Classifying the Characteristics of Effective Continuing Professional Development (CPD) for Computer Science Teachers in the 16-18 Sector

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As technology and curricula continue to evolve and develop, the prevalence and effectiveness of continuing professional development (CPD) opportunities for computer science teachers is becoming increasingly more important. However, key questions remain about what the characteristics are for effective CPD in this context. Through the presentation of existing literature and the qualitative analysis of interviews with 32 employees from 13 English colleges (n = 14 computer science lecturers, 10 course leaders, and 8 members of senior leadership) this article answers the following question: 'What are the characteristics of effective continuing professional development for computer science teachers in the 16-18 sector?' Existing literature indicates how CPD benefits from: (1) knowledge development and application to classroom teaching, (2) self-efficacy development and measurement, (3) observation, feedback and reflection, (4) collaboration and communities of practice, (5) sufficient time, and (6) institution support. Meanwhile, the thematic analysis of interview data led to the creation of five overarching themes: (1) computer science CPD should address various knowledge domains, (2) CPD requires institutional support, (3) CPD should be engaging, (4) computer science CPD should involve a combination of activities, and (5) CPD should be measurable. This qualitative article also presents interview excerpts and contributes to computing education research and practice by presenting a set of thirty guidelines which outlines the characteristics of effective CPD in the context of computer science teachers in the 16-18 sector. These guidelines could be beneficial for both CPD providers and educators in ensuring CPD opportunities are designed more effectively, and with an understanding of both parties' needs.

CCS Concepts: • **Social and professional topics** → **Computer science education**.

Additional Key Words and Phrases: Continuing Professional Development, CPD, Teacher Professional Development, Computer Science, Computing Education

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1 INTRODUCTION

1.1 Lack of Teacher Knowledge

Multi-country reports of computer science (CS) education have identified a shortfall of suitably qualified teachers for teaching CS to K-12 students [96, 99]. For England in particular, there are

A smaller scale preliminary version of this study was presented at the 2020 International Conference on Computational Science and Computational Intelligence in December 2020, which presented the findings from 13 interviews with college course leaders or equivalent. See [1].
It should be noted that this study formed part of a larger study investigating the perspectives of college employees regarding computer science teaching, where this article presents the findings explicitly relating to CPD.
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reports of general teacher recruitment challenges [4], and for computing related subjects, this recruitment problem is challenging [16, 65]. Within England, CS graduates can earn substantially more outside the teaching profession [26, 63], and so there are concerns recruitment issues for CS teachers will worsen if support is not put in place [92]. According to England's Department for Education (DfE) teacher recruitment and retention strategy, retaining early career teachers has been getting worse with over 20% of new teachers leaving the profession within 2 years and 33% leaving within their first 5 years [29].

A students' computing education depends on the skills and competences of those teaching them which includes both teacher subject knowledge and pedagogical approaches used [61, 75, 96, 98]. However, fewer teachers entering the profession can cause problems for existing teachers as they may have to teach areas they are not knowledgeable in [69]. Therefore, those teaching CS may not always have the right expertise to do so effectively [16, 96]. This is exemplified in the work by Yadav et al who explains how beginning CS teachers may lack the experience or ability to explore concepts in depth [99]. This lack of knowledge is a key issue, and addressing this is crucial for the future of CS education.

1.2 Teacher Knowledge Theory

Early history of teacher education predominantly focused on a teachers knowledge of content (content knowledge; CK), but later, there was a change to focus on one's ability to teach (pedagogical knowledge; PK). Following this, Shulman highlighted a missing paradigm described as pedagogical content knowledge (PCK) [87]. Shulman described PCK as going beyond the subject matter to the dimension of the subject matter knowledge for teaching. PCK includes understanding what makes a subject difficult for students, the preconceptions students bring, and what strategies are most likely to be applicable to learners [87]. Armoni further described PCK in their examination of research on teacher education as including knowledge of environmental contexts and knowledge of students, and concluded CS teacher preparation should cover all types of knowledge [2].

Different types of knowledge have been highlighted as important for CS teachers to develop and feel confident with [61, 85, 98]. However, developing these different types of knowledge has been suggested as a challenge for CS teachers internationally [38]. The recruitment difficulties for sufficiently qualified individuals and the rate of change of the subject matter for CS has resulted in a lack of individuals with the up to date knowledge to effectively teach CS. For instance, in their paper on understanding CS teacher experiences and challenges, Yadav et al explain how there can be teachers with a formal teaching background (and so have PK), but lack the CS CK needed to teach CS [99]. Within their study, they highlighted how there were teachers who may have programming experience (i.e. CK), but do not have a teaching background (i.e. PK) [99].

