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Can professional development effectively improve the in-service computer science teachers' teaching practice? A mixed methods study

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Article

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Abstract

This study investigates the effectiveness of professional development (PD) programs in enhancing the teaching practices of in-service computer science (CS) teachers in Pakistan. Two complementary studies were conducted: Study 1 employed a quantitative research, while Study 2 utilized a qualitative research. The findings of Study 1 revealed a significant positive relationship between PD programs and both teaching practices (TP) and self-efficacy (SE); however, no significant relationship was found between PD and job satisfaction (JS). Self-efficacy positively influenced both JS and TP, whereas no direct relationship was observed between JS and TP. Age emerged as a significant negative predictor of TP. Furthermore, SE was found to mediate the relationship between PD programs and TP, indicating that well-structured PD initiatives enhance CS teachers' instructional techniques, confidence, and technological competence. These findings underscore the importance of designing PD programs that support student success in CS courses and strengthen teachers' instructional efforts. Equipping CS teachers with appropriate tools and resources to create effective teaching learning environments is essential for achieving educational objectives. The results of Study 2 demonstrated that PD programs significantly improve CS teachers' content knowledge, instructional strategies, and skill development. PD enhances teachers' understanding of CS concepts and their ability to integrate these concepts into classroom instruction, thereby making learning more effective and engaging. The availability of CS resources and the use of effective instructional practices were identified as critical factors in improving teaching practices. In-school interdisciplinary collaboration, such as regular weekly and monthly meetings with school leadership, provides valuable opportunities to discuss instructional strategies and address teaching challenges. Collaboration beyond the school further supports teachers by enabling the sharing of experiences, refinement of teaching approaches, and exchange of ideas. PD programs for CS teachers should emphasize resource integration, student collaboration, and hands-on learning. Continuous monitoring of progress, constructive feedback, and recognition of achievements are vital for sustaining teacher motivation and ensuring ongoing improvement in instructional practices and practical skills.

Introduction

Over the past few years, there has been a notable increase in the demand for CS instruction in K-12 education (Lee et al., 2022). Several countries, such as England and Australia, have made CS a compulsory subject in schools (Escherle et al. 2016). This decision recognizes the importance of helping students in transition from being mere technology users to becoming creators of technology (Brown et al., 2014). Likewise, authorities in the United States have suggested that CS should be mandatory for all students to be taught (Escherle et al., 2016). They also emphasized the necessity of ensuring that every student actively engages in acquiring knowledge and skills in CS. To support these efforts, the Computer Science Teachers Association (2011) and the International Society for Technology in Education (2011) have released updated standards that encourage the development of fundamental CS knowledge and skills among K-12 students. However, PD and support of CS teachers are crucial factors in achieving the goals of these initiatives (Baabdullah et al., 2024). Despite increasing interest in CS education, only a small percentage of educators possess the necessary skills to effectively teach CS courses or integrate CS into contemporary school curricula (Rich et al., 2021).

Literature review and research hypothesis

Impact of CS teacher PD on TP, SE and JS

PD refers to the process and activities designed to improve teachers' knowledge, skills and attitudes ultimately enhancing student learning (Sancar et al., 2021, p. 4). PD programs in teacher education encompasses a variety of approaches, including formal education, pre-service and in-service training, induction programs, teacher cooperation,

individual research, certification programs, mentorship, peer observation, and feedback (TALIS, 2013c; Adnyani, 2015). Furthermore, teachers exhibit a high level of precision in their specific expertise and effectively utilize resources gained from PD programs in CS in their academic pursuits (Menekse, 2015). PD initiatives often employ intensive summer workshops (Zhu & Wang., 2024). For example, Milliken et al. (2019) reported that from 2012 to 2018, a series of summer PD workshops were conducted to train instructors to teach Advanced Placement (AP) CS effectively using the Beauty and Joy of Computing (BJC) curriculum. However, the program's duration was reduced from eight weeks to just one week. Although these brief summer courses do not offer continuous support to CS teachers during the academic year, ongoing PD support is considered crucial for their success (Mouza et al., 2016). Many studies on CT-PD are conducted in high-resources settings, where teachers have access to robust technological infrastructures, well-developed curricula, and continuous support from professional learning communities. For example, Northrup et al. (2022) examined US teachers' perceptions of PD program but did not account for challenges such as inadequate infrastructure or a lack of trained mentors, which are common in Pakistan.

In the term of TP, it refers to the overall effectiveness or quality of instructional methods (Ainley & Carstens, 2018). While there are various ways to define teaching quality in the field of education, researchers agree that the concept is multifaceted (Wagner et al., 2013). TP encompass the implementation of effective instruction in the classroom, which includes classroom management, teacher support, clear instruction, and cognitive engagement (Ainley & Carstens, 2018). Computer Science Teacher Teaching Practices (CST-TP) examine prior knowledge, dealing with student errors, learning activities used, communication, and student engagement (Kordaki, 2013). Brandes and Armoni (2019) found that PD programs significantly enhance the TP of high school CS teachers. For example, participation in a PD program can boost teacher SE, attitudes, and TP, especially regarding the integration of technology (Pinnock, 2006). While meta-analysis has indicated that teachers' PD does not directly affect instructional skills, it does significantly influence teacher learning, which subsequently leads to changes in TP (Hattie, 2009).

In addition, Computer Science Teacher Professional (CST-PD) program also enhances Computer Science Teacher Self-Efficacy (CST-SE) (Bauch et al., 2021). PD activities for CS teachers focus on enhancing persuasive skills, providing indirect experiences, and achieving mastery. They significantly aid in boosting TSE in the field of CS (Zhou et al., 2020). Participating in PD workshops can lead to notable enhancements in one's SE and programing proficiency (Reimer et al., 2018). Extensive studies have already sought to measure the correlation between teachers' participation in PD activities and their SE (Yoo, 2016). Most of these studies have identified a positive correlation between PD programs and SE (Martin et al., 2008). Existing studies largely ignore the role of gender in computer science teacher professional development. While Zhou et al. (2020) discuss self-efficacy among teachers, they do not examine gender disparities in CS education. In Pakistan, where female participation in STEM fields is low, understanding how PD influences male and female CS teachers differently is crucial.

Several studies have identified a direct correlation between PD programs and JS (Wang et al., 2020). For instance, enhancing the skills and knowledge of teachers through PD activities can lead to increased JS and, more broadly, improved performance (Smith & Smalley, 2018). Higher JS and engagement in PD may boost the likelihood of receiving a promotion. Furthermore, a significant pay increase contributes to a notable rise in satisfaction with knowledge sharing and peer recognition, along with greater control over once skills and work environment in pay leads to a considerable rise in satisfaction with knowledge sharing and peer recognition, as well as greater control over one's abilities and working environment. In other words, participating in PD activities can enhance JS (Molaee & Dortaj, 2015). The implementation of such PD activities could result in increased JS and a reduced burnout (Boamah et al., 2017). Based on the previous literature, this study has developed the following hypotheses.

Hypothesis 1. CS-PD has a direct positive impact on CS-TP.

Hypothesis 2. CS-PD has a positive impact on CS-SE.

Hypothesis 3. CS-PD has a positive impact on CS-JS.

Impact of CS teacher SE on JS and TP

The idea of SE, which is central to social cognitive theory, describes a person's assessment of their own ability to perform action at an appropriate level (Bandura, 1997). SE influences how people think, feel, and behave, and it has a positive and significant impact on work-related performance (Stajkovic & Luthans, 1998, p. 5). Teacher SE as the belief in one's own ability to organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context (Tschannen-Moran et al., 1998, p. 233). Likewise, teachers' belief in their ability to develop specific teaching behaviors that impact students' learning outcomes, such as motivation, engagement, and performance (Klassen & Tze, 2014). SE lays a vital role in CS-PD as it can accurately predict teaching behaviors, including engagement and perseverance (Skaalvik & Skaalvik 2016). According to the social cognitive theory Elliot (2019) asserts that SE influences teacher behaviors through the triadic reciprocal determinism framework, which encompasses personal (e.g., beliefs and expectations), behavioral (e.g., attempts and actions), and environmental factors (e.g., social context). consequently, SE has the potential to affect the decisions teachers make when faced with challenges, as it shapes their understanding and perception of the issues they encounter (Gordon et al., 2022). On the one hand, teachers with a strong belief in their abilities are more likely to view challenges as opportunities for personal growth and are willing to exert consistent effort. Conversely, teachers with a weak belief in their abilities tend to perceive challenges as indicators of insufficient skills and may give up early avoiding potential threats to their competence (Zhou et al., 2020).

