Middle School Teachers' Self-efficacy in Teaching Computer Science and Digital Literacy: Impact of the CS Pathways RPP professional development program

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ABSTRACT

Background: Researcher-practitioner partnerships (RPPs) have gained increasing prominence within education, since they are crucial for identifying partners' problems of practice and seeking solutions for improving district (or school) problems. The CS Pathways RPP project brought together researchers and practitioners, including middle school teachers and administrators from three urban school districts, to build teachers' capacity to implement an inclusive computer science and digital literacy (CSDL) curriculum for all students in their middle schools.

Objective: This study explored the teachers' self-efficacy development in teaching a middle school CSDL curriculum under the project's RPP framework. The ultimate goal was to gain insights into how the project's RPP framework and its professional development (PD) program supported teachers' self-efficacy development, in particular its challenges and success of the partnership.

Method: Teacher participants attended the first-year PD program and were surveyed and/or interviewed about their self-efficacy in teaching CSDL curriculum, spanning topics ranging from digital literacy skills to app creation ability and curriculum implementation. Both survey and interview data were collected and analyzed using mixed methods 1) to examine the reach of the RPP PD program in terms of teachers' self-efficacy; 2) to produce insightful understandings of the PD program impact on the project's goal of building teachers' self-efficacy.

Results and Discussion: We reported the teachers' self-efficacy profiles based on the survey data. A post-survey indicated that a majority of the teachers have high self-efficacy in teaching the CSDL curriculum addressed by the RPP PD program. Our analysis identified five critical benefits the project's RPP PD program provided, namely collaborative efforts on resource and infrastructure building, content and pedagogical knowledge growth, collaboration and communication, and building teacher identity. All five features have shown direct impacts on teachers' self-efficacy. The study also reported teachers' perceptions on the challenges they faced and potential areas for improvements. These findings indicate some important features of an effective PD program, informing the primary design of an RPP CS PD program.

CCS CONCEPTS

• Computer Science Education • Education • Collaborative learning

KEYWORDS

teacher self-efficacy, researcher-practitioner partnership (RPP), teacher professional development, middle school, computer science education

1 Introduction

Computer Science (CS) education is a vibrant and quickly evolving field, where the state-of-the-art applications and programming languages change frequently. Students also see the world of computers and technology change around them. This creates challenges unique to the CS education field. Teachers must not only stay abreast of all these developments but develop the self-efficacy to teach these new concepts. Researchers have confirmed the significant role of teachers' self-efficacy in predicting their behavior and performance [21], as well as their students' academic outcomes and motivation [11, 23, 28]. Preliminary research in computer science education shows that professional development (PD) is an important way for building teacher self-efficacy [29], one that must be explored further to continue chasing the highest-possible student success.

Researcher Practitioner Partnerships (RPPs) have gained increasing prominence within education, since they are crucial for identifying partners' problems of practice and seeking solutions for improving district (or school) problems [4, 5]. The impact of meaningful partnerships includes positive changes in teachers' self-efficacy in various educational research fields [4, 5, 12] However, adopting RPPs in K-12 computer science education is relatively rare [12]. Therefore, this paper reported results from our CS Pathways RPP project that explored the teachers' self-efficacy development. The ultimate goal was to gain insights of how the project' PD program under the RPP framework prepared teachers and built their self-efficacy in teaching the curriculum, in particular its challenges and success of the partnership. The study is guided by the following research questions:

1. Which attributes (factors) can account for teachers' self-efficacy profiles after their first year of the PD participation?

2. How did teachers' participation in the RPP project influence their self-efficacy in teaching the project's CSDL curriculum?

2 Background

2.1 Computer Science Teacher Self-efficacy

Although teacher self-efficacy has been the major research strand for decades [10, 15, 20], it is not until Bandura [1] transformed the research by validating the construct of teachers' self-efficacy. According to Bandura's Social Cognitive Theory, "the self-efficacy belief system is not a global trait, but a differentiated set of beliefs linked to distinct realms of functioning." [2]. Therefore, self-efficacy should be conceptualized as a domain-specific trait. Teachers' self-efficacy may vary according to different types of tasks, students, and circumstances in class [19, 24]. Following the Bandura-based definition of self-efficacy, Dellinger et al. [6] further defined teachers' self-efficacy as "individual beliefs in their capacities to perform specific teaching tasks at a specific level of quality in a specific situation". Wyatt [26] also contributed to the definition by defining teachers' self-efficacy as "teachers' beliefs in their capability of supporting learning in various tasks and context-specific cognitive, metacognitive, affective and social ways." Both definitions focused on the domain-specific trait of teachers' self-efficacy. Wyatt [26] expanded it to include the outcomes of teachers' self-efficacy. Zee and Koomen [28] reviewed Bandura's triadic reciprocal causation model that indicated teachers' self-efficacy in relation to classroom processes. In the model, domain-specific teachers' self-efficacy can have consequences for students' academic adjustments, quality of the classroom, and teachers' well-being.