1.3 The Problem and Potential Solution

Within England, there are recruitment difficulties for CS teachers, while those teaching CS may lack in certain knowledge areas. Hence, with technology changing rapidly, and the UK lagging behind other countries regarding technical expertise and digital capability [47], it is imperative CS teachers have more skills training and to develop confidence in teaching [16, 31, 84]. A major approach to support CS teachers is through effective continuing professional development (CPD) [93]. Guskey described CPD as a central component for improving education [41], while the DfE has characterised CPD as a core part of securing effective teaching [28], which should continue throughout an individual's career [30]. Furthermore, the Office for Standards in Education (Ofsted), a non-ministerial department of the UK government which regulates the standards of education, has indicated the quality and quantity of CPD can aid effectiveness and improvement within education

and positively impact pupils learning outcomes [69]. Hence, the different approaches to CPD is an important area for future research [96].

The call for CPD research is greater in the English further education (FE) sector, which consists of a variety of institutions and training providers that primarily offer post-16 level three education or skills training. Level three refers to qualifications at the third level of the Regulated Qualifications Framework (RQF) that has been in use since 2015 for England, Wales and Northern Ireland to help people understand how qualifications relate to each other. RQF level three is equivalent to level four of the European Qualifications Framework (EQF) [48]. Despite the breadth of qualifications those in the FE sector provide, Ofsted explains how there has been a relative paucity on research in this sector [69]. Meanwhile, the Augar Review of Post-18 education and funding detailed how there is less data and research available regarding colleges (the predominant FE provider [89]), relative to schools and higher education institutions [6]. It should be noted that colleges in an English context refer to educational institutions within the FE sector, that predominantly focus on the two years of compulsory education for those aged 16-18 (RQF level three), and hence, are different to the American term of college.

The lack of research on the FE sector is surprising given the FE sector has been subject to major changes in recent years [17], and has been highlighted as playing a pivotal role by the English government in developing the next generation of employees with the right computing and digital skills for the future [30, 47]. Furthermore, there are calls to support the performance of FE lecturers [88], and so effective CPD for CS teachers can help achieve these goals. However, the subject specialist elements of initial teacher training for FE lecturers has been weak [72], there are recruitment difficulties [5, 30], and there are challenges preventing CS teachers taking part in CPD such as a lack of funding [4, 14], a lack of time [92], and a heavy workload [72]. Consequently, Greatbatch and Tate state research regarding CPD in the FE sector would be helpful [39].

1.4 Research Question and Objectives

Based on the context provided, this article will aim to answer the following research question:

> *What are the characteristics of effective continuing professional development for computer science teachers in the 16-18 sector?*

To answer this research question effectively, this article will first conceptualise what is meant by CPD and investigate the characteristics of CPD deemed effective for CS teachers in existing literature. Next, this article will detail the method used for the primary research, which was to examine the perceptions of CS teachers and senior leaders within English colleges in relation to the characteristics of effective CPD for CS. This was achieved through interviewing employees (n=32) from colleges (n=13) in the South West of England. After the method is outlined, the findings from the interviews will be presented. Finally, a set of guidelines will be provided which outline the characteristics of effective CPD in the context of CS teachers in the 16-18 sector, that is informed by both literature and the primary research.

It should be noted that this article is not investigating particular topic areas for development, nor is it trying to identify what teachers do or do not know, as knowledge development is just one potential CPD outcome [45]. Instead, it is looking to identify what the characteristics are for effective CS teacher CPD in the 16-18 sector, and particularly for colleges within the English FE sector.

2 CONCEPTUALISING CPD

CPD in education has been described as ill-defined, with the perception that CPD is limited to attending courses and conferences [82]. Kennedy further argues that literature on teacher CPD

is fragmented and under-theorised and highlights that while CPD as a term has common global currency, other terms are frequently used in its place such as teacher professional learning [51]. Life-long learning is another term synonymous with CPD, which is the means by which people maintain the skills and knowledge related to their professionalism [19]. Due to the ambiguity surrounding the term, for this article, the initial definition of CPD is adopted from Guskey [41], who outlines CPD as including the following:

> 'Professional development programs are systematic efforts to bring about change in the classroom practices of teachers, in their attitudes and beliefs, and in the learning outcomes of students.' [41, p. 381]

The above quote draws attention to the aims of CPD, which link to measuring the outcomes, or impacts of CPD. Early work by Harland and Kinder created a typology of nine CPD outcomes including materials, informational outcomes, new awareness, value congruence, affective outcomes (e.g. increased confidence), motivation and attitude, knowledge and skills (e.g. CK, PK), institutional outcomes, and impact on practice [45]. They argue teachers have a unique 'outcome route' for when they participate in CPD, where they develop the aformentioned outcomes in different ways [45]. However, Collin, Van der Heijden, and Lewis allude to how CPD should take place continuously as it is a process as well as an outcome, which can include formal and informal practices [19]. Under this conceptualisation, CPD can consist of attending workshops, courses and conferences, observation, peer support/learning, receiving external support, action research, and collaboration [82]. Furthermore, as is the case with CPD documentation from the DfE (e.g. [28]), for this article, CPD should be seen as synonymous with terms such as teacher professional learning, in-service training, lifelong learning, and professional development.

