EFFECTIVE ONLINE PROFESSIONAL DEVELOPMENT: A FACILITATOR'S PERSPECTIVE

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The purpose of this qualitative study is to explore the key elements that contribute to effective online professional development as perceived by facilitators. The research focuses on a specific program aimed at integrating computer science into mathematics education, involving two cohorts of teachers over a period of two years. The lead facilitator, Haynes, has a master's degree in mathematics education and 18 years of teaching experience. The study highlights the importance of sparking interest, enabling participants to teach beyond the curriculum, and offering a personalized and diverse approach to online professional development with a focus on mathematics content. Additionally, the findings underline the value of incorporating STEM education theory through cofacilitation with an experienced teacher education researcher. The findings are further discussed in a keynote speech at the ROSEDA conference.

Keywords: Online professional development, PD facilitators, STEM education.

INTRODUCTION

Professional development (PD) has been extensively studied and conceptualized in educational literature, with varying definitions and perspectives. For example, Guskey (2000) defines PD as a comprehensive process consisting of various initiatives to develop educators' competence, abilities, and perspectives, to elevate student learning outcomes. There is a consensus among scholars that PD encompasses more than just behavioral changes (Borko & Putnam, 1995; Clarke & Hollingsworth, 2002; Guskey & Huberman, 1995) and is a crucial aspect of education that, when approached holistically and from multiple angles, can result in significant improvements in teaching practices and student performance (Borko, 2004; Cochran-Smith & Fries, 2005; Desimone, 2009; Kennedy, 2016; Opfer & Pedder, 2011; Putnam & Borko, 1997; Stewart, 2014). Thus, it is essential to continually examine and comprehend the various approaches to effectively implement PD to enhance educators' professional capabilities, knowledge, and attitudes.

The pedagogy of teacher education is multifarious, with inquiries revolving around the modalities of didactic transformation, the requisites for knowledge, and the means of incorporating acquired knowledge into practical applications (Feiman-Nemser, 2008). The theoretical framework of *how people learn* (NRC, 2000) is widespread in explicating the dynamics of teacher education.

The framework is predicated on four perspectives on learning environments: (a) the learner-centered perspective, (b) the knowledge-centered perspective, (c) the assessment-centered perspective, and (d) the community-centered perspective (Bransford et al., 2007). *The learner-centered perspective* considers that teachers have personal characteristics, cultural backgrounds, experiences, and preconceptions that affect their learning and that effective learning environments for teachers should consider these factors and their relationship with

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teacher learning (Opfer & Pedder, 2011). *The knowledge-centered perspective* focuses on what to learn and why it is learned to advance classroom practices and enact new implementations and includes the components of teacher knowledge such as content knowledge, pedagogical knowledge, and pedagogical content knowledge, the curriculum, tools, materials, and activities planned to be used during the learning process (Shulman, 1986*). The assessment-centered perspective* mainly focuses on feedback as the main focus, through reflective self-assessment and reassessment of learning to give learners new perspectives, guide researchers to understand teacher learning better, and design professional development programs (Desimone, 2009). *The community-centered perspective* focuses on creating collaborative, flexible, and inclusive learning environments where learners can share ideas, questions, and performance evaluations to enhance their learning experience (Kennedy, 2016). To effectively enhance teacher learning, all aspects of the four-component framework must be integrated into professional development design, according to Bransford et al. (2007).

Throughout the corpus of literature on efficacious professional development, scholars have begun to dub specific well-established characteristics as *consensus*. Per this consensus, Wayne et al. (2008) succinctly summarized the definition of effective professional development as follows:

"...intensive, sustained, job-embedded professional development focused on the content of the subject that teachers teach is more likely to improve teacher knowledge, classroom instruction, and student achievement. Furthermore, active learning, coherence, and collective participation have also been suggested to be promising best practices in professional development" (p. 470).