Given the importance of teachers' self-efficacy and its impacts, researchers have examined teachers' self-efficacy in various subjects, such as STEM subjects and literacy development [9, 17]. However, there have been relatively few studies examining self-efficacy for computer science education teachers; therefore, the need to research on such an important topic has been proposed by many computer science education researchers [18, 27, 29]. Rich et al. [18] examined US-based elementary teachers' self-efficacy towards the integration of computing and engineering after participating in a weeklong professional development in computing and engineering. The authors used the modified Teacher Efficacy and Attitudes Toward STEM Survey (cited in [18]) to measure both the differences and similarities of the teachers' self-efficacy between a study school and a comparison school. An independent-sample t-test on the survey data showed that teachers from both schools were likely influenced by the PD on their self-efficacy beliefs towards the importance of computing and engineering and on their confidence to teach the subjects. The results from teacher interview data showed varied individual self-efficacy beliefs for teaching the subject. The authors also found that teachers' self-efficacy and their prior experience with teaching STEM are positively correlated. Their perceived experience of implementing the curriculum successfully was an important factor for increasing their self-efficacy.

Borowczak and Burrows [3] also reported how their NetLogo PD program helped enhance content knowledge and self-efficacy in integrating CS into existing lessons and curricula. The PD program provided a constructivist environment for the pre-collegiate teachers to increase their content knowledge and self-efficacy. The pre- and post-survey results showed a significant increase in teachers' self-efficacy, which proved that the PD program had a positive impact on CS teachers. The authors concluded that the short-term PD experience can often provide beginning CS content knowledge and bolster teachers' self-efficacy. However, a long-term effect required teachers to dedicate more time to internalize the modeling software with real-world applications, as well as on-going expert support.

Besides the aforementioned studies in which the authors examined teachers' self-efficacy as an impact of the professional development program, there are a few fairly new studies that made contributions to the variety of CS teachers' self-efficacy research. For example, Zhou et al. [29] developed an instrument to measure secondary school teachers' self-efficacy in teaching computer science. The instrument was also implemented in a nine-week hybrid PD program to validate the instrument. The designed self-efficacy survey aimed to assess teachers' self-efficacy on both content knowledge (e.g., algorithm, computing impact, and programming) and pedagogical content knowledge. The examination on the instrument validity showed positive results. The implementation of the survey in the nine-week PD also showed a significant increase in teachers' self-efficacy in content and pedagogical content knowledge. The study made a contribution to computer science education by providing a validated self-efficacy instrument which can be potentially used to measure CS teachers' self-efficacy in various settings.

Yadav et al. [27] conducted a quantitative study to identify different levels of teachers' self-efficacy profiles. The authors further investigated the confounding factors that potentially contributed to the disparity in teachers' self-efficacy. To identify the profiles, the authors performed cluster analysis on the sum score of the three dimensions of teachers' self-efficacy identified in the Teachers' Sense of Self-efficacy scale (TSES). The analysis identified three clusters: low, moderate, and high. The further analysis on teachers' self-efficacy group against teachers' background showed that no difference in teachers' self-efficacy related to their teaching experience, nor their prior knowledge on computer science or programming. Teachers' academic background regarding their undergraduate education was the only factor reported that impacted teachers' self-efficacy.

The reviewed studies showed that many of the studies have recognized the significance of conducting context-specific studies on computer science teachers' self-efficacy. As Yadav et al. [27] stated, CS teachers' development still needs to be further explored, with self-efficacy remaining a focus since the methods to increase it are highly specific to CS teachers. This encouraged our study to delve deeper into CS teachers' self-efficacy and ways to enhance it through ongoing PD.

2.2 Effective CS Professional Development

Professional development has been used as an effective way to train novice computer science teachers and keep them up to date with the latest developments in the field, as well as strengthen their knowledge and improve teaching practices. Previous studies on computer science teacher professional development have identified some core features of effective PD [13, 16]. These features are believed to have positive impacts on teachers' self-efficacy.