3 RELATED WORK: CHARACTERISTICS OF EFFECTIVE CPD FOR CS TEACHERS

International reviews into effective CPD have found no single activity is universally effective, where effectiveness depends on several characteristics [23]. Some authors have tried to contextualise what is considered as good practice for teacher education and CPD internationally. For instance, Darling-Hammond examines teacher education practices and policies within Australia, Canada, Finland, Singapore and the United States [25]. Through this cross-examination, the following strategies were highlighted as promising for effective teacher education generally [25]:

- Financial subsidies for training
- Connecting theory and practice
- Use of professional teaching standards
- Connect learning to classroom teaching
- Support beginning teachers through mentoring
- Reduce teaching loads to allow time for in-service training
- Opportunities for teachers to learn with and from one another
- Sharing of research and good practice

Meanwhile, in the specific context of England, the DfE identify five standards for teacher CPD including [28]:

- A focus on improving and evaluating pupil outcomes
- Underpinned by robust evidence and expertise
- Include collaboration and expert challenge
- CPD programmes should be sustained over time
- Being prioritised by school leadership

Despite literature that exists for CPD generally, CS is continually evolving and so educators in this area must adapt their knowledge and teaching practices at a faster rate compared to other subjects to provide effective computing education [37, 91]. Therefore, a focus on CPD for CS teachers has risen to prominence amongst the CS education research community. For example, panel discussions on the subject are becoming a regular occurrence at major conferences such as SIGCSE (see [36, 49, 50]). Given the importance of CS CPD, this section will outline existing work under this context, but relate this work to those characteristics identified by both Darling-Hammond [25] and the DfE [28]. However, first this section will outline three papers which indicate a wide variety of characteristics deemed relevant for CS CPD.

Based in the US, Milliken, Cody, and Barnes discuss the development and delivery of summer professional development workshops as part of their Advanced Placement Computer Science Principles (AP CSP) course [64]. Over six years, the workshops have prepared 748 teachers, and the authors recommend CPD courses for introductory CS courses should have small well specified tasks, include reflection and discussion, classroom practice regarding programming, discussion with more experienced peers, and collaborative work [64]. Some of these factors are discussed within the CS Teachers Association (CSTA) third version of their rubric for professional development which is used to accredit US CPD programmes [37]. Hence, this serves as a good tool to utilise when considering characteristics that have been shown to be important for CS CPD. These areas include: active learning, efficacy, differentiation, equity (accessibility and inclusivity), ongoing support, collaboration, content focus, models and modeling, feedback and reflection, and sustained duration [37]. Another US based paper presents the secondary analysis of 14 instruments from 29 CPD providers and found the following aspects to be important for CS teacher CPD: development of CK and PCK, fostering a teacher mindset which understands student needs, improvement of self-efficacy, interest of teaching CS, ability to understand relevance of content for students, and having a support network [61]. These three papers have all outlined a wide variety of characteristics deemed relevant for CS CPD, and now these factors will be discussed in greater depth and in relation to existing work.

3.1 Knowledge Development and Application to Classroom Teaching

Knowledge can be defined in various ways, and as indicated by both Ryoo, and McGill et al, CS CPD in the US should address CK, PK, PCK, in addition to changes in policy, the sector, employment options, local context and understanding students' needs [61, 83]. This is echoed by studies from all four nations of the UK of Wales [65], Scotland [24], Ireland [35], and England [86], who all suggest that regardless of if you are trying to train existing teachers or recruit new ones, the development of CS subject knowledge (i.e. CK), PK and emerging research and practice must all be prioritised within CS CPD.

In their article discussing the results of a two-year study investigating how teachers used CPD material for teaching the 'Advanced Placement CS Principles' course in the US, Qian et al found experienced CS teachers had limited need for CPD, but novice CS teachers needed CPD for developing PCK [77]. The authors found for non-CS teachers who are planning to teach CS, their CPD needs were more focused on CK [77]. This calls to attention the need for understanding the knowledge and development needs of any teacher partaking in a CPD programme, and tailoring the programme for different teachers as necessary. This assertion is supported by Dong et al, who conducted two week-long CPD workshops for 116 middle and high schools teachers looking to incorporate computational thinking in their classrooms [32]. The authors analysed 58 teacher designed programming projects and through this analysis, they found that better understanding teacher needs can allow for more tailored ways to help them infuse computational thinking and programming into their curricula [32].

The findings from Dong et al [32] illustrates the importance of linking CPD opportunities to what is applicable in the classroom environment, and this factor has been cited as important for CPD generally by the DfE [28], and as important for CS CPD from several authors (see [42, 67, 77, 80, 99]). A specific example of this is in the context of programming, where Basu et al discuss the importance of mapping CPD to the broad challenges and concepts across CS standards, so CPD is applicable to whatever curricula participants are delivering, and the programming language they are teaching [9]. If a CS teacher cannot meet the needs of all their learners, they are unlikely to progress from a novice to an expert teacher [61]. Therefore, it is suggested participants on CPD programmes construct knowledge through meaningful activities as opposed to passively receiving information, where practicing new teaching strategies can ensure teachers can more effectively use the content in the classroom [37].