Teacher SE has a significant impact on JS (Shen et al. (2012), and SE has a positive relationship with JS (Türkoglu et al., 2017). For instance, teachers with high level of SE have strong communication in the workplace which leads to JS Coprara et al. (2006). Teachers with a stronger belief in their SE typically experience higher levels of JS (Moè et al., 2010). Canadian teachers with greater confidence in their abilities to effectively engage students in learning, manage student misbehavior, and oversee classroom activities reported higher levels of JS and lower levels of burnout (Wang et al., 2015).

Teacher SE is linked to the TP and attitudes that teachers hold toward their students Yesilyurt et al. 2016). Teachers with a strong sense of SE employ effective strategies that can positively influence student achievement. Teacher SE has the potential to improve behavior and is directly correlated with TP (Holzberger et al., 2014). Research on SE has shown that Teacher SE significantly impacts both motivation and PD (Klassen & Tze, 2014). Therefore, the present study has formed the following hypotheses based on prior literature.

Hypothesis 4. CS-SE has a positive impact on his CS-JS.

Hypothesis 5. CS-SE has a positive impact on his CS-TP.

Impact of CS teacher JS on TP

Locke (1969) defined JS as a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences' (p. 316). JS is an individual multidimensional psychological response to the one's job, which is influenced by environmental, psychological, and demographic factors (Crossman & Harri, 2006, p. 30). Teachers' sense of fulfillment and happiness because of their work as teacher (Ainley & Carstens, 2018). Teacher's JS refers to

overall attitudes and opinions of educators about their working environment and profession (Hongying, 2007). The level of Computer Science Teacher Job-Satisfaction (CST-JS) is linked to two key factors: the work environment and the job type. In the 2018 Teaching and Learning International Survey (TALIS), the Organization for Economic Co-operation and Development (OECD) assessed JS using a composite scale comprising two dimensions: contentment with the work environment and satisfaction with the job profession (OECD, 2018). The study revealed a significant positive correlation between JS and several factors, including teacher efficacy and professional development (Kang, (2023)). JS is the positive emotional state arising from one's appraisal of their professional role or job experiences (Rao & Karumuri 2019). The current study contributes to more comprehensive understanding of PD and TP among CS as well as the role of SE and JS in mediating this relationship.

Renzulli et al. (2010) indicated a positive relationship between JS and TP. Moe et al. (2010) discovered that JS positively influences SE and TP, underscoring the interconnectedness of these factors in fostering a fulfilling and effective teaching experience. Moreover, teacher JS is significantly affected by various factors, such as, student behavior, self-efficacy, working environment, career advancement opportunities, teacher characteristics, and school working conditions (Toropova et al., 2021). Consequently, the following hypothesis was formulated.

Hypothesis 6. CS-JS has a positive impact on his CS-TP.

Further, we integrated the above six hypotheses into a chain mediation model (see Figure 1). We aimed to determine whether CS teachers' SE and JS played the mediating roles in the relationship between PD and TP.

Effective Elements of PD

Van-Veen et al (2012) classified PD programs into traditional and modern. The traditional PD approach mostly involves lectures, seminars, and conferences separate from the workplace. The traditional format neither designates teachers' roles as active partners nor creates data attached from the daily challenges and concerns of TP (Van-Veen et al., 2012). To surmise effective elements of PD, Darling-Hammond et al. (2017) conducted a systematic review and found that successful PD programs generally include seven essential elements: content-focused approaches, active learning methods, collaborative learning environments, models demonstrating good practices, coaching and expert support, frequent feedback and opportunities for reflection, and sustained engagement.

Content in PD refers to the knowledge and skills that teachers acquire through turning programs (Garet et al., 2001). Specifically, PD content is divided into two main categories: (1) Knowledge of the subject matter and (2) knowledge of how students learn that content (Kennedy, 1998). Shulman (1986) refers the send category as pedagogical content knowledge, which is widely regarded as critical of effective PD (Desimone, 2009). Empirical research indicates that content-focused PD can significantly influence teachers' knowledge, TP, and students learning outcomes (Ingvarson et al., 2005; (Kang el al., 2013). Active learning in PD refers to the degree to which teachers are actively involved in analysis TP and learning processes (Kang el al., 2013). Ingvarson et al. (2005) found that active learning is a key component of effective PD programs, it has significant impact on teaching methodologies and student learning outcomes. By utilizing actual curriculum materials, student work, and instructional examples, teachers often engage in the active learning during PD programs (Darling-Hammond et al., 2017). Additionally, when the professional learning is relevant, teachers are more likely to engage meaningfully with the material (Darling-Hammond et al., 2009). Furthermore, PD programs that are integrated into a community of practice have proven highly effective in fostering the growth of CS teachers' (Sentence & Humphreys, 2018). For the effective element of collaboration, Birman et al. (2000) stated that PD activities involving collective participation, particularly the engagement of teachers from the same department, subject or grade, are more likely to provide opportunities for active learning and to align coherently with teachers. Collaboration enhanced the teachers' learning by improving their understanding of lesson plans and

classroom activities, while also encouraging deeper reflection, a greater willingness to share ideas, and more constructive peer feedback (Postholm, 2018). However, Menekse (2015) argue that limited collaboration between most CS professional development providers and local school leadership represents a significant barrier to the effectiveness of these PD programs

The existing literature, such as Darling-Hammond et al. (2017), highlights essential elements of effective PD that enhance teacher teaching practice and improve student learning outcomes. However, much of this study focuses on general PD initiatives across various disciplines, with limited attention to PD specifically for middle, high and higher secondary school level CS teachers. Therefore, to address this gap, we adapted theoretical framework proposed by Darling-Hammond et al. (2017) to explore the effective elements of PD for CS teachers.

Rationale of the two study

The purpose of this research is to examine how PD influences the TP of CS teachers. To address this purpose, the researcher employed mixed method research design conducted quantitative and qualitative research studies. The first study uses a quantitative design to investigate the relationship between PD and the TP of CS teachers, with particular attention to the mediating roles of SE and JS. The second study adopts a qualitative approach to explore the characteristics of effective PD for CS teachers.

Teacher training and ongoing support are vital components that can determine the success or failure of educational initiatives (Mouza et al., 2022). Although CS education has gained increasing attention, only a limited number of teachers are sufficiently qualified to teach CS courses or integrate CS content into existing school curricula (Sadik et al., 2020; Rich et al., 2021). Furthermore, effective professional development is essential for enabling teachers to learn and refine the pedagogical skills required to teach 21st-century competencies (Darling-Hammond et al., 2017). Darling-Hammond et al. (2017) define effective PD as structured professional learning that leads to changes in teacher practices and improvements in student learning outcomes.

In Pakistan, several institutions provide PD programs, including the Provincial Institute of Teacher Education (PITE), the Higher Education Academy of Research and Training (HEART), the Directorate of Professional Development (DPD), and the PSA-KP Online Academy. While these institutions offer PD programs across various subjects, insufficient attention has been given to computer science education. Moreover, although the National Education Policy (1992) mandated the introduction of CS at the school level (Malik et al., 2014), there remains a significant deficiency in both adequately equipped facilities and properly trained CS teachers in K–12 education in Pakistan (Jehan & Akram, 2023). This gap necessitates a deeper investigation into PD and teaching practices among CS teachers. Together, the two studies address distinct but interconnected aspects of this issue, contributing to a comprehensive understanding of how PD influences CS teachers' teaching practices.

Study 1 research questions

Is there exists any relationship between CS teachers professional development, self-efficacy, job satisfaction, and teaching practices?

Method

A cross-sectional survey design was applied together data from a diverse population at a single point in this study. This method aimed to capture the current state of PD, SE, JS, and TP among CS teachers in Pakistan.

Participants and sampling technique

Table 1 presents the demographic information of the participants. The participants consisted of 325 CS teachers, including 209 males and 116 females, across middle (grades 6 to 8), secondary (grades 9 to 10), and higher secondary (grades 11 to 12) school levels in Khyber Paktunkwa, Pakistan. The researcher applied a convenience sampling technique, selecting individuals from the target group based on specific practical criteria (Dornyei, 2007). Thus, the criteria for convenience sampling included selecting individuals who were readily accessible, in close geographical proximity, available during the designated timeframe, or particularly willing to participate in the study. To facilitate the recruitment of participants, the researcher joined various WhatsApp and Facebook Messenger groups popular among computer science teachers. Subsequently, the researcher contacted each potential participant individually to obtain their formal consent to participate in the study. Upon securing their agreement, the researcher provided convenient access to the survey by distributing the Google Forms questionnaire link directly through both WhatsApp and Messenger platforms. This technique allowed for a swift and accessible method of gathering data from a broad range of CS teachers, ensuring a diverse pool of respondents for the study.