First, Menekse [13] reviewed PD programs from 2004-2014 and concluded five core features for an effective PD program. The five core features were: 1) PD collaboration with teachers and school leadership; 2) providing adequate time for implementation and practice; 3) organizing active learning methods to demonstrate how to implement new teaching practices; 4) supporting teachers building up pedagogical content knowledge; 5) offering follow-up support for teachers and establishment of professional learning communities. These features are believed to be efficient ways to build teachers' CS-specific pedagogical content knowledge, as well as establish the network for CS teachers. In return, teachers' participation in high-quality PD can help enhance their self-efficacy. Reding and Dorn [16] studied a Midwestern PD program and found the best ways PD developed teachers, by analyzing their daily journal records. The PD program provided a wealth of novel resources for these teachers, who came from various backgrounds, as the PD went week by week through different core topics and lesson plans. Teachers explored new resources. When they took them back to the classroom, teachers found students to be noticeably more engaged in the lesson materials. The authors were also able to distill out three aspects that should be front and center when designing a PD program: "Comfort Level", "Practical Application" and "Student Success." In the paper, Reding and Dorn's [16] also reported the definition of three interdependent facets of knowledge that an effective PD program supported, namely explicit knowledge, implicit knowledge, and emancipatory knowledge. Explicit knowledge encompasses the direct content knowledge and traditional process of learning, whereas the implicit knowledge refers to teachers' learned behaviors and personal know-how about which ways are effective. Emancipatory knowledge delves deep into the emotional aspects of learning, in which the authors believe that the emotional components largely impact teachers' beliefs, attitudes, and actions. Therefore, it is also a significant contribution to teacher self- efficacy.

These studies both showed the promise of PD in strengthening CS teachers' self-efficacy and laid out some key concepts a successful PD program could incorporate. Our study sought to go further and deeper to study how our first-year PD program under the RPP framework encompassed some of the reviewed features of effective PD, and explained how the PD had a measurable impact on teacher self-efficacy.

2.3 Research Practice Partnership (RPP) Framework

Although adopting RPP to K-12 computer science education is fairly new, the framework has been used in the US for several decades to address general problems in K-12 education [22]. McGill et al. [12] recently reviewed RPP research in terms of its definition and component, the theoretical framework, the benefits it brought to education in general, as well as the challenges that RPPs are facing. In the report, the authors conceptualized four major partnership models and the major components within them, drawn from the similarity and shared functions among different ways of implementing RPPs. The partnership models include: 1) RPP Research Alliances focused on local problems in a specific region (district, state, etc.); 2) RPP Co-design programs focused on collaboration to design best practices for the classroom, drawing heavily from theory and empirical evidence; 3) Networked Improvement Communities offered a continuously improving iterative model for new methods to address shared challenges; 4) Hybrid RPP framework incorporating two or more of these aforementioned models.

The authors also presented *a Guide Map to Research-Practice Partnership* produced by the Education Develop Center (EDC) and the Research + Practice Collaboratory [12]. The map illustrated the method for establishing and sustaining an RPP program. The method starts by establishing an equitable partnership and agreeing on a shared framework where problems can be mutually identified. It is then branched out to all relevant stakeholders for brainstorming of solutions, and research questions. The RPP sustains itself with "cycles of inquiry" in which findings are studied and communicated, while the group goes back to agree on its next set of problems, continuing for the life of the program. In addition, the authors reiterate that the collaborative steps (e.g. collaboration to identify the problems, collaboration to identify and implement solutions, and collaborative inquiry) are the most critical elements for RPP effectiveness. Collaboration is the core of an RPP, which is valuable for ensuring the most-pressing problems are addressed, which keeps the RPP effective and relevant. Collaboration is also critical for within-district research and inquiry, so that the findings may be shared effectively and used to develop realistic solutions. Identifying and implementing solutions is crucial as well, which requires a strong collaborative infrastructure of meetings, communication, and professional support across the RPP community in order to achieve mutual and effective results within the partnerships.

Based on the RPP framework, we report the results in the following sessions on how our CS RPP PD program built teachers' self-efficacy.

3 The Project Professional Learning

This study is based on the CS Pathways RPP project [14]. The program is a three-year project funded by the National Science Foundation, in which two universities - The University of Massachusetts Lowell and The State University of New York at Albany - partnered with three urban school districts in two neighboring states. The goal of the project is to establish inclusive computer science programs at all the middle schools at the partnership districts. All stakeholders work in collaboration under the RPP, applying the SCRIPT framework [30]. The project implemented a wide range of activities during the first year to create the partnership among project researchers, district leads, and teachers. The project's PD program aims to help the middle school teachers to build their capacity in implementing the project's CSDL curriculum that eventually engages middle school students from these three districts in both digital literacy and computer science as they develop mobile apps for social and community good [14].

In the first year, the CS Pathways PD program was developed under a team of researchers from higher education, school district administrators, and teachers. The RPP team members worked closely to provide a collaborative inquiry experience for teachers who participated in the PD. The first year PD included 52 hours of meetings, combining both in-person and online activities. Since 2019, we have hosted a few face-to-face meetings at each partner school district. Starting from March 2020, the whole project moved to all virtual meetings due to the pandemic. The PD activities included discovering priorities using the SCRIPT Visions Toolkit [31] learning CSDL knowledge, learning experiences in building mobile apps, and conversations about teachers' own learning challenges [14].

4 Methodology

4.1 Data Collection

During the first year of the PD program, the participants consisted of nineteen middle school teachers teaching various disciplines, among whom twelve were teaching technology or computer related courses (e.g., Computer Application and Technology Education); and seven teachers were in other content areas including four math teachers, three science teachers. Eleven of the teachers were female, and the other eight were male.

