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Professional Development Strategies and Recommendations for High School Teachers to Teach Computer Science Online

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ABSTRACT

Based on a current Research to Practice Partnership (RPP) between a southeastern public university and a state virtual public school in the United States, ten high school teachers from a virtual school who teach Computer Science (CS) online participated in a summer workshop to collaborate through a participatory action research project regarding design, facilitation, and evaluation strategies to be included in effective professional development. The questions were posed through an online collaborative Jamboard during the summer workshop. The teacher posts were qualitatively analyzed to identify common themes. Recommendations for professional development on design included CS content, how to teach CS, and CS tools and activities. For facilitation, they recommended resources for supplemental instruction and feedback tools for providing feedback in various modalities and a tool repository. For assessment, they recommended content knowledge assessments, including lab assignments, single and pair programming, and coding assessments. Overall recommendations for a professional development course to teach CS online were also offered.

KEYWORDS

Teacher professional development; computer science online; teacher knowledge and skills; teacher recommendations

With an increase in computer science (CS) courses being offered online, the need arises to provide additional professional development (PD) opportunities for high school teachers to teach computer science online. Researchers have recognized the importance of professional development to recruit more CS teachers and better prepare them (Yadav et al., 2016). Professional development in content and pedagogical knowledge is essential for both current teachers and future teachers (Qian et al., 2018). Commonly addressed topics that effective professional development include supporting teachers in building a deeper understanding of course content and providing strategies that teachers can use to teach the content online. Martinez et al. (2016) found

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that teachers were more likely to apply activities and strategies learned during PD workshops in their practice than to include activities created independently. Creating a professional development course that supports both aspects of highly effective teaching with content and strategies can dramatically improve inquiry-based computer science teaching.

Teacher professional development strategies and barriers

Lay et al. (2020), examining a decade of research on online teacher professional development, found a recurring theme on the importance of collaboration and development of communities of practice as this leads to improved teacher learning and participation. Some of the strategies recommended by researchers are to link participating teachers as partners early on and encourage teachers to interact more, develop networks and build a stronger community of practice (Fasso, 2010). Prestridge and Tondeur (2015), determined three key elements that teachers need "investigation, reflection, and constructive dialogue; build a sense of group and individual online presence, and be supported by mentorship that responds to the various cognitive and affective demands of autonomous learners" (p. 199) to identify effective elements in online professional development.

The content of the professional development sessions should support multiple aspects of course content and strategies to support the online teaching process. Darling-Hammond et al. (2017) identified seven widely shared features of effective PD (1) content-focused, (2) incorporates active learning, (3) supports collaboration, (4) uses models of effective practice, (5) provides coaching and expert support, (6) offers feedback and reflection, (7) is of sustained duration. More specifically, Menekse (2015) evaluated research on teacher professional development in computer science based on six factors (1) PD duration, (2) support for implementation, (3) explicit focus on active learning methods, (4) explicit focus on pedagogical content knowledge, (5) collaboration with a local district or school administration, and (6) student learning data as a result of the provided PD program. They also identified three barriers to sustaining CS PD, (1) lack of collaboration between higher education institutions and local school organizations, (2) short time frame of programs and limited ongoing support for teachers, and (3) lack of clear focus on CS specific pedagogical content knowledge for teaching CS. The findings from this review show the importance of overcoming these barriers when providing PD for teachers to teach computer science effectively. Yadav et al. (2016) broadly discuss challenges that teachers face as content-related and pedagogical related. Several of the content related challenges exist from lack of CS teacher preparation and lack of support from information technology teams in

the school district. In addition, there are challenges specific to teaching CS online and some of these challenges include, debugging from a distance through shared screens or screen captures, pair programming remotely, students sharing code with each other online. Also, communication between student and teacher is key in online courses, and this can also result in challenges. Teachers are able provide immediate support when students face coding challenges when they are face to face. However, in online environments students sometimes do not reach out immediately when separated by a distance (Martin et al., 2021). Professional development can address how teachers can overcome these unique challenges to teaching CS online.