Online professional development

Online professional development (OPD) provides opportunities for teachers to create online communities, comfortable settings, and audio-visual aids (Carey et al., 2008; Elliot, 2017; Trust et al., 2016) and to receive instant help and reflect with other teachers from diverse backgrounds and disciplinary programs (Bates et al., 2016; Carey et al., 2008; Fishman et al., 2013; Trust et al., 2016) which allow them to improve professionally according to their interests and needs (Macià & García, 2016).

Research has found that both face-to-face and OPD have positive effects on teacher change and student outcomes, with little difference between the two forms of PD regarding teacher knowledge and instructional change (Dash et al., 2014; O'Dwyer et al., 2010; Parsons et al., 2019; Fishman et al., 2013; Means et al., 2013; Russell et al., 2009). However, blended professional development, which combines both face-to-face and online components, is more effective than either form alone, as it allows for the benefits of both forms to be utilized (Means et al., 2013).

Coteaching

Coteaching, which involves the collaboration of multiple individuals, has been found to have positive consequences for learners and is advantageous for the professional development of the educators involved (Yabas et al., in press). However, creating an effective coteaching partnership requires a willingness to learn from each other's differences and strengths, establish clear roles and responsibilities, communicate effectively, and negotiate conflicts that may arise (Pratt, 2014; Rytivaara et al., 2019). Additionally, at the in-service teacher education level, a unique challenge of coteaching is the need for partners to shift their self-perception of their traditional roles (i.e., teachers, pre-service teacher educators, or researchers) into that of PD facilitators (Perry & Boylan, 2018).

Research questions

There is a need to update the consensus view on effective PD as suggested by multiple studies (Darling-Hammond et al., 2017; Hill et al., 2013; Wayne et al., 2008). It would be important to consider the perspectives of individuals who work at different levels of PD in order to gain a comprehensive understanding of effective PD. While some studies have collected data from teachers (e.g., Garet et al., 2001; Penuel et al., 2007), there is a lack of research that involves the perceived roles and responsibilities of OPD facilitators (cf. Tekkumru-Kisa & Stein, 2017). Thus, this qualitative inquiry aims to investigate the characteristics of effective OPD from a facilitator's perspective.

METHODS

As a qualitative research method, phenomenology offers a means of gaining deeper insights into phenomena, including aspects that have not been previously explored, by examining how individuals experience and understand the phenomenon and uncovering its essence (Merriam, 2009). This research approach allows for discovering new perspectives and avoiding oversimplifying experiences by only considering obvious theoretical patterns (Spiegelberg, 1965). This study aimed to identify and investigate previously unexplored characteristics of high-quality professional development (PD) and coteaching experiences, along with those already described in the literature.

Context

The context of the present study is the professional development programs provided by the *STEM teacher education and research center* (*STEM center*) at a private university in Turkey. Annually, over 1,000 teachers participate in these programs. The center's most notable program, the *STEM leader teacher OPD program*, offers an 8-month training that certifies teachers as *STEM leader teachers* upon completion. All programs offered by the center align with the *STEM integrated teaching framework* and aim to promote equity, rigor, interdisciplinarity, and relevance in *STEM Education* (Corlu, 2017).

The administrator of the STEM center (*coordinator*) reached out to experienced and innovative teachers (*facilitators*) in the community and invited them to create a short-term OPD program as an advanced follow-up to the STEM leader teacher OPD program. In the second cohort of the programs, the coordinator encouraged all facilitators to incorporate a theoretical component into their program by partnering with teacher education researchers possessing relevant expertise.

The center specified certain requirements for the chosen programs, highlighting the practical application of STEM Education as a best practice and promoting the principles of STEM Education. These requirements included: one hour of synchronous online meetings per week for seven weeks, selection criteria in the form of a letter of interest for external applications (*teachers*) while certified STEM leader teachers would be automatically selected, the maximum number of teachers would not exceed 15, near complete attendance requirement, and a final summative project (e.g., a lesson plan) for participating teachers. Facilitators were responsible for developing a syllabus and collaborating with the coordinator to align the program with the principles of STEM Education.