The teacher data was collected via both the end-of-year survey and semi-structured interviews at the end of the first year PD program with the aim to examine teachers' self-efficacy profile and to gain insightful understandings of their perceptions of self-efficacy. All teachers completed the survey pertaining to their self-efficacy; more than half of the teachers (n = 10) accepted the interview.

The survey was also designed to assess the teacher participants' perceived capabilities by asking "How confident are you with the ability to do…?" There were 23 self-evaluated items spanning CSDL content knowledge and capacity to implement the CSDL curriculum. These items were created to capture three constructs of teacher self-efficacy. Table 1 shows the survey items and the corresponding constructs those items aim to measure. The survey asked the teacher participants to rate their confidence in the ability to perform the tasks on a five-point Likert scale, ranging from "Not at all" (point 1) to "Very" (point 5). Cronbach's alpha was measured to check the validity and reliability of the set of survey items. The internal consistency of the survey items is Cronbach's alpha = 0.93, which indicates that the survey items are closely related as a group of survey questions to evaluate teachers' confidence and self-efficacy.

Subsequently, all teacher participants were invited to a semi-structured interview. The interview was developed to supplement the survey to dive into the teachers' perceptions on their self-efficacy. Interview items were designed to capture teachers' experience and the impact of the our RPP PD program, which reflects their self-efficacy in knowledge growth and confidence to implement the curriculum. Sample questions asked during the interview include "What do you like or dislike about professional learning? What has been challenging or helpful?", "In which your participation in the project has impacted you regarding teaching computer science and digital literacy (CSDL)? e.g., your beliefs, decisions, or plans you made regarding teaching CSDL.", "How has this group prepared you for your teaching course load?". The teachers who participated in the interviews were almost evenly distributed across three districts. Among them, four were non-technology or content area teachers who taught subjects such as science, math and civics; the other six teachers were technology or computer teachers. The interviews were conducted through Zoom with the duration ranging from 30 – 45 minutes. The conversations were transcribed, and the transcriptions were analyzed in NVivo 12.

Table 1: Survey items and corresponding CSDL capacity

Item Index	Survey Items	Self-efficacy Constructs
F1	Set up new software on tablets	Digital literacy knowledge
F2	Ensure the tablets are charged and ready for use by students	
F3	Implements a system of distributing tablets to students for class use	
F4	Implement a system of gathering tablets and returning	
F5	Trouble shoot hardware problems with tablets	
F6	Trouble shoot software problems with tablets	
F7	Use any apps	CSDL knowledge on creating apps (with computer science concepts)
F8	Use an app to help you solve a problem in your community	
F9	Create an app using App Inventor	
F10	Create an app to solve a community problem	
F11	Create an app that is relevant and exciting to students	
F12	Create an app that has an image	
F13	Create an app that has multiple images	
F14	Create an app that has sound	
F15	Create an app that has multiple screens	
F16	Create an app that uses variables and lists	
F17	Teach digital literacy skills as part of a computer science curriculum	Ability to implement the CSDL curriculum
F18	Teach students file naming management that is relevant to apps	
F19	Teach students how to use resize images to use in an app	
F20	Teach students how to edit or select audio files for use in an app	
F21	Manage teams of students working collaboratively to develop apps	
F22	Integrate app development into my existing curriculum	
F23	Create multimedia presentations	

4.2 Data Analysis

In our former study [14], we assessed teachers' confidence in the CSDL content and their ability to implement the project curriculum through the pre-and post- surveys. The results indicated that there was a significant increase in teachers' overall confidence after their first-year participation in the project's PD. The present study aimed to further investigate in detail the attributes of teachers' self-efficacy profiles after their first-year participation in the PD program. Therefore, Principal Component Analysis (PCA) was used to explore the teachers' self-efficacy profile. In this study, PCA was carried out on the survey data to explore the salient features that could logically cluster response factors (e.g., survey items) together and explain the correlations to self-efficacy. In general, this quantitative analysis attempted to explore patterns in the data and estimate the level of structures. The teachers' self-efficacy profiles were interpreted through the feature indices that load onto each principal component. The quantitative data analysis was performed in RStudio. The dataset contains survey responses from all 19 teachers with some missing values where teachers skipped some survey items. To manage missing values in the dataset, we applied the Ipca method, which was studied as the best performed method to impute missing values under the widest range of conditions [17]. For the inclusion of factors to each dimension, we set the cut-off for eigenvalues of $\lambda > +/- .20$. We noticed that the cut-off value is lower than the conservative ones, and this is due to small numbers of factors evolved in this study. The cut-off insured only salient feature indices would be included and interpreted in each dimension.

The next portion of this study sought to understand 1) the teachers' perceptions of how their self-efficacy is influenced by the PD, and 2) whether or not technology and other subject area teachers differ in their self-efficacy. We chose the data-driven inductive approach of thematic analysis to analyze the interview data, which allows the data to determine the emerging themes [8].