Qian et al. (2018) had three recommendations for designing effective online PD for CS teachers, and this included (1) matching PD to teachers' background, (2) aligning PD with curriculum, (2) using motivational design to engage the teachers. Ni et al. (2021), in another review of computer science teacher professional development, concluded that more PD programs explored various approaches for community building and promoting teacher learning and saw the promising roles of professional learning communities.

Professional network of support

As the United States has witnessed a massive shift in curriculum demands, standards, and adaptations over the last decade, the College Board Advanced Placement (AP) curriculum and its courses are no exception. When AP Computer Science Principles (CSP) was introduced in 2016, many teachers began teaching the course with limited or no support, as professional development sessions took time to create, and needs had to be identified. Cutts et al. (2017) studied the professional development programs that existed at the time to support computer science teachers in secondary schools. This program was designed to help teachers at a time of substantial curricular change. It provided various opportunities for teachers to engage within a professional network of computer science teachers nationwide. Additional studies by Fasso (2010) and Ni et al. (2021) stressed the potential benefits of building these support groups (professional development communities) and emphasized how creating a strong learning community would assist in strengthening teachers' overall professional network of support. The creation of professional development was much needed as Menekse (2015) found that previous training opportunities were limited, and teachers would greatly benefit from the additional and more current support. Cutts et al. (2017) found the program's results successful as they witnessed teachers increase their professional confidence and saw

an overall positive change in their attitudes toward learning. Additionally (Zhou et al., 2020) highlight the benefit of these support groups within the field of Computer Science education and the level of impact their support has on teachers, leading to an increase in self confidence and higher levels of self efficacy. Methods deemed successful included the presentation of challenging pedagogical content knowledge and conceptual frameworks and high-quality teacher-led professional dialogue. Having teachers lead the sessions and act as content experts promoted engagement in self-reflection and classroom experiences, which supported teachers' personal examination of their current practices (Schön, 2017). Cutts et al. (2017) involved teachers in creating and implementing their professional learning, promoting teacher engagement, and creating critical reflection opportunities. They recommended that future professional development opportunities highlight the established knowledge held by the computer science teachers involved and create opportunities for teachers to be instructional leaders within their training and take ownership of their academic and pedagogical growth. Furthermore, as demonstrated in the literature by Cutts et al. (2017) and Goode et al. (2020), many professional development sessions were deemed successful as they sought to include the knowledge of their participants and allow the teachers to engage in the professional development opportunity as a resource. Lay et al. (2020) supported these findings as well as highlighted the importance of meaningful professional development opportunities for teachers, especially if offered in an online setting.

Theoretical and conceptual framework

There are several theories and frameworks that this study on professional development builds on. This includes reflective practice, which integrates theory and practice (Schön, 2017), and social learning theory (Bandura & Hall, 2018; Spencer, 2015), where teachers learn by interacting, sharing, and observing each other. Teachers in this workshop had the opportunity to interact, reflect and share the strategies that they thought were helpful for CS teachers' professional development. The CoI framework guided the design and implementation of the workshop. Community of Inquiry Model framework describes the process of creating a deep and meaningful learning experience through the development of social, cognitive, and teaching presence (CoI Framework, 2022). Social presence is "the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop interpersonal relationships by way of projecting their individual personalities" (Garrison, 2009, p. 352). Teaching Presence is the design, facilitation, and direction

of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes (Anderson et al., 2001). Cognitive Presence is the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse (Garrison et al., 2001; Schön, 2017). All three presences are critical to effective online course design and implementation.

In addition, the study used the conceptual framework proposed by Martin et al. (2019) on effective online courses, focusing on design, facilitation, and assessment strategies teachers use while creating professional development for teaching computer science online. The design includes the strategies included in the professional development design, facilitation focuses on the implementation of the professional development, and assessment focuses on how the PD participants are assessed and evaluated. This framework was developed in a study where award-winning online instructors discussed design, facilitation, assessment and evaluation as important elements of an effective online course (Figure 1).