Table 1 Demographic representation of the study

Variable	Category (n=325)	Frequency
Gender	Male	209
	Female	116
Age	Below 40 years	264
	Above 40 years	61
Teaching Level	Middle school	37
	Secondary school	157
	Higher Secondary school	131
Teaching Experiences	Below 5 years	106
	6 to 10	179
	11 to 15	39
	Above 16	1
School Location	Urban	159
	Rural	166
Education Level	Ph.D.	17
	M.Phil. (18 years Education)	120
	Master (16 years Education)	185
	Bachelor	3

Instruments

The researcher utilized the Teaching and Learning International Survey (TALIS) 2018 questionnaire (OECD, 2018). The TALIS 2018, international questionnaire is a standardized tool aimed at assessing various aspects of teaching and learning environments globally. It also gathered demographic information, covered 11 constructs measuring through 61 items. The respondents took nearly 25 minutes in completing the questionnaire. 34 items in the first section

covers fundamental demographics, including gender, age, teaching level, teaching experiences, school location, and education level. The following questionnaire consists of 4 factors including PD, TP, SE, and JS (see Table 2).

Professional Development (PD)

This section comprises 9 items that assess CS teachers' engagement in continuous learning and growth. It explores various avenues through which teachers seek to enhance their skills and knowledge. The responses of participants were collected using a dichotomous scale from 1 (yes) and 2 (no). TheCronbach's alpha for this scale in the current sample was 0.74.

Teaching Practices(TP)

This section, consisting of 16 items, highlights various teaching practices employed by CS teachers. An example item is "I let students use ICT (information and communication technology) for projects or class work". The items are rated on a 4-pont Likert scale from 1 (never or almost never) to 4 (always). TheCronbach's alpha for this scale in the current sample was 0.86.

Self-Efficacy (SE)

This section seeks to gauge the confidence and perceived competence in various aspects of CS teachers in different items of their teaching roles. It comprises 13 items.An example item is "Support student learning through the use of digital technology (e.g. computers, tablets, smart boards". The items are scored on a 4-pont Likert scale rating from 1 (not at all) to 4 (a lot). TheCronbach's alpha for this scale in the current sample was 0.85.

Job satisfaction (JS)

The final segment of the questionnaire explores the realm of job satisfaction, delving into the CS teachers' feelings about their profession. This scale consists of 10 items. An example item is "If I could decide again, I would still choose to work as a computer science teacher." Items are scored on a 4-point Likert scale ranging from 1(strongly disagree) to 4 (strongly agree). TheCronbach's alpha for this scale in the current sample was 0.60.

Table 2 Showing the reliability of the questionnaire

Variable	Original TALIS No	No of items	Cronbach's alpha value
PD	TQ-22	9	.74
TP	TQ-42	16	.86
SE	TQ-34	13	.85
JS	TQ-53	10	.60

Data collection and data analysis

The researcher collected data from CS teachers at middle, secondary and higher secondary schools in Pakistan using the TALIS 2018 questionnaire. The researcher utilized Google Forms (developed by Google) to gather the basic information regarding PD, SE, JS and TP. The link to the online survey (Goggle Form) was distributed via WhatsApp and Messenger among CS teachers.

The results presented herein reflect a descriptive statistical analysis conducted on key variables: PD, SE, JS, and TP. Additionally, we considered socio-demographic variables, including gender and age. In our analysis, teachers' PD served as the independent variable, TP as the dependent variable, and SE and JS as mediating variables. We aimed to conduct a chain mediation analysis and control for gender and age. Since PD, gender, and age were categorical variables, they were coded in the following manner for analysis: for PD, a lower degree of PD was coded as 1, and a higher degree of PD was coded as 2; for gender, male was coded as 1, and female was coded as 2; for age, '40 years and below' as coded as 1, and '41 and above' was coded as 2.

Before undertaking mediation analysis, a Pearson correlation analysis was conducted to ascertain the existence of a linear relationship conducive to mediation analysis. This step is critical for affirming the reliability and validity of the subsequent mediation analysis. We performed a regression-based mediation analysis using the PROCESS v4.2 plugin in SPSS 24 to examine the relationship between PD, SE, JS and teaching practices. Confidence intervals for mediation effects were estimated using the bias-corrected bootstrap method, with a 5000-sample bootstrapping. All variable scores were standardized to Z-scores before the analysis of mediating effects (Preacher & Hayes, 2008).

Results

Descriptive Statistics and Pearson Correlation Analysis

The results in Table 3 showed that the PD of CS teachers was (M=1.59, SD=0.50), which means that more than half of the teachers have a positive attitude towards PD participation and continuous learning. Their SE was (M=46.42, SD=0.50), which means that most teachers have strong confidence in their ability to successfully complete tasks in teaching. Their JS was (M=28.98, SD=5.35), indicating that most teachers hold a relatively positive attitude towards the existing teaching work; Their TP was (M=54.50, SD= 6.84), indicating a high level of overall teaching practice. Additionally, Pearson correlation analysis showed that SE was positively correlated with PD (r =0.21, p = 0.001), p< 0.05. JS was positively correlated with SE (r = 0.18, p = 0.001), p< 0.05; TP and PD were also significantly positively correlated (r = 0.38, p = 0.001). 0.05, and SE (r = 0.47, p= 0.001) p< 0.05. However, gender was negatively correlated with PD. There was a significant negative correlation between age and PD (r = -0.19, p = 0.001), p< 0.001. 05, SE (r = -0.11, p = 0.049) p<. p< 0.05 (r = -023, p= 0.001).

Table 3 Descriptive statistics and correlations among PD, SE, JS, TP, gender and age

Variables	M	SD	1	2	3	4	5
PD	1.56	0.50	—				
SE	46.42	5.35	0.21***	—			
JS	28.98	3.20	0.06	0.18**	—		
TP	54.50	6.84	0.38***	0.47***	0.08	—	
Gender	1.36	0.48	-0.17**	0.003	0.01	0.03	—
Age	1.19	0.39	-0.19***	-0.11*	-0.03	-0.23***	-0.05

Note: The provided information includes the Pearson correlation coefficients and the corresponding levels of significance; M is mean; SD is standard error; $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Cohen's (1988) guidelines for correlation coefficient, small: \ (0\le r\le 0.29\), medium: \ (0.30\le r\le 0.49\), and large: \ (0.50\le r\le 1.00\).

Chain mediating effect analysis

Table 4 and Figure 2 show the path analysis results of the chain mediating effect model. First, we found that PD had a direct and significant positive predictive effect on TP (β = 0.29, p = 0.001). PD also had a significant positive predictive effect on Teacher SE (β = 0.20, p < 0.001). Second, Teacher SE significantly positively predicted JS (β = 3.14, p = 0.002). Third, there was a significant positive predictive effect of SE on TP (β = 0.40, p < 0.001). Therefore, we do not reject hypotheses 1, 2, 4, and 5. Our findings indicate that PD does not have a significant predictive effect on JS, nor does JS significantly predict TP, which means we cannot accept hypotheses 3 and 6. Additionally, among the control variables, only age was identified as a significant negative predictor of TP (β = -0.13, p = 0.006), suggesting that an increase in teachers' age is associated with a diminished capacity to engage in teaching practice. Overall, the results show that active participation in teacher professional development activities can not only directly promote teachers' teaching practice, but also indirectly improve the effect of teaching practice by enhancing teachers' self-efficacy.

Table 4 The influence of CS teachers' PD on TP: the test of the mediating effect of SE and JS.

Variables	Equation 1				Equation 2				Equation 3			
	Dependent Variable: CS-SE				Dependent Variable: CS-JS				Dependent Variable: CS-TP			
	β	SE	t	p	B	SE	t	P	β	SE	T	p
Constant	0.11	0.25	0.46	0.465	-0.01	0.25	-0.05	0.964	0.18	0.21	0.89	0.374
Gender	0.03	0.06	0.61	0.543	0.01	0.06	0.25	0.805	0.07	0.05	1.59	0.11
Age	-0.07	0.06	-1.24	0.216	-0.01	0.06	-0.16	0.870	-0.13**	0.05	-2.76	0.006
PD	0.20***	0.06	3.54	< 0.001	0.03	0.06	0.46	0.647	0.29***	0.05	5.91	< 0.001
SE					0.18**	0.06	3.14	0.002	0.40***	0.05	8.43	< 0.001
JS									-0.01	0.05	-0.30	0.764
R^2	0.05				0.03				0.33			
F	5.52**				2.86*				31.51***			

Note: β is the standardized path coefficient; SE is the standard error; t is the t-test statistic; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$; R^2 is the explanatory quantity of the equation; F is the F-test statistic.