This descriptive and exploratory inquiry of interview data involved an iterative and reflective process. The first step concerning the inductive thematic analysis was the initial coding of the interview conversation. The coding strategy "open, axial, and selective" [25] was employed. As illustrated in Figure 1, open coding was the initial level of coding, in which we took the vast interview transcripts and distilled the teachers' responses into discreet, individual feedback about particular constructs of the PD, which teachers reflected either beneficial or challenging to their self-efficacy. Going interview by interview, any applicable content from the answers was assigned its code, with each code corresponding to a tangible theme, such as teacher support, collaboration and community, app creation ability, etc. By doing this, we aimed to capture a rich description of the teachers' perceptions. As the interview analysis progressed, the categories of each code were continuously reviewed to make sure they were distinct and did not overlap, or as needed, separating the codes out into two separate ones when the responses covered separate constructs. Axial coding, as the second level, took place after all the transcripts were reviewed and coded. This step dynamically transformed the data into five broad categories, such as collaboration and community, which all teachers had personal experience with throughout their experience in the PD. The findings will be discussed in detail in the next section. Finally, the selective coding, while sound in the theory presented by [25], was not performed in this study as the five axial groups are better left independent of each other to provide understanding on how each one impacts the teachers' self-efficacy. NVivo 12 was used to support the whole process of coding cycles and the final capture of the construction of meaning.

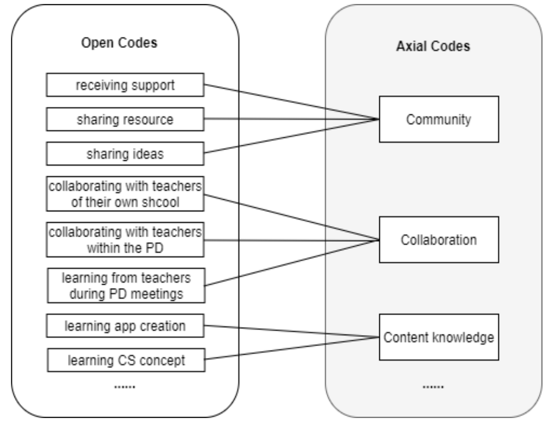

Figure 1: Open and axial coding model

The second step involved dividing the coded responses based on each teachers' backgrounds, specifically whether they were a CS/technology teacher or from another subject area. Afterwards, the interviews were re-coded where the teachers indicated a difference in how the PD impacted their self-efficacy. For example, a CS teacher was quoted that a meeting helped them "teach better" whereas a non-CS teacher instead said it helps them "learn better". This encompassed all five constructs from the axial coding to examine where teachers did in fact perceive their self-efficacy differently.

5 Findings and Discussions

5.1 Teachers' Self-efficacy Profile

The eigenvalues from the PCA analysis for the top ten dimensions are reported in Table 2. As shown in Table 2, the first dimension alone accounts for about 44% of the total variance. The scree plot (shown in Figure 2) was also generated to visualize the variance explained by each dimension. The scree plot (Figure 2) also shows the cut-off point, where most of the variations are explained by the chosen dimensions. Adding more dimensions beyond this cut-off point would not show significantly conclusive results as those dimensions accounted for a smaller and smaller fraction of the overall variance. The clearest cut-off in Figure 2 appears to be in between Dimension 3 and 4 where the variance percent drop from about 13% to only 8%, which means three dimensions should be included to interpret the teachers' self-efficacy pattern. In total, the first three dimensions can account for 76.7% of the total variance.

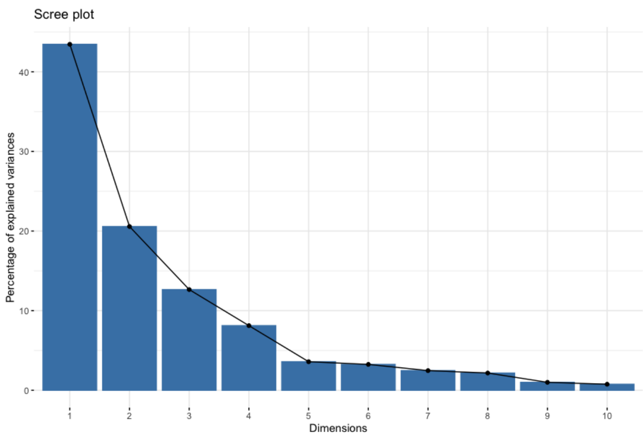

Figure 2: Scree plot of principal component analysis

Table 2: Eigenvalues from the PCA analysis

Dimension No.	Eigenvalue	Variance percent	Cumulative variance
Dim.1	3.16	43.49	43.49
Dim.2	2.17	20.54	64.03
Dim.3	1.7	12.61	76.64
Dim.4	1.38	8.13	84.77
Dim.5	0.91	3.6	88.36
Dim.6	0.87	3.26	91.62
Dim.7	0.76	2.48	94.1
Dim.8	0.71	2.17	96.27
Dim.9	0.48	1.01	97.28
Dim.10	0.42	0.76	98.05