As a form of CPD, some authors describe the benefits of action research (where teachers conduct small-scale research in their own classes). Brandes and Armoni discuss how CS teachers in Israel used action research, and how sharing this with their peers fostered a process of reflection of their teaching, and an improvement in practice [11, 12]. Meanwhile, in an English context, Sentance et al describes supporting 22 primary and secondary CS teachers in research projects and observed:

> 'Teachers learned a range of new skills in terms of being able to plan and execute a small-scale research project, and their data shows that they gained an understanding of how children learn computing and ways in which deeper learning of computing can be facilitated. This makes it an important approach for computing professional development where teachers can develop an awareness of good pedagogical strategies.' [86, p. 23]

Action research projects and linking CPD to classroom practice can be an effective component of CS CPD. However, this feature is not a new concept (e.g. see [23, 44]). However, given the frequent developments and advancements of CS, this calls for a greater need for action research, examples of good CPD programmes and an understanding of CS teacher needs, particularly in areas where this is lacking such as for CS teachers within the English FE sector.

3.2 Self-Efficacy Development and Measurement

In their paper on teacher change, Ertmer and Ottenbreit-Leftwich discuss how the differences in what a teacher does and what they know relates to their confidence, or self-efficacy in a subject [34]. As described in the popular work of the late psychologist, Albert Bandura, self-efficacy relates to how those with a greater belief in their own abilities are more effective and generally more successful than those who do not [7]. Bandura further explains how mastery experiences (experiences of success) are the most influential source of evidence in building ones self-efficacy [7]. Therefore, CPD that can build a teachers' self-efficacy are likely to lead to more positive applications of what was learnt from CPD into the classroom. Hence, it should come as no surprise there is an emerging corpus of CS CPD research which refer to Bandura and the concept of self-efficacy. For example, Zhou et al introduced, validated, and applied an instrument to measure 59 US high school CS teachers' self-efficacy in CK and PCK for CS [101]. Through their nine-week hybrid CPD programme, teachers significantly improved their self-efficacy in teaching CS. Measuring self-efficacy can be used an evaluation metric for identifying CPD impact, but this is rarely assessed long term [82].

By measuring a teachers' self-efficacy before an initiative and afterwards, it becomes possible to ascertain how much impact CS CPD has on a teacher [61]. Reporting evidence of self-efficacy improvement has been described as a critical practice to ensure CPD meets the goals and needs of the participants involved [37], and by evaluating self-efficacy before an intervention, CPD can

be tailored for different teachers [77, 79]. For example, McInerney, Exton, and Hinchey, attempted to measure self-efficacy development for 107 Irish high school teachers over two years where participants took part in six days of CS CPD provision [62]. The authors wanted to survey subject confidence development to inform future CPD delivery, but only 17 participants completed the surveys at both the beginning and end of the programme [62]. Meanwhile, other authors have conducted self-efficacy surveys to simply gauge teachers confidence in certain topic areas, or to facilitate follow-up studies (e.g. see [57, 94]).

3.3 Observation, Feedback and Reflection

Darling-Hammond discusses how a high proportion of CPD is embedded within educational institutions and makes frequent use of peer-observation and coaching to identify problems and improve teaching practice [25]. Meanwhile, the DfE has indicated how effective CPD includes opportunities for reflection, feedback and evaluation [28]. This has been reported to be the case within the English FE sector, with case study research by Lahiff indicating how post-observation feedback offers a learning space for the development of a teachers' pedagogy [52]. Other authors have indicated how observation is an opportunity for college teachers to obtain feedback on their classroom performance [71]. However, both of these studies report on teaching observation generally, and not in relation to CS teachers.

Literature on CS teacher observation and feedback has been more profound in the US, where it has been highlighted how feedback on performance can help reinforce learning, and identify areas for further practice [37]. Early work by Ni et al [68] describes an academic-year-long programme where high school CS teachers engaged in peer observation of classroom teaching and creating a collaborative portfolio, and the authors found these initiatives led to an increased sense of community, more teacher confidence, and reported plans for a change in teaching practices. Margolis, Ryoo, and Goode support these findings, where in-classroom coaching can help positively impact changes in pedagogy, a teachers CK, and limit feelings of isolation [58].

The related concept of reflection has been discussed as an important component for CS CPD. Internationally, there are authors who describe the importance of reflection in CPD programmes for high school CS teachers in the US [15, 67], Israel [11], Scotland [24], and in England [85]. For instance, Sentance and Csizmadia describe the design and implementation of a certification scheme for in-service Computing teachers, where part of the certification includes reflecting on at least 20 hours of eligible CS CPD [85].

Despite the benefits of observation, feedback and reflection, there is little research exploring these factors in the setting of CS educators within the English FE sector, and whether CS educators find them beneficial. This is an interesting area of research given that studies on English FE colleges have revealed that Ofsted has resulted in observation being viewed as a 'tick box' exercise with a focus on accountability, than on professional development [71]. In fact, one study revealed how 13 out of 18 FE college teachers thought the main aim of observation was for quality control [33].