Purpose of the study and research questions

It is important to assess the needs of CS teachers while designing professional development since the teachers have different backgrounds (Ni & Guzdial, 2012). Researchers have broadly studied strategies for conducting professional development. However, there is a need for more research to examine online teacher professional development specific to teaching computer science online, specifically on designing, facilitating, and assessing professional development courses. The research team recommends that any

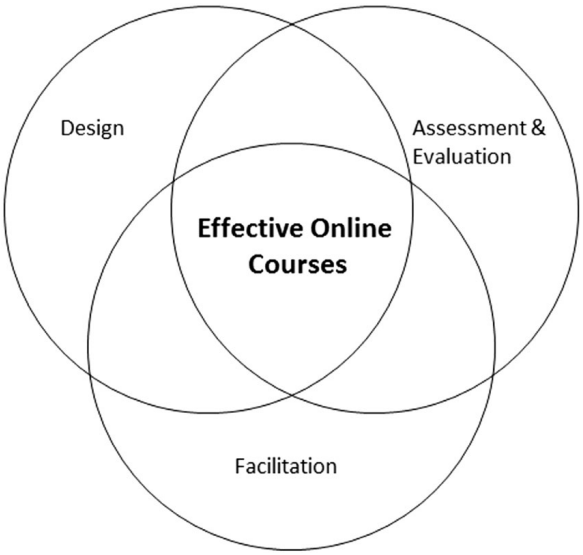

Figure 1. Strategies for effective PD online courses.

online professional development created to support computer science teachers should be differentiated to support the needs and interests of the teachers and should be created purposefully to engage teachers in new pedagogical practices. This is addressed through the following two research questions:

1. What design, facilitation, and assessment strategies can be used when designing a professional development course for high school teachers to teach computer science online?
2. What recommendations do current teachers have for designing a professional development course for high school teachers to teach computer science online?

Methods

In this section, we describe the context of this research study, research design, workshop participants, data collection method, and data analysis.

Context

The context of this study is based on a Research to Practice Partnership (RPP) currently held between a southeastern public university in the United States and a state Virtual Public High School. As part of a National Science Foundation Grant - Computer Science for All, the research team collaborated to create and offer online professional development to teach high school teachers the AP Computer Science Advanced course. Our RPP approach emphasizes the role of our lead teachers from the State Virtual Public School (SVPS) as key researchers in shaping the design of the online professional development for computer science instruction. Using a participatory research-action approach, the project team engaged the lead teachers during the project's first year to identify critical instructional strategies and resources to be included in professional development for teaching computer science online. Teachers were invited to participate in a summer workshop conducted for four days from 9 am to 12 pm. The teachers were put into the role of "content experts," working to identify best practices. This participatory action research approach allowed the RPP team to capture ideas and outcomes from the teachers to guide the professional development design. Approval was received from the Institutional Review Board from the southeastern public university before research began.

Research design

Participatory action research methods focus on planning and conducting research when the participants are doing meaningful actions (Bilandzic &

Venable, 2011). Jacobs (2016) describes participatory action research as a type of action research that is collaborative and combines action and reflection with participation from stakeholders to work collaboratively to co-create new knowledge as they seek solutions to address various concerns and issues. Throughout this study, this salient definition has guided the research process. Jacobs has discussed the benefits of using this qualitative research method for students and teachers, as it allows the teacher to become more collaborative, participatory and engage the students fully.

As the context of this study is based on a Research to Practice Partnership (RPP), the focus on meaningful action research has taken priority. Similar to most participatory research designs, this study and RPP follows the same "iterative cycle of research, action, and reflection" (Macbeth, 2019; Schön, 2017) in the way of building relationships within the SVPS community. This type of research best lends itself to uncovering vital information, and within the context of our study, this information is gathered directly from teachers currently in the field. It is the research team's hope to incite change that supports future computer science teachers with their current professional development needs. With these end goals in mind, our study was designed using a qualitative participatory action model, which allowed the research team to analyze responses collected through JamBoard. In this method, the teacher responses collected were anonymous. The teacher's responses and input led to a great discussion that supported this project's data collection.

