: computational thinking self-efficacy (see Table 1). The effect sizes of these significant changes were moderate to high (Cohen's *d*s ranging from 0.59 to 1.26. This results indicate the effectiveness of the RUSMP WeTeach_CS Collaborative in developing CS teachers into more self-efficacious and more knowledgeable ones. There were four pathways teachers signed up for—originally there were 3 but the last pathway was added to serve the needs of the teachers better.

We also looked to see if there were any significant differences among teachers based on their pathways (using one-way ANOVA) in terms of the constructs that were measured. Four pathways did not show any differences in any areas (all p values greater than .05 with $F(3,16)$ statistics ranging from 0.23 to 1.74)implying that all pathways impacted our teachers about the same. Given these results we can confidently say that the program was able to serve the needs of different groups of CS teachers in a balanced way that improved their self-efficacy in CS, self-efficacy in CS teaching, and TPACK in CS.

Measure	N	Paired differences			Cohen's *d*
		Mean Gain (post-pre)	S.D.	*t*-value	
CS Self-efficacy	20	0.37	0.65	2.59*	0.59
Computational Thinking Self-efficacy	20	0.23	0.62	1.62	0.37
CS Teaching Self-efficacy (instructional strategies)	20	0.75	0.84	3.98**	0.91
CS Teaching Self-efficacy (general)	20	0.75	0.61	5.50***	1.26
Content Knowledge	20	0.62	0.62	4.42***	1.01
Pedagogical Content Knowledge	20	0.80	0.72	4.95***	1.13
TPACK	20	0.58	0.75	3.41**	0.78

Notes. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 1. Paired Samples *t*-Tests of Teacher Beliefs and Knowledge

Open-ended responses from teachers indicated that their gains from the program included deeper understanding of the subject matter (i.e., CS), confidence in teaching CS, different perspectives, and opportunities to collaborate. In particular, teachers expressed that the connections made with other CS teachers within the program and opportunities given to collaborate with one another as well as the abundance of resources and materials provided exceeded teachers' expectations. Teachers also commended about the program with regards to the professionalism they received, the quality of the facilitators and trainers. All teachers found the content and the structure of the collaborative met their needs indicating differentiated pathways based on the needs of the teachers served their interests well. Several teachers pointed out that they would like to participate more programs like this one in the future. The following testimonials from three teachers sum up the success of the program:

> *The amount of information and support […] [t]he conference and meetings have all exceeded what I anticipated and the CS Discoveries training was amazing.*

The collaborative has presented a wide diversity of CS applications that are interesting and relevant. It has also provided good preparation and support for the certification test.

Just discovered so many resources. The sessions were very helpful. Learned lots of different methods.

In addition, four teachers were interviewed about the specific components of the program. One teacher from each pathway was randomly selected for a short (about 15 minutes) phone interview. One of the most important things that was common across all interviews was the friendly yet professional, prompt, and helpful communication of the projects directors that served teachers' needs, engaged, encouraged, and supported them. Another point made by interviewees was that all components of the program (regardless of their pathways) was very informative, well-planned, engaging, and to-the-point.

In addition, the collaborative nature of the program was emphasized by interviewed teachers. Having a community of people not only from different CS background but also from different schools with different points of views was considered a great asset to the program by teachers. Several teachers also noted that assuming the students' role as some of the program activities required was a great way to see the instruction from the student perspective and what to expect in the classroom.

Quite a few teachers expressed their frustration with having barriers at the administrator level in terms of implementing what they have learned through the collaborative in their classes. The future programs will have greater potential to improve CS education if the administrator buy-in to the program (i.e., strong commitment) is somehow achieved.

Conclusions

This study shows the success of a CS collaborative with its key components aligned with the important features of the effective professional development identified in the literature as well as its unique features including providing a variety of pathways to serve the needs of the teachers in the best way and constant and close interaction with teachers. The experience, knowledge, and connections of the key personnel who know the right resources and are able to utilize these resources are key to such a successful program. In addition, knowing the school districts, schools, and teachers in terms of what they need to improve CS education on their campuses is also vital to design an effective program for teachers. In addition, we believe constant communication, establishing the trust between facilitators/directors and teachers (i.e., being on their side), and establishing a community of learners (not feeling left out or feeling alone to fight the struggles they face). Future professional development programs should consider finding ways to increase school/district administrator awareness and support for CS courses and long-term and continued professional development support for teachers.

Acknowledgements

This study is based, in part, on a project partially funded through the WeTeach_CS Collaboratives, a program administered by the University of Texas at Austin's Center for STEM Education (Grant #3065), and partially funded by Code.org.

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