3.4 Collaboration and Communities of Practice

Collaboration and being involved in communities of practice (CoP) are highlighted characteristics of effective CPD by the DFE [28] and in reviews of international practice [23, 25, 34, 56]. Macia and Garcia reviewed 23 articles related to online communities and networks as a form of CPD and found the main practices include conversations to share experiences, resources and knowledge, providing emotional support, and to develop collective projects [56]. However, a key problem was a gradual lack of teacher engagement over time, the impact on teaching practice is rarely assessed, and that the field of CPD regarding online communities and networks is at a relatively early stage of development, with the review considering multiple subject areas [56].

For CS there is an emerging body of research on the use and benefits of collaboration and CoP, particularly from the US where collaboration and support networks are recommended practices (see [40, 64, 76, 80]). A specific example of this is the experience report of the 'Alice community of practice' for middle and high school teachers regarding the teaching of programming and developing lesson plans [22]. The authors deem the initiative successful, but provide some important recommendations for success. These include having multiple teachers from a single school (or district), having institutional support, choosing the right workshop location, including follow up support and interactions, and teachers forming local CoP [22]. A more recent example is the report of an AI book club where 37 middle school educators took part in a 20 hour CPD programme consisting of a weekly communal experience of discussing selected readings, ongoing asynchronous discussion, and weekly breakout groups to discuss AI [54]. The authors described the model as highly effective to engage and sustain interest in AI literacy and building a CoP, while reiterating the importance of providing time for educators to reflect, and that seeing others struggle meant their own frustrations were eased [54]. Feelings of isolation can negatively impact self-efficacy [61], but CoP can help overcome feelings of isolation and frustration [43, 99]. Meanwhile, a stronger sense of community occurs with face-to-face CPD courses than online ones [79].

It is not just the US where collaboration has been identified as beneficial for CS teachers. In New Zealand, Ott and Meek discuss their experience of pair teaching a first year undergraduate web development course, where CPD is a by-product of self and peer-review [74]. Meanwhile, in Australia, one paper outlines the launch of 'CS in Schools' where volunteer computing professionals are matched with secondary schools teachers to help develop coding skills [97]. Furthermore, in Scotland, Cutts et al discuss their findings and experiences of their teacher professional development network (PLAN C project) for secondary school teachers [24]. They recommend that for the development of effective CS teacher CPD, policy makers require educating in how CS requires both a deep understanding of concepts, subject-specific pedagogy (i.e. PCK), and practical skills [24].

Within England, collaboration and CoP have been highlighted in guides of CPD for teaching and learning in the FE sector [31, 39, 53], and in research papers [52, 90]. However, CS teachers arguably need CoP more than those teaching other subject areas due to CS being such a rapidly evolving subject. For example, survey responses from 115 UK CS teachers indicated many CS teachers have expressed interest in running computing clubs at their schools to aid student learning, but are lacking the support networks for this to be effective [10]. As described by Broad, there are barriers teachers in the FE sector face when attempting to access CPD opportunities, where workload and time constraints are preventing teachers from developing effective CPD networks [14]. Given the known challenges for FE teachers and the lack of research considering collaboration and CoP for CS teachers in FE settings, it would be beneficial to ascertain teachers' views in this area.

3.5 Sufficient Time

Adequate time is required that is free of the pressures of constricted timetables and deadlines for CPD to be effective [23, 28, 52, 71]. This is especially the case for CS teachers, where the evolution of the subject matter calls for a greater frequency on the need to upskill. Moller and Powell discuss the initiative of 'Technoteach', a University-based model for supporting prospective CS teachers in Wales, and they explain how UK teachers are under extreme pressures and attempts to partake in CPD programs on top of teaching commitments inevitably leads to failure [66]. Unlike many summer CPD programs, the Technoteach initiative took place over the academic year, where schools were required to agree to release their teachers for one day a fortnight to partake in the programme [66]. As a model, this has been recommended by Darling-Hammond regarding the reduction of teaching loads to allow for in-service training [25], and because of this, teachers had the opportunity to apply each days learning from the Technoteach CPD almost immediately. While short CPD

programmes can be effective at introducing small topics (and help improve CK), for true change, teachers need opportunities to learn and practice over a period of time [37]. For example, one study which focused on the teaching of programming revealed that for both one-off workshops and online training, teachers were unable to move beyond the exercises to how to deliver programming to their students [42]. In this instance, teachers may have gained some CK but not the PCK to teach what they know effectively, with the authors indicating how teachers would require more time and support to make any lasting changes [42]. Therefore, it is no surprise follow-up support has been highlighted as beneficial for many CS CPD programs (e.g. see [67, 80]). CoP are one example which lend themselves to providing follow-up support, as are using forums [76].