Workshop participants

The research team recruited ten online computer science teachers from SVPS to participate in the summer workshop. Five teachers were female, and five were male. The teachers had varied experiences teaching for SVPS, ranging from just beginning to teaching to 13 years of experience. Among the ten teachers, they averaged five years of teaching experience with SVPS. Seven of the teachers were approved by the College Board to teach APCSA or APCSP. All ten of them had earned licenses either in Business Information Technology Education or Technology Engineering and Design Education. The participants engaged in a weeklong seminar where the research team presented topics such as Approach, Challenges, Solutions to Online APCSA, Online Teaching Strategies, Engagement within Online Learning, Autograders, Other Online Tools, and Culturally Relevant Computing and Social Impact. In addition to presentations, participants actively engaged in discussions surrounding these topics and responded to the question, What design, facilitation, and assessment strategies are helpful to include in a Professional Development Computer Science Course

for High School Teachers? To address the second question, What recommendations do current teachers have for designing a professional development course for high school teachers to teach computer science online, teachers were given a draft professional development course that was being developed for initial feedback and recommendations.

Data collection method

The southeastern university research team conducted the summer workshop synchronously via Zoom. This provided the opportunity to discuss teacher perceptions related to the research questions. During this workshop both research questions were posed through an online collaborative Jamboard activity. Jamboard (Google, 2017) is a digital interactive and collaborative whiteboard developed by Google to work within the Google Workspace.

The first research question, "What design, facilitation, and assessment strategies are helpful to include in an AP Computer Science advanced course?" was posed using three Jamboards: one for design, facilitation, and assessment. The second research question was asked, "What recommendations do you have for designing an online professional development course for high school teachers to teach computer science online?" through a separate Jamboard. Teachers individually posted their responses to each question on the Jamboards. They could post more than one response to a Jamboard.

The researchers conducted the Jamboard sessions as an electronic form of the KJ Method (Scupin, 1997), also known as an Affinity Diagram method. Affinity diagrams have been used effectively in Human-Computer Interaction (Lucero, 2015) as both a design method and as a research technique to gather data for various purposes (Gray et al., 2014). In this work, the researchers used a method common in contextual inquiry (Beyer & Holtzblatt, 1999) typically used as a bottom-up technique to gather requirements.

The Jamboard session began with a question posed at the top of the screen. Each participant posted a note with their ideas/answers. All participants continued to post until no new posts were made. Participants were encouraged to post but were not required to participate. Also, their posts were anonymous, and the system did not keep track of the participants' names unless the teachers chose to disclose their names in their posts. If the teachers included their names, this was deleted before analysis. As a collaborative activity, each new post reminded others of other ideas. This is what Lucero (2015) calls the creating nodes phase. Once this phase was completed, the researchers asked participants to move posts around and place them near similar notes. This is the clustering nodes stage.

During these two stages, the researchers remained available but limited their participation to answer questions about the technique. In the end, the group discussed the notes posted, with the facilitator asking for explanations for topics that were not clear to all people involved in the discussion.

Data analysis

Throughout the summer workshop, the participants were asked to engage with a Jamboard on an online collaborative activity responding to specific questions. This tool allows for collaboration by using a digital whiteboard, making it easy to create and share ideas in real-time, regardless of distance. Document content analysis (Corbin & Strauss, 2008) was used to analyze the posts on the Jamboard (see Figures 2, 3, and 4, for example) through a process of reading and identifying common themes (Saldaña, 2021). These common themes are depicted with squares surrounding the clusters. To improve credibility, the process was completed by two independent coders that consisted of one faculty researcher and one computer science education graduate student. The larger research team then discussed the initial findings for agreements and disagreements.