The factor loadings (λ > +/-.20) for attributes in each of the three dimensions are presented in Table 3. And it is the correlations among all factors that consist of the teachers' self-efficacy profile. Eventually, there are three resulting groups of teacher participants showing their self-efficacy profiles. The first dimension captures teachers with strong self-efficacy in their ability of app creation and confidence in teaching CSDL after the PD (Dim.1 = 43.5%); Dimension 2 indicates that teachers who had relatively less self-efficacy on their digital literacy knowledge, but showed more confidence in app creation after participating in our PD program for one year (Dim.2 = 20.6%); Dimension 3 represents teachers who believed themselves having strong digital literacy knowledge but very low capacity in teaching CSDL (Dim.3 = 12.7%). Accordingly, about half of the teacher participants demonstrated high self-efficacy (Dim.1), and the rest of them showed moderate (Dim.2) to low (Dim. 3) self-efficacy. High self-efficacy teachers showed high perceived capability on all the three aspects (DL skills, app creating, and implementing the curriculum), while moderate and low teachers showed their perceived capacity on two or less aspects.

Table 3: Factor loading of attributes in three dimensions

Dimension 1	
Teacher Self-efficacy Feature Indices	Loadings
F1: Set up new software on tablets	-0.24
F7: Use any apps	-0.21
F8: Use an app to help you solve a problem in your community	-0.22
F9: Create an app using App Inventor	-0.26
F10: Create an app to solve a community problem	-0.24
F11: Create an app that is relevant and exciting to students	-0.26
F12: Create an app that has an image	-0.24
F13: Create an app that has multiple images	-0.22
F14: Create an app that has sound	-0. 22
F16: Create an app that uses variables and lists	-0.22
F17: Teach digital literacy skills as part of a computer science curriculum	-0.24
F18: Teach students file naming management that is relevant to apps	-0.25
F20: Teach students how to edit or select audio files for use in an app	-0.22
F22: Integrate app development into my existing curriculum	-0.2
F23: Create multimedia presentations	-0.27
Dimension 2	
Teacher Self-efficacy Features Indices	Loadings
F2: Ensure the tablets are charged and ready for use by students	-0.38
F3: Implements a system of distributing tablets to students for class use	-0.41
F4: Implement a system of gathering tablets and returning	-0.41
F12: Create an app that has an image	0.23
F13: Create an app that has multiple images	0.26
F14: Create an app that has sound	0.26
F15: Create an app that has multiple screens	0.26
F16: Create an app that uses variables and lists	0.23
F21: Manage teams of students working collaboratively to develop apps	-0.27
Dimension 3	
Teacher Self-efficacy Feature Indices	Loadings
F5: Trouble shoot hardware problems with tablets	0.38
F6: Trouble shoot software problems with tablets	0.46
F7: Use any apps	0.33
F8: Use an app to help you solve a problem in your community	0.25
F19: Teach students how to use resize images to use in an app	-0.33
F21: Manage teams of students working collaboratively to develop apps	-0.24

The study also drew conclusions of the teachers' self-efficacy by examining the similarities and differences between the groups. A comparison across three groups highlighted the distinct features of teachers' self-efficacy in each group (high, low and moderate self-efficacy). Teachers with high self-efficacy (Dim.1) showed a strong perceived capacity to create apps and to teach CSDL curriculum, whereas low self-efficacy teachers (Dim.3) showed no such perceived capacity. Comparing the group of teachers with high self-efficacy (Dim.1) and those with moderate self-efficacy (Dim.2), the moderate teachers presented characteristics of high perceived capacity in creating apps, but lacking capacity in teaching the curriculum. A notable distinction of teachers' self-efficacy among three groups is that only teachers with high self-efficacy showed perceived capacity in creating apps relevant and exciting to students (see F10 and F11 in Dim.1). Although moderate teachers perceived an increase in their app creation capability (see F12 to F16 in Dim.2), they did not report the capability in creating apps that were highly relevant to their students. This significant finding was further investigated in the teacher interviews to further understand this phenomenon.

5.2 Impact of the CS Pathways RPP PD on Teachers' Self-efficacy

To develop further understandings of how teachers' PD experience impacted their self-efficacy, this section presents the emerging themes from the thematic analysis of the interview data. Teachers' reports of RPP PD experience were organized into five features of the PD program. Each feature appeared as a significant factor, which teachers perceived as influencing their self-efficacy in both learning and teaching CSDL. The feedback was broken out into positive evidence and opportunities for improvement, both of which provide valuable insights that can inform the design of the PD program.