Teachers had diverse backgrounds participating from all over Turkey, with no restrictions on the subjects they taught, even though they were mostly mathematics teachers in addition to teachers of physics, information technology, and elementary school teachers.

The present inquiry is conducted across two distinct groups or cohorts over two years for a particular OPD program on computer science and mathematics education: During the first cohort, the facilitator was solely tasked with the planning and delivery of the program, entitled *block-based coding applications for mathematics,* while the coordinator actively participated by observing the program's implementation weekly. The first program aimed to capture the relationship between computer science and mathematics, help teachers increase students' motivation to learn mathematics, and design enhanced mathematics learning experiences. The program covered topics such as geometric shapes, art and mathematics, computational art, number theory and coding, and the connection between trigonometry and coding in a Scratch context.

Compared to the first cohort, the design and implementation of the second cohort program were carried out through closer collaboration between the facilitator and coordinator. This arrangement resulted in integrating an experienced teacher and a teacher education researcher as cofacilitators. Consequently, the second cohort was rebranded *from algorithmic thinking to computational thinking*. The program covered a more comprehensive range of subjects, including algorithms, number theory, geometry, computational art, data science, outdoor mathematical and statistical education using Scratch/Snap! and NetLogo for computational thinking. Additionally, the program included perspectives from mathematics education theory such as developing proof and reasoning skills, APOS theory, constructionism, the history of mathematics (e.g., abacists and algorists), computational thinking in math education, and complexity in mathematics education.

The facilitator

Haynes, the 42-year-old leading facilitator of the OPD, holds a master's degree in mathematics education and has 18 years of teaching experience. He currently serves as a mathematics teacher and head of the department at a private school in Istanbul. He has published several books on the application of block-based programming languages. He graduated from a popular English-medium public university in Istanbul with a degree in mathematics. He worked as a software engineer for two years before entering the field of education. His interest in block-based programming languages arose from teaching fifth and sixth graders and led him to self-study and research Scratch. With prior experience designing one-shot PD programs for his colleagues in areas such as 3D design, robotics, and coding applications, Haynes joined the STEM center community after finding the potential impact promising. He was introduced to the theoretical framework and principles of STEM

Education by *Steven*, the coordinator and his cofacilitator in cohort two, whom he did not know prior to joining the community.

Steven is a mathematics education professor. He had extensive experience as a school teacher, teaching subjects such as mathematics, science, and education technologies. In addition, Steve has designed and facilitated several PD programs and has a research interest in STEM teacher education. As the coordinator of the STEM center, he conveyed the principles of the theoretical framework to the PD facilitators and ensured the program's consistency and sustainability through ongoing support. During the second cohort, Steve also served as a cofacilitator with Haynes.

Data collection & analysis

The process of gathering data for both cohorts in the OPD program was a multi-step endeavor aimed at acquiring comprehensive information about the program through the lens of the facilitator. First, a comprehensive review of the literature on effective professional development and coteaching was conducted to achieve this. Second, the syllabi for both cohorts were thoroughly examined, motivation letters from external teachers were inspected, and recorded sessions lasting up to seven hours were analyzed for each cohort. Finally, the lesson plans served as the final summative assessment. Based on these evaluations, semi-structured interview protocols were prepared, each lasting approximately 60 minutes. The interviews were recorded and later transcribed word-for-word to provide a verbatim account.

The interview protocol for the first cohort's OPD program focused on gaining a deeper understanding of Haynes' motivations, journey, and role in the course design and implementation. In contrast, the interview protocol for the second cohort's OPD program explored topics such as decision-making during co-facilitation, and the impact on professional development for teachers and facilitators.

First, the researchers wrote analytic memos and personal reflections on the data (Saldaña, 2013). These notes became the initial codes, which were strengthened by multiple forms of evidence. Second, the codes were grouped into categories and themes, with some codes forming a single category and others forming a broader meaning through recursive or similar codes.