Table 5 provides a detailed summary of the outcomes of the mediation analysis. In particular, our analysis of the mediation model revealed a total effect size of g was 0.36, with a direct effect size of g was 0.29, which constitutes 80.56% of the total effect. However, we only found one significant indirect effect size, which existed in the path of 'PD→SE→TP'. The observed indirect effect size of g was 0.08, which constitutes 22.22% of the total effect; and there were no significant indirect effect sizes in the other two indirect paths (i.e., PD→JS→TP and PD→SE→JS→TP).

Table 5 The effect sizes of the mediating analysis.

Effect Size					95% CI		Ratio to Total Effect
	g	SE	T	p	LLCI	ULCI	
Total Effect	0.36***	0.05	6.97	< 0.001	0.26	00.47	—
Indirect Effect: PD→SE→TP	0.08	0.03	—	—	0.003	0.16	22.22%
Indirect Effect: PD→JS→TP	-0.0004	0.003	—	—	-0.01	0.01	—
Indirect Effect: PD→SE→JS→TP	-0.001	0.002	—	—	-0.01	0.004	—
Direct Effect	0.29***	0.05	5.91	< 0.001	0.19	0.38	80.56%

Note: g, standardized effect; SE, standard error; t, t-test statistic; ***$p < 0.001$; LLCI, lower-level confidence interval; ULCI, upper-level confidence interval.

Study 2 research question

What are the effective elements of CS teachers' PD regarding TP in Pakistan?

This research question is informed by a substantial body of literature indicating that effective PD programs are content focused, incorporate active learning, and foster collaboration (Darling-Hammond et al., 2017). However, there is limited understanding of how these elements operate in low-resource settings such Pakistan, especially in the context of CS education. By addressing this gap, the present study aims to generate practical insights for designing PD programs that are both effective and contextual appropriate.

Method

A qualitative research design was employed in this study, specifically adopting a phenomenological approach. This design focuses on gathering and analyzing detailed information about the individuals' lived experiences within a particular context (Creswell et al., 2007). Accordingly, this study explored the perspectives of 10 urban CS teachers from Khyber Paktunkhwa, Pakistan, who had recently completed PD programs, focusing on how various PD elements influenced their TP within their schools.

Participants

Table 6 presents the demographic information of the participants. Specifically, the participants comprised 10 middle, high and higher secondary school level CS teachers in Khyber Paktunkwa, Pakistan. A purposive sampling technique was used in this study. According to Patton (2002), this technique is commonly used in qualitative research to identify and select information-rich situations while optimizing the use of available resources. This involves actively selecting individuals or groups who possess relevant knowledgeable and skilled related to a topic of interest (Creswell & Plano Clark, 2011). In addition to knowledge and experience, Spradley (1979) emphasized the importance of availability and willingness to engage, as well as the ability to articulate and express one's experience and thoughts clearly. The participants were chosen on the bases of two main reasons. First, participants were purposively selected based on their relevant experience and demonstrated interest in contributing to the study. All the selected teachers were easily

accessible, which facilitated efficient data collection and continues engagement throughout the research process. Second, all participants had substantial teaching experience, ranging from 3 to 25 years. Third, each participant had recently completed a PD program organized by the Elementary & Secondary Education Department (E&SED) of Khyber Paktunkwa, such as the Digital Literacy Program (DLP), which was designed to enhance digital competencies in government schools. The program aimed to improve teachers' pedagogical knowledge, instructional practices, and confidence in using visual programming tools. This face-to-face program was delivered over 18 days. It combined lesson planning workshops, project-based learning activities, and reflective exercises, all carefully aligned with provincial curriculum standards and the broader goals of 21st-century education.

Table 6 Demographic representation of the respondents

NO	Participant	Teaching experience	Education level	Teaching level	Gender	Location
1	T1	8 Years	Master	Secondary	Male	Urban
2	T2	12 Years	Master	Secondary	Male	Urban
3	T3	10 Years	PhD	Higher Secondary	Male	Urban
4	T4	17 Years	Master	Higher Secondary	Male	Urban
5	T5	25 Years	Master	Higher Secondary	Male	Urban
6	T6	4 Years	M.Phil	Middle	Male	Urban
7	T7	7 Years	Master	Secondary	Male	Urban
8	T8	5 Years	Master	Middle	Male	Urban
9	T9	3 Years	M.Phil	Middle	Male	Urban
10	T10	15 Years	PhD	Higher Secondary	Male	Urban

Interview Outline

Interview is a valuable method for gathering information and gaining insight from individuals (Monday, 2020). As a more naturalistic and less structures data collection techniques, it is expected to broaden the scope of understanding of the phenomenon under investigation (Alshenqeeti, 2014). According to McCracken, (1988), "interviews are among the most challenging and rewarding forms of measuring instrument that any researcher can use in their qualitative research, as they seek to explore the meanings of central themes that are part of the participant's life experiences. In other words, interviews are highly effective for uncovering the details of each participant's experiences. Using interviews as a tool for collecting qualitative information is regarded as the most basic and suitable method. This is because interviews aim to explore the meanings of central themes that constitute a part of the participant's life experiences. In this study, the interview questions and sub-questions were designed to elicit a broad spectrum of detailed responses from the participants, aiming to gather in-depth information about the professional development and TP of CS teachers. This study addressed four central interview questions, Q1. Could you please briefly introduce yourself, including your educational background, teaching location, and years of experience as a computer science teacher? Q2. How did PD program programs improve your TP? Q3. What are the salient features of your TP? Q4. What types of PD activities (e.g., workshops, coaching, and peer discussion) have had a significant impact on your TP? These central questions were supported by several additional questions related to the main idea, to obtain more in-depth information about the issue under study.

Data Collection

The researcher conducted semi-structured interviews to collect data from CS teachers. Collecting data through a semi-structured or in-depth research interview is advantageous in variety of situations, including when the purpose of the research requires gathering detailed and specific information, when personal contact and building rapport with respondent are important, when the research questions necessitate comprehensive and nuanced responses, and when the time requirement and the need for a thorough and meticulous process are deemed significant (Saunders et al., 2019). In this study, the researcher personally visited each participant to conduct interviews. The interviews were carried out individually, lasted between 30 to 40 minutes. Conducting the interviews in the participants' native language (Pashto) allowed for more authentic and meaningful conversations. The data collected method included handwritten notes, and audio recordings.

Data Analysis

In this study, the researcher employed a hybrid thematic analysis incorporating both deductive and inductive approaches (Swain, 2018). During the first round of coding, deductive codes were utilized, based on the elements of effective PD identified by Darling-Hammond et al. (2017), such as content focus, active learning, and collaboration. A preliminary codebook was developed using these categories, and the researcher independently applied the codes to the interview transcripts to identify segments aligning with each element. The second round involved thematic coding to identify inductive codes within participants' responses, allowing for the emergence of new themes (Strauss & Carbin, 1997). Braun and Clark (2006) define inductive thematic analysis as a method for identifying, analyzing, and reporting patterns within data. Three researchers independently coded the data and engaged in collaborative discussions to ensure inter-coder reliability (O'Connor & Joffe, 2020). Moreover, four raters, one expert with a PhD in education and three PhD students from the faculty of education at Shaanxi Normal University, reviewed the coding framework. Their feedback resulted in minor to codebook, such as clarifying them and merging overlapping. The finalized codebook was then used for the comprehensive interpretation and reporting of the findings. Inter-rater reliability was established through consensus building, and the final codebook was then developed for subsequent interpretation (see Table 7).

Validity and Reliability

To confirm the validity of the analysis, the researcher double-checked the coding structure and consulted with an external peer who has extensive publication experience in qualitative research within teacher education to obtain supervisor perspectives and opinions. Furthermore, to enhance the dependability of the findings, all participants were explicitly encouraged to participate in member checks, where they could verify the reliability, modify their insights to prevent misunderstandings, and provide additional data. For example, the researcher permitted each participant to view his own transcriptions but not the other participants' transcriptions. Participants, such as T1, T3, T6, T9 and T10, conformed the accuracy of the data without requiring any further correction. However, the remaining participants provided minimal revisions, and most of these corrections were typographical mistakes such as misspelling of scientific words. Considering this, William (2024) assert that the foundation of concerns commonly articulated as validity and reliability is the qualitative research to generate high-quality studies.