Positionality statement

The authors of this paper are an interdisciplinary team of four faculty researchers with various backgrounds. One faculty is in Computer Science with 20+ years of experience teaching at the college level. Two other faculty are from Education, one with experience as an online education researcher and practitioner. The second education faculty has experience

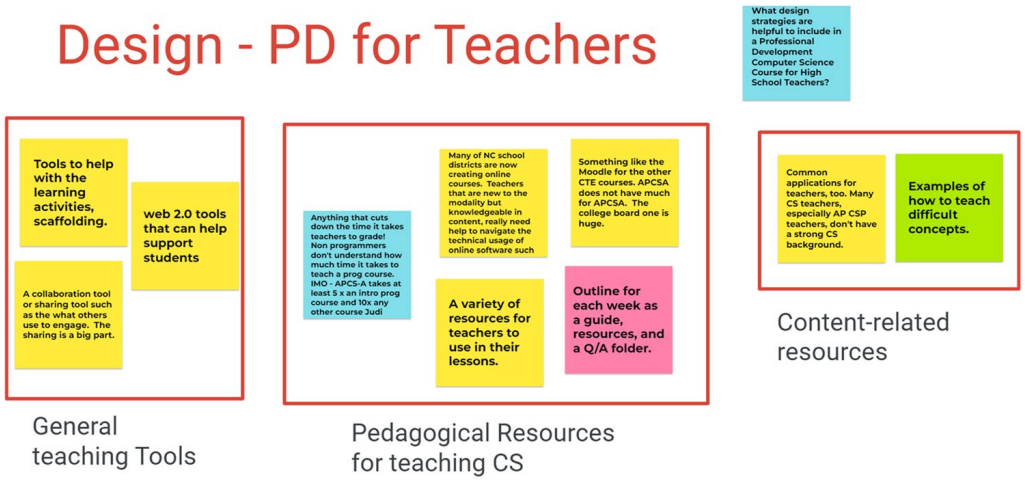

Figure 2. Design - PD for teachers Jamboard.

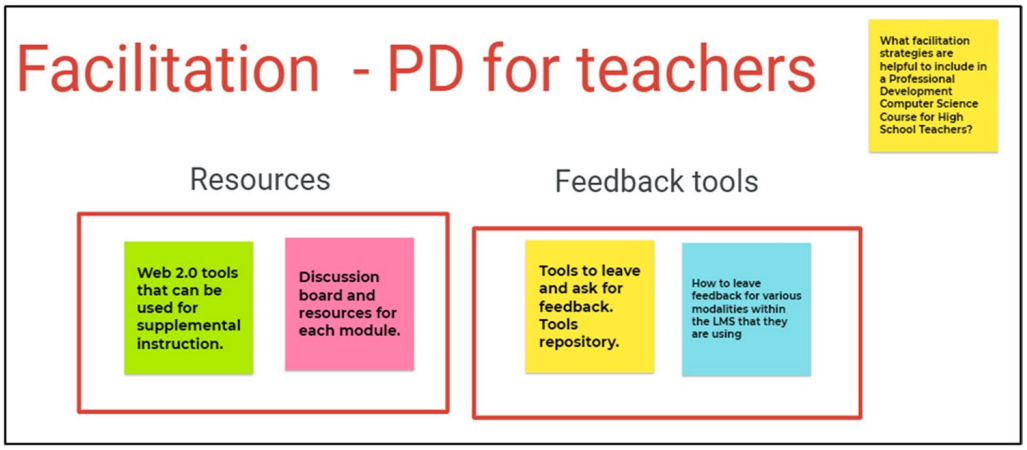

Figure 3. Facilitation - PD for teachers Jamboard.