FINDINGS FOR EFFECTIVE PD CHARACTERISTICS

Motivated for mastery: fostering interest and inspiration

Haynes was trying to find passionate teachers eager to learn about innovative teaching methods. So, he delved into the motivation letters of external teachers and later found that those who had already considered the benefits of block-based programming for teaching mathematics were genuinely invested in the subject.

Sadly, Haynes says that many school administrators require teachers to attend PD programs without considering their interest in the subject, resulting in teachers merely obtaining certificates for promotion instead of developing effective teaching skills. He recalls one instance where some applicants briefly wrote about their excitement for PD, but the lack of detail revealed it was to fulfill a school obligation.

I delved into the motivation letters and discovered they were brief. So, I encouraged teachers to add more detail. I aimed to foster interaction. Unfortunately, some teachers approach professional development without giving it much thought. I can share the standard view in Turkey - the administration imposes it. However, as the teacher thinks it over, they become more convinced that it benefits themselves and their students.

However, Haynes saw this as an opportunity to build a connection with the teachers. He encouraged them to add more detail to their letters and fostered interaction. Haynes believes that as teachers reflect on the benefits of computer science for teaching mathematics, they will become more convinced of its value for themselves and their students.

Haynes' ultimate goal is to ignite a spark in teachers and show them the limitless potential of computer science for teaching mathematics in the classroom. He wants to share his experience and inspire others to take their learning into their own hands. With resources like Scratch projects available for beginners, Haynes believes that motivated and curious participants can achieve high-quality teaching of some rigorous mathematics topics in their classroom. According to Haynes, one motivated teacher can lead to a chain reaction and create a community of innovative educators at their school.

Breaking the boundaries of centralized curriculum and fostering creativity in the classroom

Haynes understands the struggles that come with the centralized curriculum and its impact on teachers. The endless cycle of exams, school administrators, parents, and even students policing the curriculum can make the teaching profession feel suffocating. He believes that teaching is made trivial with a set curriculum designed to provide uniformity across the nation's schools and create the illusion of equity for all students. However, Haynes is on a mission to break these boundaries and empower teachers to take control of their teaching.

The curriculum may tell the teacher what to teach, like how to add rational numbers and teach it with strict subheadings, but we have to offer a new path for teachers to explore their passions and creativity in the classroom. It will not be easy, but it is worth the fight to set teachers free and allow them to enjoy teaching in the classroom truly. The curriculum should not limit what is taught...This is also due to the lack of effort [on the teachers' part]. For example, they only explain what they are told to explain. Mathematics is not just about what is included in the curriculum.

Haynes understands that it should be up to the teacher to bring mathematics to life in the classroom. Despite some subjects being touched upon briefly in the curriculum, with regards to computer science, Haynes believes that the limiting type of instructions, such as "don't *do this, don't do that*", set by the curriculum on what not to teach is not productive, particularly for subjects such as mathematics. Instead, he deems a teacher should "*go in the direction of what the class wants*".

Moreover, he recognizes the value of allowing teachers to tap into their creativity and inspiration in the classroom and emphasized the importance of fostering their passion and confidence through the OPD. Haynes elaborates about his thinking that no curriculum can keep up with the rapid technological advancements and how mathematics plays a role in these advancements.

...math is maybe the same as 20 years ago; at least the topics are the same, but computers are not the same as five years ago... like finding the LCM and GCD using a line, but why do we need the Euclid algorithm? They [students] personally do not need it in their daily life, and mathematicians also do not need it much, perhaps only in Diophantine equations. However, computers do need it. That is where the connection to computer science comes in. Solving a problem for a computer is different from solving it in daily life, mathematics, or physics. Each discipline, like physics, chemistry, sociology, and computer science, has a different perspective. The goal is to understand the differences and see that [mathematics] exists in bigger things.