Table 7 Coding scheme showing journal responses and individual CS teacher transcripts

Theme	Code	Definition	Example
CS Content focus	CS Knowledge	How a computer works and how to use it	"After taking PD program, my knowledge has highly improved in teaching CS courses."
	CS Instructional Strategies	CS specific techniques and approaches used to facilitate learning.	Due to PD, my teaching method is very improved, and PD enabled me to teach effectively and manage the class environment."
	CS Resources	It refers to the materials, tools, and references used to support and enhance the learning process of CS.	"Use of computer-based resources makes the learning process more effective."
Active learning towards CS teaching practice	Designing CS Lesson plan	Designing a lesson plan for a CS teacher involves creating a structured outline of the topics to be covered, learning objectives, teaching methods, assessment strategies, and resources to be used during a particular class session or series of sessions.	"I usually prepare and sort out CS courses, then try to relate the concept used in the real-world case examples."
	Enacting CS instruction	CS students actively engage in practical or hands-on activities to emphasize the concept of theory during the classroom instructions.	"First, I present the lesson, then I give them practical work related to the topic; after completion of the task, I modify it and give them suggestions to avoid mistakes."
Collaboration among CS teachers and other subjects teachers	In-school interdisciplinary collaboration	CS teachers collaborate to develop creative lesson plans, discuss issues related to behavior or academic performance, assess the challenges and progress of each student, and provide a supportive and encouraging work environment to one another.	"I collaborate with my teaching staff by writing different letters, preparedness of lesson plans and handling other official institute tasks."
	Beyond school collaboration	collaboration outside of the school refers to local schools working with organizations in the local community or the global community	"I gain valuable knowledge, skills and attitudes from partner institutions, contributing to mutual growth and development."

Results

CS Content Focus

Improving CS Knowledge through PD

PD is crucial for keeping teachers updated with advancements in CS education. Additionally, PD is important for improving teachers' knowledge, which emerged as a key theme in this study. Participants were asked to describe their knowledge of CS. The specific knowledge, expertise, and skills that CS teachers gain and develop as part of their continuous PD improve their teaching skills and help them stay up to date with the field's achievements. The following

responses of participants revealed that their CS knowledge is significantly improved after receiving PD program. In this regard, Teacher T5 stated the importance of PD in expanding his deepened teaching CS knowledge and staying current with the latest development.

After taking PD program, my knowledge has significantly enhanced in teaching CS courses. PD has deepened my understanding, and I now believe that every teacher should participate in PD programs regularly to stay updated. (T5)

Similarly, the analysis of the semi-structured interviews revealed that PD plays a crucial role in enhancing the digital literacy and subject expertise, enabling teachers to utilize technological resources and their application in teaching. For example, CS teachers T10 and T4 shared how PD significantly enhanced their ability to work with computers, broadening their knowledge of subject-specific resources. *"PD has increased my knowledge, using and implementing the latest technology in the classroom." (T10)*

Before PD program, I did not have enough knowledge to use computers effectively. PD program has brought changes in my teaching skills. Due to PD, I gained much knowledge about computer related resources, deepening my understanding of their functions, features, and practical applications in various educational and professional contexts. (T4)

Furthermore, T7 described how PD enabled to deepen his conceptual understanding and create a more engaging learning environment. The following excerpt explains how PD improved his conceptual understanding and create a more engaging learning environment.

PD program made my teaching activity-based and interactive. It developed my practical skills and also enabled me to involve all the students in class activities. (T7)

Increasing CS Instructional Strategies through PD

Through effective PD program, CS teacher can effectively inspire, engage, and prepare students for a successful career in the field of CS while keeping them up-to-date with the latest advancements. When the respondents were asked about the instructional strategies, CS teachers stated that participation in PD program allows them to improve their teaching strategies, and implement modern instructional techniques effectively. Furthermore, participants reported a noticeable improvement in their ability to deliver lessons, mange classrooms, and engage students in learning activates. In this regards, teacher T1 highlights that *"PD has significantly improved my teaching method. It has enabled me to integrate instructional strategies, such as project-based learning and interactive discussions, which have enhanced students' engagement and comprehension."(*T1)

Likewise, teacher T7 highlights the practical application of PD.

Participation in PD activities has brought a positive change in my teaching methodology as I practically involve all the students in the activities. For example, I use project-based learning where students work in teams to solve real-world problems. This this is not only enhances their technological skills but also fosters collaboration and critical thinking. (T7)

T9 emphasized that, nowadays, PD programs for teachers play a crucial role to provide practical strategies for managing divers teaching environments. He stated, *"Before PD program, I don't know how and when to complete the course on time. However, after participating in the PD program, I became fully aware of how to manage my course schedule effectively."*(T9)

Using CS Resources to Improve Teaching Practice through PD

Participants receive PD program to enhance their teaching skills by utilizing computer-related resources such as textbooks, online platforms, open-source software, and real-world examples. The majority of participants responded that they have access to sufficient and up-to-date computer-related resources in their classroom to facilitate the teaching and learning process. For example, teachers T5 and T1 explained that PD program has, significantly enhanced their ability to use a variety of computer resources in their teaching approach. "*I usually use multimedia materials, textbooks, and real-life examples in the teaching-learning process. It helps students to understand concepts better and makes the learning process interactive."*(T5)

Through PD program, I have gained extensive knowledge about computer-related resources and their application**s**. I utilize a variety of resources, including textbooks, online learning platforms, open-source software, and real-world examples. These resources help students grasp complex IT concepts and gain practical experience."(T1)

Likewise, teacher T9 explained how PD equips teachers with digital tools that enhance their ability to teach effectively. *"I often use computer-based resources in my teaching. It makes the learning process more effective."*(T9)

Teacher T8 clarified that PD enhances digital literacy and pedagogy by integration of tools. Likewise he stated that these resources modernize teaching methods and motivate students to effectively engage in the learning process. "*Due to PD program, I became able to use Google and Microsoft Excel for formulas, involve students in computer activities, and use chat GPT. These resources are helpful in teaching-learning processes."* (T8)

However, teacher T6 highlighted the challenges posed by the lack of resources, as it restricts the ability to deliver engaging and effective programming lessons, ultimately hindering students learning. *"In our school there is a lack of computer laboratories, and multimedia tools like projectors. Without these resources, I rely heavily on verbal instruction and chalkboards, which is not the best approach for teaching programming concepts."* (T6)

Active Learning towards CS Teaching Practice

Improving Lesson Planning Skills through PD

CS teachers must create well-structured lesson plans to communicate with students and support learning in the classroom effectively. Participants were asked to describe how PD programs has influenced their lesson planning practices, and their responses revealed significantly improvements in their ability to create structured, students-centered lesson plans. CS teacher acknowledged the significance of aligning lesson structure with students' cognitive development to ensure an effective learning experience. *"Lesson Plan must be designed according to student's age, level of maturity and capacity of learning."* (T2)

Likewise, teacher T3 explained *"Due to PD program, my lesson plan skills have significantly improved regarding the topic that is to be taught. Before designing a lesson plan, I start by defining clear learning objectives and then structure the plan to achieve the desired objectives. I incorporate a mix of lectures, discussions, group activities, and assessments to ensure comprehensive learning."* (T3)

Teacher T6 explained "*PD program has improved my lesson planning skills and conducting various types of assessment skills such as formative assessment." (T6)*

Moreover, teacher T8 stated the importance of adjusting lesson structures to match individual learning abilities, ensuring that students receive instruction appropriate to their level of comprehension. *"PD has enabled me to design an effective lesson plan, I often design lesson plans for students according to their needs and mental level." (T8)*

T10 emphasized that "*Participation in PD has able me to design a good lesson plan. When I am going to design a lesson plan for students, I follow these steps as a learning objective, content selection, engaging students in learning activities, gathering essential resources, and making proper assessment plan for students' evaluation daily. (T10)*

Enacting CS Instruction

Learning by enacting is a highly effective learning strategy that stimulates constructive cognitive processes by grounding to-be-learned materials to relevant action. Most of the respondents stated that they often use lecture methods for delivering lessons. While some respondents provided suitable explanations regarding their enacting instruction. It is clear that CS teachers employ various enacting instruction, including flipped classrooms and activity-based teaching. They focus on discussion, problem-solving, and hands-on activities, restricting note preparation and encouraging student communication. For example, teacher T6 described that:

I often use the flipped classroom model, where students engage with course materials, such as video lectures or online readings, before the class. During class time, I also focus on discussion, problem-solving, and hands-on activities to reinforce their understanding. (T6)

Teacher T2 stated "*First, I present the lesson, then I give them practical work related to the topic; after completion of the task, I modify it and give them suggestions to avoid the mistakes*." (T2)

Teacher T3 shifted away from traditional lecture-based instruction, instead promoting student interaction and collaboration in the classroom. He emphasizes an interactive and student-centered teaching approach.