3.6 Institution Support

CPD being prioritised by school leadership has been identified as a key standard for teacher CPD by the DfE [28], and this highlights the importance of having institution support for CPD. Darling-Hammond highlights how this can be in the form of financial subsidies or reducing teaching loads [25]. This has been mentioned in the context of Technoteach [66], and by Cooper et al who highlights the importance of having institution support for CS teachers partaking in CPD [22]. They explain how this includes having support from both a curricula perspective and in ensuring teachers have the sufficient infrastructure in place for any required software [22]. This has been found to be a problem for the CPD programs in the US [79], and in the UK where resource issues have been identified as a key issue for CS [84]. A pertinent report on this matter is the Royal Society report 'After the Reboot: The State of Computing Education in UK Schools and Colleges' which outlines how a lack of support for computing subjects by school and college leaders can influence the resourcing, funding and access to CPD opportunities [92]. For example, Sentance and Csizmadia discuss how despite attempts at making the cost of their certification for UK CS teachers minimal, headteachers are not willing to pay for teachers to take it [85].

Ofsted has indicated how leadership is central to curriculum development and accountability [69], and for effective CS teaching, this includes partaking in CPD. If the leaders within an organisation are not supporting staff to access CPD, it is going to be challenging for staff to do so. However, from an institution perspective within the UK, more localised CPD options are preferred as they require less of a time and financial commitment [16]. However, these have already been described as being less effective than lengthier options with elements of networking with other teachers. Hence, leadership teams should be aware of the benefits and need for CS teachers to undertake CPD, but CPD providers should acknowledge the constraints which institutions face in allowing staff to partake in CPD.

4 METHOD

4.1 Research Design Overview

Many characteristics have been reported as important for CS CPD. However, the majority of literature primarily reports on reported experiences of CPD initiatives, and although the literature review highlighted examples from various countries, a high proportion of these experiences stem from the US. There are reports of the characteristics required for CS CPD in England, but these fail to address the unique context of colleges within the FE sector, that have received less attention and support than schools or higher education institutions [3, 6]. Meanwhile, CPD literature on the FE sector does not have a focus on CS, but given the rapid development of CS as a subject, the importance of CS teacher CPD is more prominent than in other subject areas [37]. Hence, this section will outline the methods utilised to explore the perspectives of CPD for CS teachers in the specific context of English colleges, where a qualitative research design was chosen as this

values people and their perceptions [21]. More specifically, this article reports on the findings from semi-structured interviews with multiple stakeholders (n=32) from colleges (n=13) in the South West of England.

4.2 Study Participants

4.2.1 Researcher Description. The researcher is a white, British, middle-class male under the age of 30 working as a CS lecturer in a UK higher education institution. The researcher has been involved in government funded projects set out to address the UK digital skills gap, with colleges being identified as a key research area. The author has worked with a variety of schools and colleges nationally and has anecdotal experience of the challenges faced by CS lecturers in colleges. The author has undertaken educational research utilising semi-structured interviews with multiple stakeholder groups, and has used computer aided qualitative data analysis software (CAQDAS) such as NVivo. This experience would have influenced and guided the research question, the initial literature search, and the methods used to conduct the research.

4.2.2 Participant Information. Lincoln and Guba argue that to enhance the credibility of what is found, triangulation of evidence should be used [55]. Given this article is looking to ascertain perspectives on the characteristics of effective CPD for CS teachers within colleges, multiple stakeholders were considered from multiple colleges. There are several stakeholders who influence the CPD for CS teachers within colleges, which go beyond those directly involved in the teaching. One of these stakeholders are course leaders (or head of departments), who directly manage a team of CS teachers. They have managerial responsibilities and generally have a reduced teaching load compared to CS lecturers. The other key stakeholders are members of senior leadership (higher in the hierarchy than course leaders) who would dictate the overall college strategy and budget, and hence, opportunities for CPD as indicated in section 3.6: Institution Support. Obtaining multiple perspectives can help counter threats to validity [18, 81], and is a method used successfully in literature which investigates CPD for those working in colleges [71]. In total, 32 employees were interviewed from 10 general FE colleges (GFEC) and 3 sixth form colleges (SFC) across the stakeholders types of lecturers (n=14), course leaders (n=10), and senior leadership (n=8). Further participant information can be found in Table 1. For clarification, GFECs offer a range of education and training opportunities for those aged 14 upwards, and although they primarily offer RQF level three qualifications (consisting of both vocational and academic qualifications), they can offer RQF level two courses, and higher education courses (RQF levels 4-6) [70]. Meanwhile, SFCs typically only offer education for those aged 16-18 (RQF level three qualifications), and predominantly specialise in academic qualifications such as A-Level provision [89].

4.2.3 Researcher–Participant Relationship. Four participants were known to the researcher before the study commenced. For each of these participants, the relationship existed due to the researchers' prior role of where they delivered computing-related workshops and presentations within schools and colleges as an external speaker. While there was no prior knowledge of these participants perspectives regarding CPD, this impacted the research process as the recruitment process differed such as the initial email contact due to already exchanging emails. There were no ethical considerations deemed relevant given the nature of these prior relationships.