Haynes aimed to empower teachers to produce lesson materials that integrate computer science into mathematics teaching by the end of the OPD. In addition, the goal was for participants to become equipped to create lesson plans that fit their unique situations and incorporate computer science into mathematics. He quotes Conrad Wolfram (Wolfram, 2020) to summarize that computers change the way mathematics is done, so the teachers should adapt:

If math in a world without computers is the same as math in a world with computers, then there's a serious problem here. That's what Conrad was saying about math. Like, if I ask Siri to solve an equation for me, right? I say, find the roots of x^3-3x^2+7x+5, it can do that, right? Now compare that to a world where that doesn't exist. I'm not even talking about just finding the roots of an equation. If the way you explain math is the same in a world with computers and a world without, then that in itself is a big problem.

Diversified and localized online professional development

Haynes makes a compelling case for the value of diversity in PD content, recognizing that every participant brings unique perspectives and needs to the table. To ensure that everyone could find a way to connect the content of the OPD to their classrooms, he offered a variety of examples and activities, as well as supplementary resources. On the one hand, he urged participants to embrace a wide range of content, as it increases the chances of capturing everyone's interest and may even lead to new opportunities. On the other hand, Haynes emphasized the unifying power of art and its impact on human experience, showcasing the connection between mathematics and art in the context of the OPD.

An algorithm is beautiful. People often say *how beautiful* when they see it. ...everyone has a sense of beauty. Art is a place where everyone can come together easily. It is interesting, like a telepathic experience. In Turtle art, everyone says it is beautiful when you draw something. Everyone finds something different and understands something else when they look at it.

Haynes stresses the significance of understanding the backgrounds of teachers in order to be an effective PD facilitator during design and implementation. He notes that while many online resources, such as YouTube videos and online courses, are available for teachers in the US or Europe, they may not always apply to Turkish teachers. The issue is not language barriers but how teachers learn and do their profession. Haynes emphasizes that knowing the unique characteristics of teachers is crucial for delivering effective OPD.

I could see teachers' strengths and weaknesses over the years [as head of both mathematics and information technologies departments]. So, we designed the program to fit the needs of Turkish teachers. We considered the local education system, the subjects the teachers teach, their knowledge levels, the knowledge level of their colleagues at schools, the students and curriculum.

Haynes also weights the significance of a secure environment for open communication, as some participants may hesitate due to their concerns. To enhance interactivity, it's vital to establish a relaxed ambiance where individuals feel at ease to express themselves. This is particularly evident in the case of mathematics teachers in Turkey, who are subjected to societal pressure and expected to be error-free.

In contrast, the coding world operates differently. Even experienced programmers at leading companies like Google are less afraid of making mistakes. It's widely accepted in this field that errors are a natural part of writing code. People often begin by copying and pasting code from Google, a common practice. Mistakes are not perceived as a hindrance in this industry. However, this is not the case in mathematics, where mathematicians are confident in their abilities and make fewer mistakes.

Haynes highlights the importance of diversity and customization in OPD content, considering participants' unique backgrounds and needs and the impact of art in bringing everyone together. He also emphasizes the significance of understanding the local education system and teachers' knowledge levels and concerns for effective OPD design and delivery.

Pragmatic approach

Haynes stresses the significance of considering that teachers who participate in professional development are eager to acquire practical knowledge that they can immediately apply in their classrooms. This is why he went above and beyond to incorporate hands-on examples that teachers can utilize as-is or tailor to fit their unique classroom environments.

Teachers think about how the knowledge they gain will impact them immediately, not in the long term. [In a successful OPD program], the most important thing is for teachers to leave with both a full head and a full pocket, ready to put their new skills into practice in the classroom.

Haynes faced challenges in creating the syllabus as he revised it multiple times. The issue was figuring out the most important, relevant, interesting, and helpful information to include. According to Haynes, the critical factors in determining what to include in the syllabus were whether the teacher can use the information directly in the classroom and if the teacher can adapt the information to different contexts. Haynes narrowed down 30 pieces of information to just six that would be covered in a seven-week OPD program. The difficulty was determining which six were the most critical and relevant and presenting them in a coherent context. The primary considerations were whether the teacher could adapt and use the information directly.