I restrict note preparation and involve the students in classroom communication, giving focus on practical work rather than theory. Teacher and student, according to their mental level, focus on activity-based teaching, arrange group discussion in the class, and divide the lesson into parts. (T3)

Similarly, T10 also emphasized the significance of utilizing digital tool and interactive activities to boost student engagement. Further, he described the role of technology in promoting activity-based learning. "*I use activity-based learning in the classroom. I also use different software for easily designing different tables and charts.*" (T10)

PD has also motivated teachers to embrace problem-solving and conceptual learning techniques that emphasize student engagement. For instance, CS teacher T7 point out that PD redirected focus toward conceptual learning and student participation. "*After PD program I give much focus on students' activity-based learning and work on their conceptual thinking. Group activities and problem-solving methods adopted in the class.*" (T7)

A balanced approach that incorporates lectures, hands-on activities, and case studies offer real-world relevance to the lessons, Such as Teacher T9 response emphasize the significance of merging traditional lectures with practical applications. "*I use in IT class is typically a combination of lectures, hands-on practical exercises, and real-world case studies. I aim to create an interactive learning environment where students can apply theoretical knowledge to practical situations.*" (T9)

Collaboration among CS Teachers and Other Subject Teachers

Promoting School Interdisciplinary Collaboration for Improving Learning Environment

Collaboration among teachers is an important element of effective PD. Furthermore, Collaboration between CS teachers and other teachers within a school is vital for creating a well-rounded and technology-enhanced learning environment. The researcher asked the respondents if they could be engaged in any school-related activities inside

the school to enhance the teaching and learning process. The respondents work with teaching staff to prepare lesson plans and participate in weekly meetings with the head teacher to discuss institution, student, course completion, timetable, and best practice. For instance, teacher T9 highlights the administrative role that CS teachers often undertake, demonstrating how interdisciplinary collaboration extends the institutional tasks that support a well-organized learning environment. *"I collaborate with my teaching staff by writing different letters, preparedness of lesson plans and handling other official institute tasks."* (T9)

CS teacher T1 identified that interdisciplinary collaboration helps to refine educational policies and teaching strategies. *"We actively participate in weekly basis meetings at school along with the head teacher; in this meeting, we discuss different issues regarding our institution for a better learning environment."(T1)*

Further, T4 underscored the structure approach taken by school to address educational and administrative matters systematically, reinforcing the significance of interdisciplinary school collaboration in maintaining a well-organized learning environment. "*We conduct meetings weekly, monthly, and on an emergency basis in our school. In these meetings, we discuss different issues about the school, students, teaching staff, course completion, timetables and debate programs.* (T4)

T8 emphasized that "*We collaborate best practices in the teaching-learning process and discuss outcomes, time management and emotional support of new teachers.*" (T8)

Beyond School Collaboration

Collaboration between computer teachers and other schools is important as it promotes peer learning, teamwork, problem-solving, sharing experiences and resources. CS teacher identified that due to beyond collaboration their teaching skills, methodologies and practices were improved. The participants' responses revealed that participation in joint workshops and conferences improved their teaching experiences and communication skills that directly affect the teaching-learning process. For example, T9 identified the importance of beyond school collaboration in improving teaching skills.

I collaborate with other school teachers, which has improved my teaching skills and practices. It also provides a lot of opportunities to me and other CS teachers to interact and communicate with each other's and share our opinions and expertise. (T9)

T5 emphasizes *"Yes, I know collaboration with other schools is very important for me. I always participate in different activities such workshops, lesson planning sessions and also discuss teaching strategies. It enhanced my teaching effectiveness, which directly help in students' learning outcomes."* (T5)

T3 emphasize the joint benefits of collaboration, where both teacher and institutions thrive through the exchange of experts. *"I gain valuable knowledge, skills, and attitudes from partner institutions, contributing to mutual growth and development." (T3)*

Further, teacher T6 identified the role of beyond collaboration PD in refining teacher methodologies. Engaging in structured activities with peers from different institutions broadens pedagogical knowledge and fosters a more effective classroom. *"I participate in PD workshops, joint projects, and conferences regarding teacher development programs, which enhanced my methodological skills. Furthermore, collaboration with teachers enhances my teaching experience and promotes an effective teaching-learning environment." (T6)*

General Discussion

Improving PD and teacher support: insights from correlational analysis

The results from the analysis found that SE has a significant positive correlation with PD. This means that PD enables CS teachers to observe the student engagement as they apply newly learned teaching strategies, which can increase their SE beliefs. The results in this regard are partially consistent with those of Hall (2008), who also found a significant relationship between self-efficacy and PD. However, Guo et al. (2011) indicated that teachers' self-efficacy beliefs have received less attention in teacher education and professional development. The reason for these differences may be that PD provides new knowledge, teaching methods, and skills that can increase CS teachers' confidence in their ability to teach effectively and support students' learning. This emphasize that PD should include the opportunities for CS teachers to innovate teaching strategies and observe their positive impact on student engagement in order to enhance their self-efficacy.

The researchers also found that JS has a significant positive effect on SE. This means that when the CS teachers are satisfied with their job, their SE increases accordingly and they are able to teach their students comprehensively. However, the findings of the current study are not supporting other empirical evidence. For example, Viel-Ruma et al. (2010) indicated in their findings that there was no significant relationship between TJS and collective efficacy. This finding confirms previous research Skaalvik and Skaalvik (2010), which suggested that JS is positively related to teachers' SE. A one possible explanation could be a supportive working environment among the CS teachers. Another possible explanation could be professional development opportunities for CS teachers. These two factors may increase their confidence in teaching and improve their ability to effectively teach the subject.

Moreover, results from the findings revealed that TP is positively correlated with PD. In other words, PD provided CS teachers with advanced strategies, CS knowledge and tools that enhanced their teaching practices. This finding is aligned with previous research of Gheith and Aljaberi (2018), which asserted that TP related to PD were found to exhibit a strong positive correlation with teachers' engagement in reflective practices. The reason for this could be that PD provides updated CS knowledge, innovative methods and opportunities for skill enhancement, empowering them to improve their teaching practices. The implementation of good teaching techniques could potentially improve their confidence, knowledge and skills. In term of CS-TTP was positively correlated with SE. This positive correlation indicates that, through effective teaching strategies and methods, CS teachers can improve their teaching practices, and as a result they are able to manage and deliver the lesson successfully and gain more confidence. This finding is in harmony with that of Topkaya (2016), who concluded that the TP course had a positive effect on the SE of pre-service social studies teachers. The difference between the current study and the study conducted by Topkaya (2016) is that the current study's focus is on CS teachers TTP and SE, while the previous study focuses on TP and SE of in service social study teachers. The reason of this positive correlation could be that CS teachers teaching practices abilities and confidence provide them with the opportunities to involve their students in classroom activities and achieve the possible learning outcomes.

Furthermore, in terms of gender, the results revealed a significant negative correlation between CS teachers and their participation in PD. It shows that the majority of the female CS teachers have not participated in PD program. For example, in STEM, gender equity in PD often lacks the important factors necessary to effectively promote and implement equity (Battey et al., 2007). Furthermore, significant divergences in gendered motives, conditions, and outcomes of PD have been observed at the university level (Tsymbaliuk et al., 2020). The negative correlation between gender and PD may be due to social dispositions, cultural norms, and societal expectations that disadvantage certain gender, leading to pay differentials and unequal family responsibilities.

Additionally, the current results indicated that the age of CS teachers' has a significant negative correlation with PD, SE, and TP. This significant negative correlation indicates that as CS teachers' age increases, their participation in PD,

confidence in their teaching abilities and adaptation of effective teaching practices decreases. For example, studies suggest that the age of teachers has no significant effect on PD (Tanang & Abu, 2014). Due to their limited exposure to pedagogical development and technology, older teachers may exhibit lower levels of SE beliefs and fewer PD opportunities. The negative relationship between age and PD may also be exacerbated by their adherence to outdated teaching methods that do not keep pace with the rapidly evolving needs of the CS field.

Exploring the mediating processes: the impact of PD on the TP, SE and JS among CS teachers

Concerning the mediation analysis, the results suggest that PD has a notably positive impact on TP and SE. PD positively impacts SE and TP among CS teachers by increasing confidence, improving skills, and providing networking opportunities, as well as emphasizing relevancy, which in turn improves PD networking and collaboration. For instance, PD programs improve teachers' knowledge, skills, and attitudes (Gabriel et al., 2011). Similarly, Zhou et al. (2020) conducted a nine-week PD program, and the results of their study indicated that the program significantly enhanced the SE of CS teachers in pedagogical content knowledge. Consistent with Zhou et al. (2020), a well-structured PD initiative carried out by Nugent et al. (2022) led to an increase in SE among K-8 CS teachers. The difference between the current study and Zhou et al. 2020) is that in the current study, the main focus is on that CT teacher PD, SE and TP applying mediation analysis, while the previous study focused on the CS teachers SE in content knowledge and pedagogical knowledge. However, the researcher found that PD did not have a significant impact on CS teachers' JS. This indicates that CS teachers were not satisfied with their job after participating in the PD program. However, this finding is inconsistent with previous research (Song and Mustafa 2015), which found a positive relationship between PD and JS. Furthermore, teachers who participated in PD activities tend to experience enhanced JS, improved their skills, and increased their overall satisfaction levels (McGill et al. 2021). The lack of significant impact in our study may be attributed to the possibility that if CS teachers are not actively involved in the PD programs offered, they may not reap the intended benefits. Further, Lack of interest, motivation or commitment and low salary may reduce the effectiveness of PD programs on JS.