Collaborative Resource and Infrastructure Building. The majority of the teacher participants appreciated that the RPP PD program introduced the vast existing resources on learning and teaching computer science, such as resources from *Code.org* and *ScratchEd* community. This served as a gateway into the computer science education community. Teachers with strong confidence in their computer science and digital literacy knowledge also found the discussions of computer science education research articles during the PD group meetings solidified and challenged their thinking in terms of teaching computer science concepts and enhancing computational thinking skills for their students. In addition, the project sponsored teachers to attend the Computer Science Teachers Association (CSTA) Annual Conference. Teachers who attended the conference spoke highly of the opportunity for their content knowledge growth and network building.

Besides the aforementioned resources that teachers perceived as beneficial to their self-efficacy development, a number of teachers also suggested that they wanted to see the PD program progress - specifically to accumulate social capital and build infrastructure, such as a repository of curricular resources shared among the PD members. Notably, one teacher (Teacher I) suggested that the PD program could develop summative or formative assessments to evaluate teachers' knowledge growth over the PD.

Content Knowledge. On one hand, some teachers claimed that they learned much more about coding and app creation knowledge, which made them comfortable to introduce computer science concepts and troubleshoot for students when they encountered technical problems. On the other hand, several teachers expressed that while the PD provided much-needed exposure to a wide range of CS topics, they felt it moved too fast for them to fully comprehend everything. Therefore, they hoped the PD program would work on building their basic knowledge on computer science concepts through didactic instruction rather than an inquiry-based approach. As Teacher E stated, "I don't know what I don't know." Teacher I suggested that the PD program could better support their learning through more group activities and assignments with feedback provided afterward.

> Teacher E: "*Even though I just said that I didn't know what I didn't know, I feel like I still learned a lot just from being thrown in and being like 'oh god am I gonna know anything about any of this?' I still got some kind of an introduction*."

> Teacher I: "*I think those short little quick testing to see how we're doing in that kind of thing again within the small group would be really helpful. In addition to more content knowledge, I would absolutely appreciate it*."

Furthermore, those teachers who were deficient in content knowledge also found themselves intimidated by some technical conversations during group meetings, which indicates that the PD program needs to better engage teachers with low prior CSDL knowledge.

> Teacher G: "*So I did have some software experience. But in terms of coding, in creating apps, I had never done anything like that. So, I was a little bit nervous during the very fast meeting.*"

Pedagogical Content Knowledge. As mentioned in the Resource and Infrastructure section, some teachers appreciated being introduced to pedagogies and best practices from computer science education research. For example, Teacher G said it was fascinating to learn pair-programming as a new teaching strategy, and he/she could not wait to apply it to his/her classroom. Other teachers also found the strategy of bringing industry professionals into their classrooms as a good way to motivate their students. Notably, teachers who shared positive opinions on PD enhancing their pedagogical content knowledge, were those who had strong self-efficacy on their CSDL content knowledge. On the contrary, teachers with lower CSDL knowledge showed less confidence on their pedagogical content knowledge growth. As a consequence, they also showed less confidence in teaching the curriculum. This finding is also aligned with the PCA result that moderate to low self-efficacious teachers perceived themselves having less capacity in teaching the CSDL curriculum. The interview result showed that this phenomenon is due to the group of teachers feeling they were less confident in their CS base knowledge (e.g., debugging).

> Teacher E: "*I think I can guide them through some of it for sure and I'm always willing to try, but I don't want to lead the heavier stuff until I have a better knowledge base, because I want to make sure if they get stuck I can help debug them if they can't figure it out themselves*."

Collaboration and Community. Enhancing collaboration and building a professional learning community is one of the most significant goals of the RPP PD program. All the teachers regardless of their content areas provided fairly positive feedback during the interviews on how collaboration and community helped them build self-efficacy. First, the PD program organized group meetings to promote network building among teachers. Teachers stated that the group meetings prompted ideas and allowed them to expand their teaching ideas and challenge themselves. For example, Teacher I thought it was nice to sit in the PD meetings to listen to other teachers and brainstorm ideas, and then bring the idea back to his/her own school district.

> Teacher I: "*Yeah, I mean I think that I definitely developed a more collaborative relationship with the tech teacher that's in my own building. We met in our building. Definitely afforded me the opportunity to do that. So yeah, that's been great*."

Second, the PD program made teachers realize the power of collaboration between content area teachers and technology teachers. Specifically, content area teachers were eager to expand the scope of their curriculum, but may lack the full technical know-how. The PD program helped bridge this gap through building the network between the two groups of teachers.