Haynes initially favored Scratch over Snap! during the first cohort due to the community surrounding Scratch, which offered numerous ready-to-use resources for teachers. However, after a year, he confidently switched his preference to Snap! for the second cohort.

When I talk about Scratch, I find that it is not the best language for explaining math and other subjects. At the time, I wanted to use Snap, but its version was not stable yet and had some bugs. The website was not even opened, and there was no community to share problems or bugs. You had to write directly to the developer. That is why I did not use it in the first year. Later, when the website was up, and a community was formed, they started fixing the bugs. I would still choose Snap! now, because it is a more advanced tool. The main difference is that Scratch does not have factorials or return functions and is limited for mathematics. However, if there is no community, how can we continue to learn? I learned on my own, but what about others? With just 3-5 people, nothing will happen. But with 60 million people or 1 million people, something can happen. It is great when you do a search and find someone who has already thought about it, and you can say *Aha, someone has already thought of this*.

Haynes stresses the importance of considering information's immediate application and adaptability in creating effective OPD programs. He also highlights the importance of carefully considering design decisions, such as incorporating a supportive community, to enable teachers to use the acquired knowledge in the classroom effectively.

Discovering the power of mathematics

Haynes is determined to ignite a passion for mathematics during the OPD. He firmly believes that grasping the subject requires a holistic approach. Through his computer engineering studies, Haynes discovered the true power of mathematics, seeing its practical applications come to life. He understood that not all learning might seem useful now, but if teachers in the OPD could uncover the connections and big picture, it could break down preconceived notions and deepen teachers' understanding of mathematics.

For example, I realized...about mathematics while taking computer engineering classes and thought, "Why didn't they teach me this before?" I need to see a real-life application of polynomials; why are they useful? I have seen rings and objects in space, but what is the practical use of polynomials in real life? Can you give me one example? In computer science, I learned about the five keys for nuclear missiles, which are related to encryption and decryption. Here, I learned that polynomials were used for that. This was discovered in the 1960s, but polynomials are actually very old. I am not saying that polynomials are only used in this context but seeing even one example changed my perspective on mathematics. Suddenly, I understood why I saw those rings [in abstract algebra]. Of course, not everything we learn will be directly useful to us in our jobs. We cannot be that pragmatic. Not every line we read will be useful. But when I see the big picture and understand the connections, it breaks down my prejudices. Unfortunately, many of our teachers do not learn mathematics through practical applications.

Haynes believes that having a shared focus, in this case, mathematics, for participants to discuss is key to their engagement during the OPD. Participants' confidence level in the mathematical concepts affected their ability to discuss and interact. The better the comprehension of mathematical concepts by teachers, the higher the level of interactivity during the PD. Haynes highlights that deeper understanding leads to increased interest.

Haynes stresses the significance of considering participants' prior knowledge while designing the OPD. He points out that previous mathematics content knowledge can directly impact participants' cognitive load.

Teachers had mixed feelings about the mathematical examples in the OPD. They liked the examples but said they had trouble understanding them on their first try and had to watch the [recorded] videos multiple times. It can be hard to learn new concepts, especially if you are at an elementary level for both math and coding. Also, doing two things at the same time can be a challenge.

Haynes notes that working with coding applications can be challenging for both teachers and students, who are often new to the field. To overcome this, the facilitator, Haynes, aimed to balance basic and interesting examples to keep motivation levels high. He started with simple activities and gradually incorporated more challenging yet engaging examples throughout the program. Despite all, he is particularly aware and concerned with the level of content knowledge of middle school mathematics teachers and information technology teachers.