The mediating role of SE

The researchers also found that SE significantly and positively predicted their JS and TP. This means that CS teachers' with higher SE are more likely to have higher JS and use more effective TP. In line with this, several studies have found a positive relationship between SE and various measures of teacher performance, such as JS and TP (Toropova et al., 2021; Subramaniam et al., 2023). The main difference is that in the current study, the researcher investigated the relationship of CS-SE with JS and TP, while the latter studies only focus on JS and TP. However, Vettori et al. (2022) found that there is no significant relationship between SE and JS. This could be that when CS teachers have confidence in their ability to engage students, employ effective teaching strategies, and manage their classroom competently, they tend to experience greater JS and demonstrate improved TP.

The mediating role of JS

The results found that the JS of CS teachers does not predict their TP. The JS of CS teachers' is influenced by external factors such as benefits, salary, and administrative support that do not directly impact the daily instructional decisions in their TP. Nevertheless, the current finding is not consistent with the previous studies. For example, Huang et al. (2013) found that teacher JS has a significant positive effect on teaching quality assurance and teaching effectiveness. This positive and significant difference is due to the setting and sample of the study. For example, Huang conducted their study in a college setting with a total sample of 201. Another potential reason for this significant difference is that Huang collected the data from two different colleges, such as technical and vocational

colleges. However, the sample for the current study is taken from one specific region. Therefore, the results of the current study and the results of their study are not consistent with each other.

Chain mediating effect of SE and JS

We examined additional potential chain-mediated models and, surprisingly, identified only one significant indirect effect. This effect was observed in the pathway involving PD, SE, and TP. This suggests that CS-SE plays an important role in mediating the impact of PD on TP. This finding was corroborated by the study of Lin et al. (2022), who found that teacher SE acted as a mediator for the effects of transformational leadership and growth mindset on professional attitudes and TP. Similarly, Noben et al. (2021) reported that a PD program designed for college-level teachers led to a significant increase in SE beliefs, which in turn shaped their conceptions of teaching. The main difference between the previous study of Noben et al (2021) and the current study is that, the previous study conducted at college level, while the current study investigated the CS teachers at middle, secondary and higher secondary schools. However, no significant indirect effects were found in the pathway from PD to JS and TP. This means that CS teachers' participation in the PD program does not increase their JS and does not improve their practices. The results found that direct relationship between PD and TP. In other words, PD influences the TP without being meditated on by JS. To improve their TP as a result of PD indicates that CS teachers do not need to increase JS. A possible explanation for this finding is that CS teachers may be motivated by other factors such as student learning, personal growth, and a sense of responsibility. Nevertheless, the current result does not support the previous study by Berhanu (2023), who found a significant and positive relationship between teachers PD, JS, and classroom performance. Furthermore, no significant indirect effect was found on the path from PD to SE to JS to TP. In other words, the absence of significant indirect effects suggests that JS and SE, as combined mediators, do not play a substantial role in the relationship between PD and TP. The reason for this may be that CS teachers can adapt new knowledge and skills to TP through the PD program, regardless of their SE or JS. Also, the study may have a sample size or population of CS teachers that may reduce the power to detect significant indirect effects.

Effective professional development for CS teachers

CS Content Focus

The results revealed that content focus is a crucial component of effective PD for CS teachers. In other words, CS teachers' participation in PD programs leads to notable improvements in their subject knowledge, and instructional strategies. These programs emphasize the practical applications of computer technology and the effective use of various resources, such as software, textbooks, online platforms, and real-world examples. Utilizing these resources during instruction enhances students' understanding of IT concepts and improves their ability to acquire practical knowledge, ultimately fostering more effective and engaging learning experiences. One possible reason for this effect may be that PD programs provide structured opportunities for CS teachers to engage in continuous learning, which enhances their subject knowledge, instructional strategies and ability to effectively integrate technology and resources into their teaching. The current findings align with those of Ingvarson et al. (2005), who found that content focus significantly affects teachers' knowledge and practices. The difference between the literature and the current study arises from the context and methodological approach. For example, Ingvarson's conducted a large-scale quantitative study within the framework of the Australian Government Quality Teacher Programme, focusing on a broad range of teachers across multiple regions. In contract, the current study employed a qualitative approach, exploring the experiences of CS teachers from one specific region.

Active Learning towards CS teachers' Teaching Practice

The results of the study revealed that active learning has the potential to enhance CS teachers' skills and students learning outcomes. More specifically, active learning for CS teachers has significantly improved lesson planning skills, which encompass defining learning objectives, structuring plans, and incorporating lectures, discussions, group activities, and assessments for comprehensive learning. This approach creates a better learning environment in the classroom by engaging students in various practical activities. One possible reason for these improvements is that PD provides CS teachers with hands-on-experiences and continuous engagement with interactive teaching strategies. Through this process, teachers develop a deeper understanding of instructional strategies, enabling them to implement more effective lesson plans that foster student engagement. These findings align with previous results, which indicated that PD includes opportunities for active learning by enhancing teachers' knowledge and skills, (Hastings, 2024), and transforming classroom practices by employing communicative activities (Tareen et al., 2022). Fundamentally, these communicative activities maximize opportunities for group discussion collaborative dialogue. Furthermore, Birman et al. (2000) stated that active learning within PD provides teachers to observe instructional practices, receive feedback through peer observation, implement lesson plans in real classroom settings, and evaluate instructional outcomes to enhance teaching effectiveness.

Collaboration among CS Teachers and other Subjects' Teachers

The findings of the current study revealed that collaboration among CS teachers is an important element of effective PD, contributing to a successful school environment and enhancing teachers' teaching abilities, techniques, and practices. More specifically, interdisciplinary collaboration among CS teachers within schools involves teamwork, participation in meetings, and building relationships with other teaching and non-teaching staff. This creates a productive environment for both teachers and students. For example, the CS teachers noted that Beyond School collaborating improves their pedagogical experiences and communication skills, which directly impacts the teaching and learning process. In line with these findings, several studies have found that collaboration activities assist teachers to learn from one another's experiences. Such interaction provide opportunities for teachers to exchange information on instructional practices, identify areas for improvement, and solve problems collectively (Carrillo & Flores, 2020; Carrillo & Flores, 2022). Additionally, Vangrieken et al. (2017) stated that learning opportunities related to collaboration among teachers improve instructional practices and enhance students' understanding of school organization. Furthermore, Durksen et al. (2017) described that during collaboration, teachers have the opportunity to encourage one another by sharing practices, helping each other with feedback and collaboratively creating innovative teaching materials. These findings suggest that collaboration not only enhances individual teaching abilities but also contributes a cohesive and supportive school environment, ultimately benefiting both teachers and students.

Conclusion and implications

This study employs a mixed methods research design to investigate how PD effectively improves the TP of in-service CS teachers in Pakistan. It integrates quantitative and qualitative data collection and analysis techniques to comprehensively explore the research topic.

For study 1, the aim was to explore the relationship between PD, SE, JS, and TP of in-service CS teachers. The findings indicate that engagement in PD programs not only positively impacts teachers' confidence and beliefs but also significantly enhances their SE in lesson delivery. However, the study did not identify a direct relationship between PD and JS. Furthermore, the result reveals a direct positive relationship between in-service CS teacher SE and their TP. This relationship strengthens confidence and improves their instructional methods.

For study 2, the aim was to identify the effective elements of in-service CS teachers' PD regarding teaching practice. Results revealed that PD improved teachers' knowledge and enhanced their understanding of CS concepts, teaching

methodologies, and the practical application of resources. Active learning was also identified as a crucial element of effective PD. In-service teachers emphasized that a well-designed PD program equipped them with the skills to create structured, purposeful lesson plans and incorporate diverse teaching methods to engage students. Teachers reported that PD positively influenced their ability to design effective learning environments. Collaboration was also identified as a vital element of effective PD. CS teachers emphasized the value of collaborating with colleagues to share best practices, address instructional challenges, and collectively improve the teaching-learning process. Collaboration across the school, especially with other school teachers, was emphasized as a means of promoting their different kinds of skills that help in creating a foster learning environment.