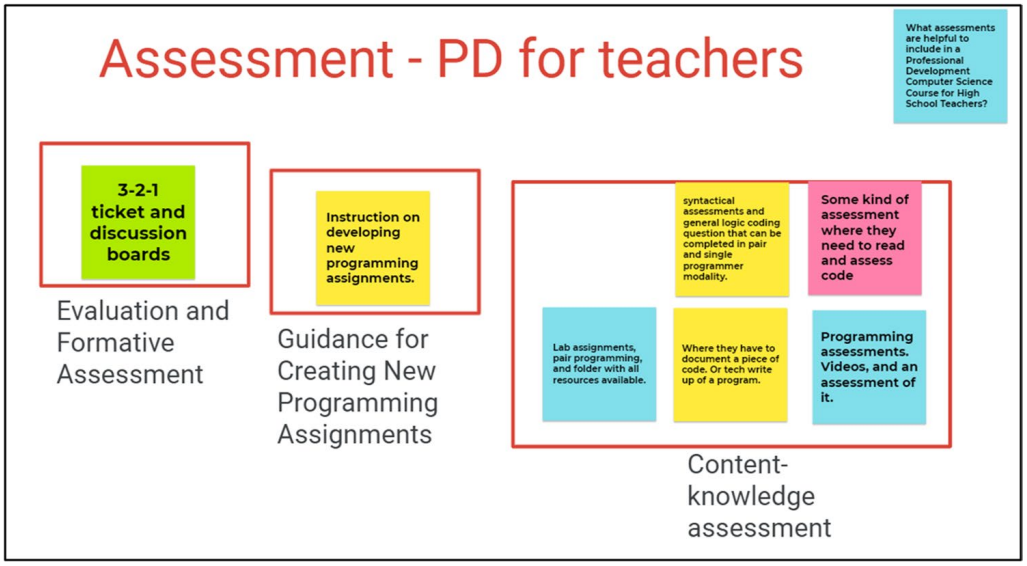

Figure 4. Assessment- PD for teachers Jamboard.

in community outreach with High Schools. The last member of the team, an emeritus professor, is the evaluator for the project with years of experience in educational assessment. Another group member is an educator/administrator for the SVPS system. Finally, two graduate students complete the research team, both in Education, one with a BS in Computer Science.

Each researcher in this project contributes different expertise and points of view, thus making the project truly a collaborative effort. As a result, we engage in reflexive discussions, often exploring how each of our disciplinary backgrounds brings a different lens to the data we are exploring.

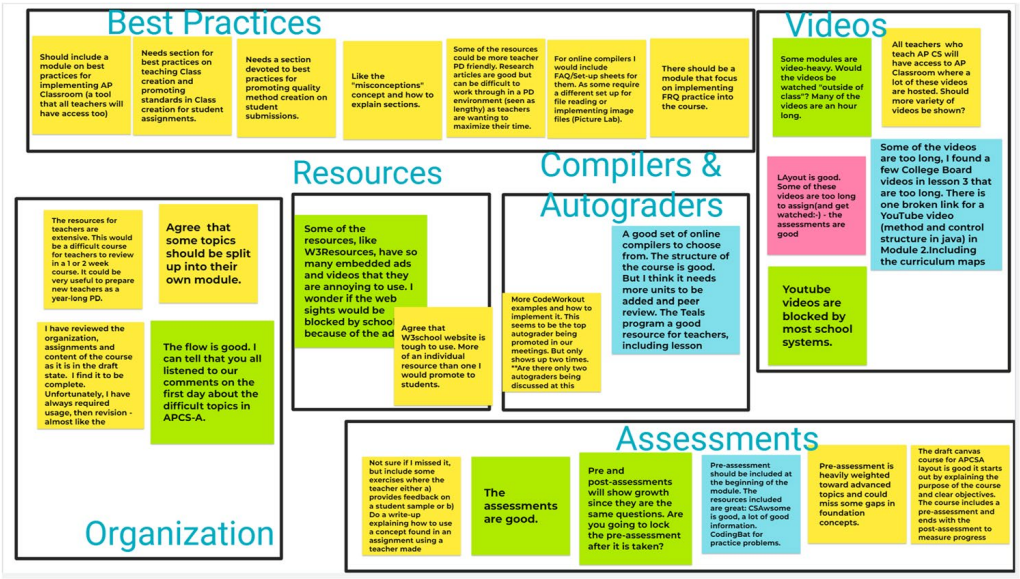

Figure 5. Overall recommendations for online CS professional development JamBoard.

Results

The findings from the online collaborative activity responding to the question on design, facilitation, and assessment strategies in professional development for teachers are included below.

Design strategies

As part of the design of the online PD (Figure 2), the lead teachers recommended including general teaching tools, pedagogical resources and content-related resources. They especially for teachers who may not have a strong CS background examples of how to teach complex CS concepts. For pedagogical resources, they recommended an outline to guide each week. In addition, they also recommended including general teaching resources such as tools to assist with scaffolding learning activities, collaborative tools to share with each other and web 2.0 tools to support students.