For example, information technology teachers do not necessarily graduate with much mathematics knowledge. Forget about mathematics; there is no algorithm course in their teacher education. There is a coding course but no algorithm course. Yet, it is one of the most challenging classes, even for computer engineers...because it is not just about doing things in sequence. Our concern is how to make the computer do it.

Haynes believes that understanding mathematics is crucial for participants in OPD and that their prior knowledge of the subject can impact their learning experience. He believes in taking a holistic approach to learning mathematics and that seeing its practical applications can change participants' perspectives and break down their prejudices. He also stresses the importance of having a shared topic and the level of confidence in mathematical concepts for participant engagement and interaction.

Balancing time

The duration of OPD is an important factor for Haynes in achieving goals. Depending on the PD's aim, the program's length can vary. For example, if the goal is to provide deep expertise in a subject, a longer duration is required, while a shorter duration may suffice if the aim is to raise awareness. The program length of the OPD was imposed on the facilitator by the coordinator, and the program's design needed to reflect this.

Haynes suggests that attention span should be considered in OPD duration and suggests an active-passive balance to prevent loss of attention. He knew that the suggested duration is 80 minutes, beyond which the cognitive load may become too demanding. Considering these factors, OPD programs can be designed for maximum impact and effectiveness.

Haynes stresses the importance of time in learning and suggests that multiple PD sessions are necessary to understand and apply the material thoroughly. He believes that participants should have at least three to four hours per week to repeat and study the material and highlights the impact of PD workload on participants, who often spend extra time re-watching sessions and internalizing the material.

In addition, Haynes acknowledges the importance of creating a comfortable and interactive environment for participants. The first few weeks may be hesitant as participants adjust to the new environment, but as they become more comfortable and interactive, they will be more participative.

Haynes emphasizes the need to consider the work schedule of in-service teachers who are often the OPD participants. The duration of the OPD should not disrupt their work routines. Haynes considers this by putting himself in their shoes and empathizing with their situation.

Online & offline engagement: finding the best of both worlds

Haynes values in-person interaction over recorded videos (e.g. YouTube or other MOOCs) for better human connection and engagement. He likes the interactive nature of synchronous lessons and believes they enhance discussions and self-reflection. Despite this, he acknowledges the importance of having a structured platform for sharing and managing materials and feedback. He faced challenges with managing final projects and sought a web platform to solve them.

Haynes plans to combine recorded videos with in-person sessions and assign tasks based on the videos for discussion in the coming years. When participants requested homework for motivation and self-reflection, Hayes agreed, saying even adults need homework to revise. Haynes emphasizes the importance of allowing immediate application and reflection for stronger comprehension.

Harness the power of theory through cofacilitating

Haynes stresses the importance of having a well-defined goal and how using *understanding by design* (Wiggins & McTighe, 2005) framework helped him maintain that focus during the OPD design. He notes that for all educators, it's crucial to have a clear objective, like learning about computer science or incorporating mathematics, to determine their end goal.

> I have used the backward design [when designing the OPD]. First, what are my expectations at the end? Where am I headed? Because now, fields like computer science, which is a broad field, especially now with math entering, they are infinite worlds. If you start with this, there are many places you can start from. And there are even more places you can finish. So, I will start with 100 doors, but there are millions of exits at the end. Where will I come out? Otherwise, we will be lost; it is an easy area to get lost in. … we are talking about two separate, huge disciplines. They are like DNA spirals, yes, exactly like that. They are not the same, but they overlap a lot. They support each other. So, where we will come out is our most challenging part.

During his preparations for the OPD, Haynes reached out to several experts in the field, including Samuel from a university in the USA who had developed the mathematics portion of a programming course. Haynes and Samuel formed a connection as they discussed their experiences and knowledge in the field. Samuel shared his own work and insights with Haynes, who greatly benefited from their conversations and was able to gain a better understanding of how to approach incorporating computer science into mathematics from theoretical and practical perspectives. Haynes' research and consultations, including his interactions with Samuel, helped him in developing the OPD for the first cohort of teachers, giving Haynes a strong foundation to build upon.