4.3 Participant Selection and Recruitment

4.3.1 Focus on the South West. There are over 240 colleges in England, but this study focused on the South West which has 23 colleges in the region. Colleges in the South West have been reported as having the highest staff turnover at almost 20% [4], and they have the highest official vacancy rate in England for teachers [63]. Furthermore, the South West has been reported as having a lack

Table 1. Participant Information and Interview Details

Int ID	Role	Exp (Years)	Gender	Col Type	Col ID	Int Length	Method
1	Senior Leader	16-20	Male	GFEC	8	31 mins	MS Teams
2	Senior Leader	6-10	Male	GFEC	11	45 mins	MS Teams
3	Senior Leader	21+	Male	SFC	2	39 mins	MS Teams
4	Lecturer	6-10	Male	GFEC	5	27 mins	MS Teams
5	Lecturer	21+	Male	GFEC	5	41 mins	MS Teams
6	Lecturer	3-5	Male	GFEC	10	23 mins	MS Teams
7	Lecturer	6-10	Male	GFEC	3	48 mins	Google Meet
8	Course Leader	6-10	Male	GFEC	1	24 mins	MS Teams
9	Course Leader	11-15	Male	GFEC	11	36 mins	MS Teams
10	Lecturer	3-5	Male	GFEC	1	31 mins	MS Teams
11	Course Leader	6-10	Male	SFC	9	22 mins	MS Teams
12	Senior Leader	0-2	Male	GFEC	6	36 mins	MS Teams
13	Senior Leader	0-2	Female	SFC	9	30 mins	MS Teams
14	Course Leader	11-15	Male	GFEC	4	51 mins	MS Teams
15	Senior Leader	16-20	Male	GFEC	4	27 mins	MS Teams
16	Lecturer	21+	Male	GFEC	5	44 mins	MS Teams
17	Course Leader	6-10	Male	GFEC	8	25 mins	MS Teams
18	Lecturer	16-20	Male	SFC	2	31 mins	MS Teams
19	Lecturer	21+	Male	GFEC	13	29 mins	MS Teams
20	Lecturer	3-5	Male	GFEC	5	25 mins	Zoom
21	Course Leader	11-15	Male	GFEC	6	27 mins	MS Teams
22	Senior Leader	16-20	Male	GFEC	1	33 mins	MS Teams
23	Lecturer	6-10	Female	SFC	9	30 mins	MS Teams
24	Lecturer	3-5	Male	SFC	7	25 mins	MS Teams
25	Course Leader	11-15	Male	SFC	2	19 mins	MS Teams
26	Lecturer	6-10	Male	GFEC	1	23 mins	MS Teams
27	Course Leader	16-20	Male	GFEC	12	28 mins	MS Teams
28	Senior Leader	21+	Male	SFC	7	26 mins	MS Teams
29	Lecturer	0-2	Male	GFEC	8	25 mins	MS Teams
30	Course Leader	11-15	Male	SFC	7	33 mins	MS Teams
31	Course Leader	11-15	Male	GFEC	5	29 mins	MS Teams
32	Lecturer	6-10	Male	GFEC	6	56 mins	Telephone

of employers for CS graduates [27]. Hence, this places an increased emphasis on the importance of the skill set and knowledge of the teachers in this region who would be educating students entering the future workforce. Therefore, the first stage of participant selection involved targeting those from colleges in the South West.

4.3.2 Sampling. Based on targeting colleges in the South West, each of the 23 colleges were contacted. Work investigating CPD in colleges has included colleges which varied in size, location and overall profile [1, 71, 72], and this study aimed to replicate this approach. A purposeful sampling strategy enabled the selection of individual participants from each college, in addition to the four known contacts stated. This was conducted through initially contacting participants by identifying their publicly available contact email addresses available from college websites. If this information was not available, generic college email addresses were used to make initial contact with the college. Once contact with a participant was made, a snowball sampling strategy was used to further identify relevant participants. Overall, 20 individuals explained they were not able to accommodate the

research, but seven of these provided details of potential participants. No response was received from 39 individuals, but 40 did agree to take part in the research. However, only 32 were involved in the research, as eight individuals either had a change in circumstances, or they stopped responding to communications. This was not deemed an issue as this sample of 32 participants represented a range of employees across 13 of the 23 colleges in the South West, and saturation was occurring in the data. The recruitment of participants and the subsequent data collection took place virtually between August 2020 and December 2020. However, the sample reflects the lack of gender diversity in CS, with only two participants identifying as female. However, out of those who agreed to participate but did not, there were two who were female. It should be noted how within the CS departments of the sample colleges, seven had no reported female colleagues. Hence, recruiting a more gender-diverse sample in this context was a challenge.