Implications

Based on the findings of the study, several practical implication can be drawn for policymakers, CS teachers, and students. These implications highlight the importance of early exposure to in-service CS, targeted PD, and enhanced teaching methods to improve TP. Primarily, making CS a compulsory subject from primary through secondary education ensures that students progressively develop computational thinking, problem-solving, and digital skills. Early exposure also allows teachers to implement developmentally appropriate instructional strategies and scaffold learning more effectively. Second, to motivate teachers' engagement and satisfaction with PD, participation should be tied to tangible benefits, such as salary increases, certifications, or promotional opportunities, thus encouraging consistent application of new teaching methods and long-term professional growth. Third, for PD to translate into improved practice, schools must be equipped with computers, internet, and teaching resources. Without these, teachers are limited in applying hands-on, student-centered techniques learned through PD programs. Fourth, teachers should be encouraged to stay updated with emerging technologies and pedagogical approaches. Regular engagement in PD fosters a culture of innovation in teaching practice and ensures relevance to student needs. Fifth, PD should equip teachers to adopt strategies such as flipped classrooms, activity-based learning, and project-based approaches. These shift the classroom focus from teacher-led instruction to student engagement and exploration. Finally, lessons that include real-life applications, collaborative tasks, and discussions deepen conceptual understanding and encourage students’ active participation enhancing the overall quality of instruction.

Limitations and Recommendations

In this study, the researchers acknowledge some limitations that should be considered when interpreting its findings. First, this study does not explore other factors such as school climate, feedback, school digital facilities, leadership support, and teaching in diverse environments. While these factors could play a significant role in shaping the effectiveness of PD programs, they were not examined in this research. Second, this study does not explore in-service CS teachers across educational levels, including primary schools and higher education institutions (e.g., college and university). This narrow focus restricts the broader applicability of the findings to other educational contexts. Third, this study does not fully explore the unique challenges faced by in-service CS teachers regarding PD. These challenges include limited access to updated training programs and coaching opportunities. Fourth, this study was conducted over a short timeframe, which limits understanding of the long-term effects of PD programs. The limited duration makes it difficult to determine whether the observed impacts on teachers’ teaching practices are sustained over time.

To address the limitations and build on its findings, several recommendations are proposed for future research. First, future studies should explore the direct influence of PD on JS among in-service CS teachers. Understanding this relationship could provide valuable insights for designing PD programs that not only enhance teaching practices but also improve teachers’ overall JS and well-being. Second, future research should explore the influence of school climate, feedback mechanism, school digital facilities, leadership support and teaching in diverse environments on

the effectiveness of PD programs. Examining these factors could provide insight into how different school settings and instructional challenges impact teachers' ability to implement new teaching strategies. Third, to enhance the generalizability of findings, future studies should include a larger and more diverse sample of in-service CS teachers and students across multiple schools and regions. A more representative sample would provide a clearer understanding of how PD programs impact teachers and students in varied educational settings. Fourth, future studies should examine the long-term effects of PD programs. Conducting longitudinal research could provide deeper insights into how these programs influence teachers' practices. Fifth, future research should examine in-service CS teachers at different educational levels, including primary level schools and higher education institutions. Understanding the unique PD needs for teachers across various academic stage could help tailor training programs to better support teachers working with students different age groups and learning abilities. Finally, future research should examine the barriers faced by in-service CS teachers in greater depth to design more targeted and effective PD interventions.

Declarations

Ethical approval

Ethical approval for this study was obtained by the Institutional Review Board (IRB) at Shaanxi Normal University (Approval No. LB430009). All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The approval was granted on 14th December 2022. All research procedures were performed following the guidelines and regulations outlined by the approving body.

Data availability statement

The data used in this study are currently analyzed as part of a doctoral thesis, the dataset will be available from the corresponding author upon reasonable after the competition of the dissertation.

Informed Consent Statement

Written informed consent was obtained from all participating teachers prior to data collection, which took place between 18 December 2022 and 20 January 2023. Each participant was provided with a consent form outlining the purpose of the study, the voluntary nature of participation, assurances of confidentiality, and the right to withdraw at any time without penalty. To indicate their agreement, participants were required to check a box stating, "I agree to participate in the study," and sign the form before taking part.

No data were collected from minors or vulnerable populations. No contradictory ethical statements are included in this manuscript

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Figures

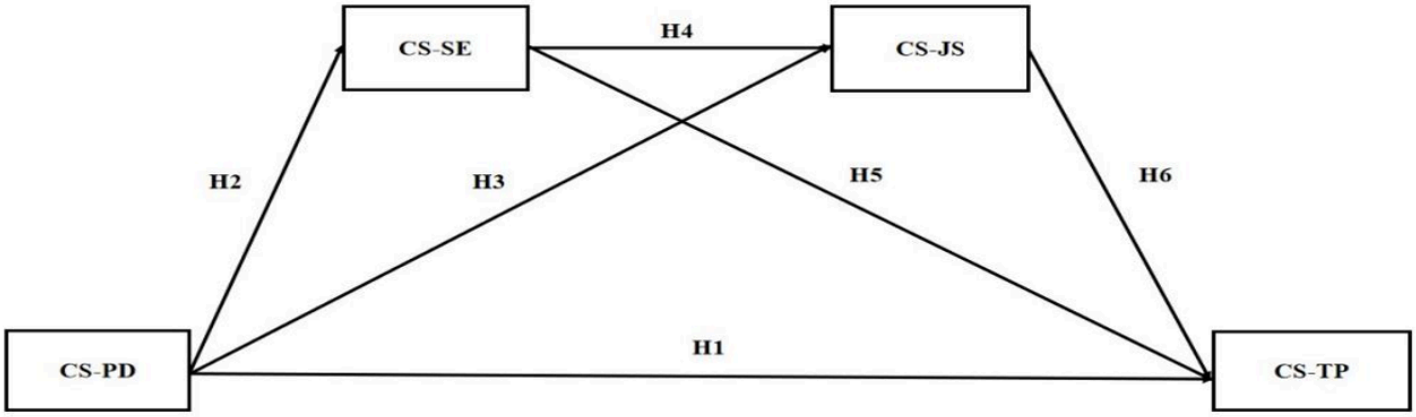


Figure 1

Diagram of the chain mediation hypothesis model

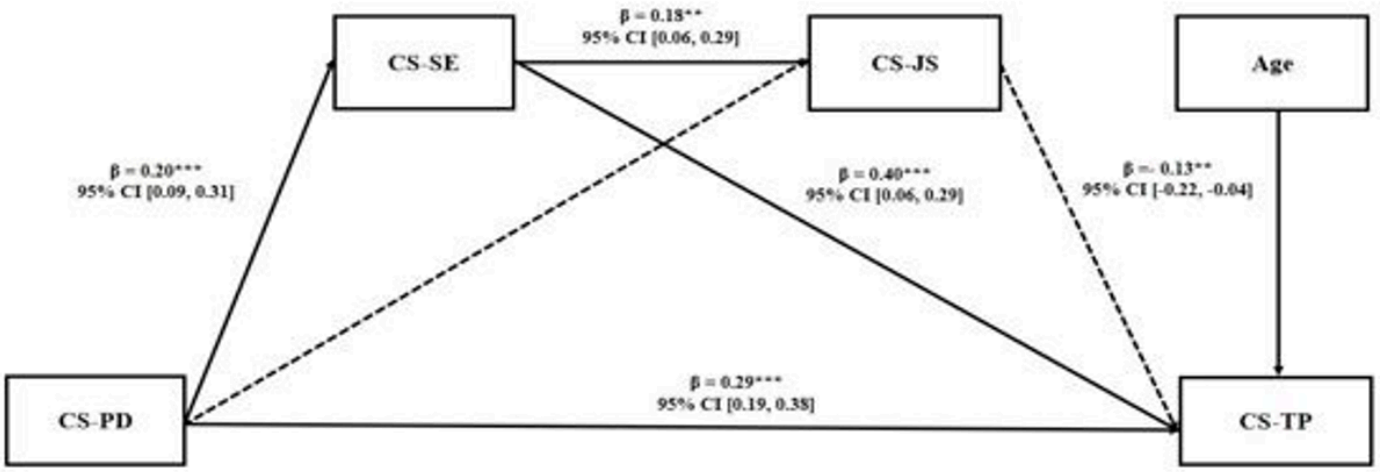


Figure 2

Mediation analysis with path coefficients

Note: A solid arrow signifies a significant path, while a dashed arrow indicates a non-significant path. CI stands for confidence interval ($^{*}p < .05$ and $^{**}p < .01$).