Facilitation strategies

During the facilitation of the PD (Figure 3), the lead teachers recommended including resources for supplemental instruction and feedback tools. This included tools for providing feedback in various modalities and a tool repository. Teachers included using web 2.0 tools for supplemental instruction and discussion board and resources for each module.

Although web 2.0 tools were mentioned to be used as part of design, the teachers also saw the value of using it during facilitation.

Assessment strategies

When asked about assessment strategies for online PD (Figure 4), the lead teachers recommended focusing on content knowledge assessments, including lab assignments, single and pair programming, and coding assessments. They also recommended providing guidance for creating new programming assessments that were not already online, which students can locate, creating formative assessments through the discussion board, and using 3-2-1 to get feedback on the course. The 3-2-1 exit ticket strategy is a type of reflection activity where students respond to three questions (e.g., 3 things learned, 2 things might implement, 1 question) to reflect and summarize their learning while also asking questions that they might have.

Overall recommendations

Several themes were identified when asked for overall recommendations for designing a professional development course for high school teachers to teach computer science online (Figure 5). To answer this question, a draft version of the professional development course that was designed was shared with the teachers to get initial feedback and provide additional recommendations. Lead teachers recommended providing best practices to teach computer science online. They offered suggestions on the organization of the course. They suggested including various short videos and being aware that YouTube videos might be blocked per the K-12 school system's policies. They provided guidance on resources that schools may block and are tough to use but also stressed the importance of including resources on online compilers to choose from and supported auto graders that can be used. Finally, they provided comments on assessments, focusing on pre-and post-assessment.

Discussion

Based on the research shared in the literature review, the research team identified the need to continue to build upon the current studies on the importance of creating high-quality professional development opportunities for online computer science educators. Through the Research-to-Practice Partnership (RPP), several themes and recommendations emerged around the idea of necessary professional development sessions that would assist teachers by filling the current gap in Professional Development (PD). The

involvement of the practitioners in identifying the areas of need for professional development was necessary for building ongoing trust with the practitioners and identifying meaningful ways to support both computer science teachers and students. The inclusion of practitioners in the identification of professional development needs aligns with the findings of Cutts et al. (2017), which mirrors the increased success of professional development when teachers are actively engaged and involved in the creation.

The team began to group and identify commonalities among recommendations for PD sessions, focusing on the design of content, facilitation, and assessment. Each of these areas was identified as a need due to the specialty of online computer science and the relative newness of the content related to the College Board examination.

Professional development on design of content

As identified in the Jamboards, teachers felt the need to have additional support with design related to the content of the course, Qian et al. (2018) noted the additional need if teachers were considered to be "novice" computer science educators. They recommended general teaching tools, pedagogical resources and content-related resources for teaching CS. Scaffolding and collaboration tools were recommended to be important as part of general teaching resources. Piotrowska and Alekseeva (2020) discuss the importance of scaffolding in CS courses. Similarly, the use of collaboration tools have also been studied by resources in CS courses (Ludvigsen & Mørch, 2010). Web 2.0 tools were recommended both in design and facilitation. This shows that high school teachers value these tools in teaching CS. Teachers also recommended including a number of pedagogical resources in addition to the tools. These could be resources that they could directly integrate into their lessons or be in the form of an outline that can guide their lessons. This is aligned to Yadav et al. (2016) study who found that teachers categorized their challenges as pedagogical and content-related and providing professional development on these two aspects directly addresses their need. Teachers recommended that further professional development opportunities be available to support the overall design of computer science content and explicit support in teaching computer science. Falling under the category of "How to teach computer science," teachers also identified that additional support on computer science tools and activities would be beneficial (Prestridge & Tondeur, 2015).