For his collaboration with Steven during both cohorts, Haynes was pleased that Steven treated him as a peer, exchanging ideas and viewpoints despite Steven's academic background. This mutual respect only enhanced their discussions.

> Steven was breaking the mold of what I thought academics were like. He challenges my perception and the stereotype that academics are disconnected from the reality of schools and teachers. Normally, if I were working with a typical professor, I don't think it would be as fulfilling, but with him, the experience has been much more enlightening.

The bond between Haynes and Steven was further fortified in the second cohort, as they collaborated in an exhaustive examination of objectives and content. Haynes acknowledges the essentiality of Steven's role as the architect of the OPD and views himself as the principal craftsman. Haynes believes that the architecture of the OPD is of paramount importance and is a determinant factor in the program's success.

Throughout the implementation phase, Haynes was cognizant of the influence of Steven's past experiences and the utility of incorporating the findings of other researchers, as well as incorporating mathematical education theories to enhance the practical applications of the program. Haynes perceives that the joint effort between them significantly enhanced the efficacy of the OPD.

This OPD is something that needs to be constantly refreshed. I have been saying *this is how it was here, this is how it was there*, but why? Steven has more [theoretical] experience in this because he has a broader perspective. For example, when preparing for the second cohort, we looked at last year's lesson together. I was a bit more focused on my immediate environment, but he had a broader perspective. I may have provided the main material for the topic, but in the end, it was the theoretical perspective ...that made the work beautiful. I felt [what I was doing] was right and good but now I knew why it was good. Because without it, it was just a rough building, but now it's a well-finished and beautiful building.

Haynes believes that computer science, compared to mathematics, is still relatively young in terms of its history. As a result, there are still some aspects of the integration of computer science in mathematics education that have yet to be researched. Theoretical discussion within the OPD has given Haynes a clear idea of where the field is headed in the future, and Haynes sees this as the most important aspect, as it helps guide their next steps as teachers and educators.

Haynes states that student learning through teacher effectiveness in the classroom are the primary objectives of the OPD. Haynes is aware of several PDs where computer engineers explain technical concepts, but believes they are not effective. Haynes emphasizes that success of this OPD lies in finding ways to integrate technical concepts, such as coding, into mathematical teaching strategies. Haynes feels that this approach blends theory and practical applications in both mathematics and computer science education, creating a unique and effective path for future OPDs. He provides some insights from OPD sessions:

As a teacher, I find it effective when I can bring all the pieces together. That is true but I need an example [how theory and practice are integrated]. Doing things separately and trying to fit them together later is not only difficult but can also be confusing. The key is to add the right ingredients at the right time to make it complete. Steven could observe student reactions in real-time during the OPD and make necessary comments from theory. This kind of integration is what makes our OPD valuable. At the end of each class, Steven could summarize the main points to bring the broad picture in front.

According to Haynes, the integration of computer science into mathematics education still has a long way to go. He believes that theoretical discussions in the OPD program play a crucial role in shaping its future direction. He recognizes the iterative nature of OPD design, where feedback and evaluations from all stakeholders, including academicians, facilitators, teachers, and if possible, students, should inform each step in the program's development. Haynes attributes his understanding of the importance of having a broader perspective to Steven and the theories presented during the second cohort.

CONCLUSION

Results show that the elements of consensus view for effective professional development—content (*discovering the power of mathematics*), duration (*balancing time*), collective participation (*online & offline engagement: finding the best of both worlds*), active learning (*breaking the boundaries of centralized curriculum and fostering creativity in the classroom*), and coherence (*diversified and localized online professional development*)—are consistent with the findings from this study on OPD from a facilitator's perspective. In addition, this study reveals some new insights regarding effective PD characteristics in *motivated for mastery: fostering interest and inspiration*, *pragmatic approach*, *harness the power of theory through cofacilitating*.

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