> Teacher F (Science Teacher)*: "So a couple times in class, my colleague was starting to do Scratch with Girls Who Code, and she would come over and talk to me. And I was like well, if you do this, this, and this, and she was like 'I don't know what that means. Can you talk to my students? Yeah, I'll just make sure nobody's punching someone over here.' So, I'll go talk to the kids, and that's fun. I can give my expertise, like okay, these are the two pieces that you're missing. You have 3 of the 4 things that you need, but the one piece here you don't have. Once they have that, then all of the sudden their project is taking off."*

> Teacher G (Technology): "*The knowledge I have in terms of graphing linear functions. You know, like I can handle that piece, and then what kind of app can we build that will graph this linear function for you, for example. And then for me to kind of explain to [Colleague's name removed] what a linear function is, how it works, what an input output value means, and then she/he takes care of the technical piece. I think it would be almost like a nice marriage of the two, you know, the content specific to computer science.*"

Although teachers spoke highly of our RPP PD's effort to enhance the collaboration and community building, they also see other opportunities for the PD program to better build teachers' self-efficacy. For example, several teachers suggested the program to organize small group meetings within the same school district after big group meetings. They believed a smaller group within their own district would break some intimidation caused by peer-pressure. The PD providers also believe this idea would provide an opportunity to sustain and consolidate the PD results to each district.

> Teacher I: "*Well, I definitely feel more comfortable sharing everything with the teachers in our own district. So, I think, from there, once you realize that there's a lot of us feeling the same way. Then I think you feel more comfortable sharing with the larger group..... People in my own district, they know me, they know I am a decent teacher, they know I'm not a fool. When I say to them, I have a hard time with this. They're not going to judge me even though I think starting out that way and then bringing it to the larger group would be helpful.*"

Teacher Identity. The results showed teachers also changed their own sense of identity and perceptions of their roles in implementing the CSDL curriculum under the RPP PD. Teachers recognized their own roles and values in teaching the CSDL curriculum. Most content area teachers saw themselves in computer science education with the role centered around building their students' curiosity and excitement about learning CSDL, while having technology teachers work with students to deal with the more technical parts. In particular, teacher G stated that she wanted to send an encouraging message to his/her students that even as a "non-computer teacher", he/she can give them the skills they need through the way of cooperation with CS/Technology teachers.

> Teacher G: "I will say this, that I feel like What I can bring to the table is very much how we can integrate this into a content area class. I think that sometimes I get caught up in, you know, why isn't this if-then statement working and you know the ins and outs of building an app. And I lose sight on sort of what my role as the content teacher is... I think the more kids see that a quote unquote 'non-computer teacher' can give them the skills they need. It's like, wow, anybody can do this."

Our findings indicate the above five aspects provided by our RPP PD program as the most significant factors impacting teachers' self-efficacy development. There were external factors that emerged from the thematic analysis, which also contributed to, or negatively impacted teachers' self-efficacy. Issues such as the lack of support from local school administrators, Covid-19-related challenges (e.g., remote setting delayed the curriculum implementation), and limited access to resources for students (e.g., Chromebooks and tablets) were unfortunately all too common. These significant restrictions and challenges will require greater attention from school districts in order to resolve than PD alone can provide, but these can be highlighted as long-term improvement opportunities.

6 Conclusion and Implication

The goal of this study was to explore the impact of the CS Pathways RPP PD program on the teachers' self-efficacy development in teaching a middle school CSDL curriculum. This study examined the attributes that describe the teachers' self-efficacy profiles, and the full reach of the RPP PD program to the participating teachers. The overall findings from both quantitative and qualitative analysis are highlighted in this section.

The PCA resulted in three distinctive dimensions that accounted for about 77% of the total variance, with each dimension representing a profile of teachers' self-efficacy. A comparison among these three resulting groups showed that the higher the teacher's self-efficacy, the more likely they were to be dynamic and successful CSDL teachers, engaging students with full confidence; as a consequence, the more competent they are in the CSDL skills and the more confidence they have in teaching CSDL curriculum. Thematic analysis on the interview data yielded results on both how the program RPP model provided teachers with active learning experience that enhanced their self-efficacy and potential opportunities for the PD program to better support teachers. The interview results identified five features of the PD program that helped teachers build their self-efficacy. These five features reflect how the RPP framework results in a higher quality PD program that builds capacity for teachers, which is likely to have a positive and timely impact. In addition, throughout the interviews, teachers unanimously stated that the PD's collaborative environment helped build their self-efficacy. This is by far the main benefit of the PD program under the RPP framework, despite some external headwinds such as resource constraints, and school administrative support, and RPP provides a framework to highlight the need to improve these in the future.

The main contribution of this research is that this study added clarity to the limited body of research around CS teachers' self-efficacy, especially since the study was conducted based on a PD program under an RPP framework, for which the prior study is even sparser. Findings from this study offer insights directly informing the PD program of its potential improvements. The five identified features of the PD program can enlighten future PD design. Currently, the project is also working on developing the project curriculum repository and working with a few teachers to co-design curriculum resources, which reflect the culmination of all the RPP project efforts to date. Conducting research on whether and how the co-design and implementation of the curriculum influence teachers' self-efficacy can be a future direction.

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