Professional development focusing on facilitation

Recommendations for professional development sessions that fell within the scope of facilitation include additional support for identifying and

implementing tools with the purpose of supplemental instruction in mind. Another common recommendation was to have further support building and integrating learner discussion into online learning environments to increase student interaction. The work of Lay et al. (2020) supported this area by focusing on increasing both teacher and student participation in online environments by first capturing the attention of the teacher. Similar to increasing learner interaction, practitioners also suggested using web 2.0 tools to provide supplemental instruction and additional support in building their repository of online tools and strategies to provide students with meaningful feedback. This shows the importance of providing students with feedback while teaching CS online and the findings align with researchers who have studied providing feedback in various methods in computing courses (Gao et al., 2016; Neumann & Linzmayer, 2021; Voghoei et al., 2020). The need for additional support in this area aligned with the study by Gray et al. (2019), highlighting the need for cooperative learning strategies to support engagement in computer science coursework.

Professional development focusing on assessment

With such a significant emphasis on assessment within the computer science courses as they align with the College Board (2019) examinations, teachers identified the need to access high-quality content-based summative assessments including lab assignments, single and pair programming, and coding assessments. Based on what was shared via the Jamboard (Figure 4), many teachers found that the assessments available to them were also available to the students, making the assessments unreliable at truly gauging students' understanding of the course content. Due to this issue, teachers suggested additional training to support the development of new programming assessments that were not already found online and an opportunity to assess code as part of the professional development. Extending the notion of secure and authentic assessments, teachers also identified the need to find and create unique formative assessments that could be integrated into an online course. This aligns with the findings of the study by Alozie and Knudsen (2020) who found that middle school teachers discussed the importance of using various types of formative assessments including reflective types of assessments through journals and portfolios, and assessment items.

Overall recommendations

Based on all the interactions with the study participants, a few overarching themes and recommendations emerged, such as the need to incorporate

best practices into each area of professional development. The implementation of "best practices" within this context applies to every aspect of teaching and learning as well as the course design and tool section. Within this umbrella of "best practice" falls the potential support Professional Learning Communities offer and the support they can provide (Fasso, 2010; Ni et al., 2021). Additionally, many of the study participants identified the need to have access to high-quality, developmentally appropriate videos for their students. Several practitioners identified challenges with the videos currently being used in their classrooms and within the district-designed Canvas course. They expressed that many videos were either too long, covered too much material within one video, or were blocked by the district due to safety concerns. With these challenges in mind, teachers requested assistance in selecting supplemental supporting materials and showed interest in a professional development session designed to meet this need. Lastly, the participants found the resources on online compilers challenging to choose from and requested support in identifying high-quality and easy-to-use auto-graders. Creating and supporting these participants with a professional development session on auto-graders was widely requested.

Limitations

The data collected from this study results from participatory action research through JamBoard with one virtual public school in the southeastern United States. There are a few limitations to consider when reviewing the recommendations and conclusions drawn from our data set. The results may not apply to every virtual classroom. The results may not apply to computer science classes in non-virtual school settings.

Additional considerations that can be considered a threat to the study's internal validity include the study's small sample size, the single trial conducted, and the online setting in which the study took place. There were only ten teachers who participated in this activity. However, given the small number of teachers who teach CS online, this was a rich data set. Each of these factors could have impacted the final results of the Jamboard responses. For this reason, it is recommended that additional rounds of testing be conducted, such as promoting ongoing communication with the virtual public high school and recreating this study with another virtual public school to see if similar results are presented.

Future research

Additional research is recommended to continue to push the field of computer science education, especially related to online teaching and

learning. The professional development sessions mentioned within this study are just the starting point of a series needed to support computer science teachers. Interviews to elaborate on how these PD topics can be helpful can be conducted. Also, when the PD is designed and offered, findings from the implementation on what strategies were beneficial to the teachers will be of importance.

Implications

The findings of this study have implications for teachers, students, administrators, and designers. Teachers who are currently teaching computer science courses in an online setting or those who wish to teach computer science online in the future can benefit from the various topics in PD discussed in this study. Through ongoing, high-quality professional development, computer science teachers will continue to strengthen their teaching practice and support the various learners within their online class environments. Administrators can benefit from the findings such that they can offer PD for the teachers on these topics if they teach CS online. Designers who design PD and online CS courses can benefit from the findings and integrate them into the workshops and courses they design. Finally, students benefit if their teachers are able to attend PD aligned to these topics that make them successful.

Disclosure statement

The authors report there are no competing interests to declare.

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