4.3.3 Sample Size Considerations. While 32 participants may be viewed as too small of a sample in quantitative research, for qualitative research, concerns about generalisability and external validity are not as prevalent [18]. Robson and McCartan explain how qualitative research is not meant to be generalisable [81], while Collis and Hussey explain how qualitative research usually results in findings understood only in their specific context, consisting of relatively small samples [20]. Hence, this study provides some detailed findings regarding perspectives of CPD for CS teachers, but under the specific context of employees from colleges in the South West of England. While the results could be transferable elsewhere, caution should be applied in how differing contexts may influence the extent of transferability. However, Bassey contends 'fuzzy generalisations' can be made from studies like this one, where qualitative estimates can be made such as 'it is likely that...' [8]. Therefore, readers are encouraged to consider how the contextual underpinnings of the findings of this article differ to their own institutional and/or political context, and identify where fuzzy generalisations could apply to their own context.

4.4 Data Collection

4.4.1 Data Collection Method. Semi-structured interviews were chosen as the data collection method as they have been used successfully in other studies investigating different internal college stakeholders (e.g. [1, 14, 33, 46, 52, 71, 73]), and they allow the opportunity to further investigate interviewee responses [18]. Although the lack of standardisation in semi-structured interviews can result in concerns regarding dependability and reliability [18], an interview guide was created to ensure there was similarity between questions in each interview. Questions included asking whether lecturers take part in CPD (and if so, when, how, and how much), whether CPD was needed, what they find as effective CPD, what are their needs to take part in CPD, and what are the general college perspectives on CPD.

Most interviews took place virtually via Microsoft Teams (MS Teams), with three exceptions, one via Zoom, one via Google Meets, and one via telephone. While face-to-face interviews may have revealed some extra contextual information, virtual interviews were deemed more suitable due to their accessibility, and the prevalence of COVID-19 during the time of the interviews that caused some access restrictions. Interviews were held for 19 to 56 minutes, with an average interview time of 32 minutes.

4.4.2 Anonymity, Confidentiality, and Informed Consent. There are ethical considerations within interviews which must be acted upon due to the potential for harm, stress, or anxiety for participants interviewed [18]. One way to address this was through informed consent. This study provided both a participant information sheet and consent form for participants to read through and agree too before interviews commenced. These documents provided details about how participants would remain anonymous, how their identity or college would not be disclosed, and how their information

would be securely stored. Additionally, this study followed the authors home institutions guidelines 'Research Ethics: A Handbook of Principles and Procedures', and the research project was approved by members of the research ethics board of the authors home institution such as the head of school, and research lead. Due to not involving any vulnerable participants or conducting and covert research, formal approval through attending a University Research Ethics Committee (UREC) was not required, with the project being approved in writing.

4.4.3 Recording and Data Transformation. Reliability and dependability refer to the accuracy and precision of what was found [20], with the aim of minimising error and bias [100], so there is trust in the research and integrity in the presented outcomes. Hence, when using MS Teams, the in-built recording functionality was used to record the interviews if interviewees had agreed to this. Interviewees were provided with the choice to have their camera on or off. Recordings were saved to Microsoft Stream and only available to the researcher. Recordings were downloaded and saved upon a password protected external hard-drive. In the cases when Zoom and Google Meets was used for interviewing, the researcher audio recorded the interviews via Quick-time Player with interviewee approval, and these recordings were saved to the same hard-drive. Recordings were initially transcribed using Otter.ai software where interviewees had agreed to its use (both through signing the consent form and confirming when asked after the interview was complete). While this software was fast and accurate, the researcher listened to each interview through twice, so manual transcription additions and amendments could be made where there were errors and to ensure consistency. Once transcripts were processed by Otter.ai, they were downloaded into the password protected external hard-drive, and subsequently deleted from the Otter.ai software.

4.5 Analysis

4.5.1 Data-Analytic Strategies. Braun and Clarkes' six stages of Thematic Analysis [13] were followed for the analysis and coding of interview data, as thematic analysis focuses on patterns across a dataset, and is an analysis process familiar to the researcher. While the first stage (transcription), has already been discussed, it should be noted how thematic analysis focuses on what was said than how it was said [13]. Therefore, a transcription including pauses and non-semantic sounds was not required. The second stage (reading and familiarisation) involved reading all interview transcripts and making informal notes. The third stage (complete coding) involved uploading transcripts to the CAQDAS Nvivo, which was used to organise files and to help manage the coding process. Once complete, a complete-coding process was employed which involved coding anything deemed relevant without being too selective [13]. This was deemed phase one of the coding process and included 134 codes. Phase two of coding involved the creation of categories based on initial codes, and whether those codes were accurate. Some codes were split, and others grouped, resulting in 170 codes, with 23 as category headers. Next was stage four of thematic analysis (searching for themes), and therefore phase three coding involved checking the categories created and creating some initial themes. Phase three resulted in 170 different codes, but they all fitted within 15 themes. Stage five (reviewing themes and creating a thematic map) involved what was referred to as phase four, where the themes created were refined once more, and phase five repeated this process with continual checks until there was a final set of distinctive coherent themes. This resulted in 6 overarching themes which together contained 19 themes. The final stage (defining and naming themes), involved ensuring each theme had a clear scope and purpose [13], with minor changes made to the created themes. See Figure 1 for an overview of the thematic analysis process.

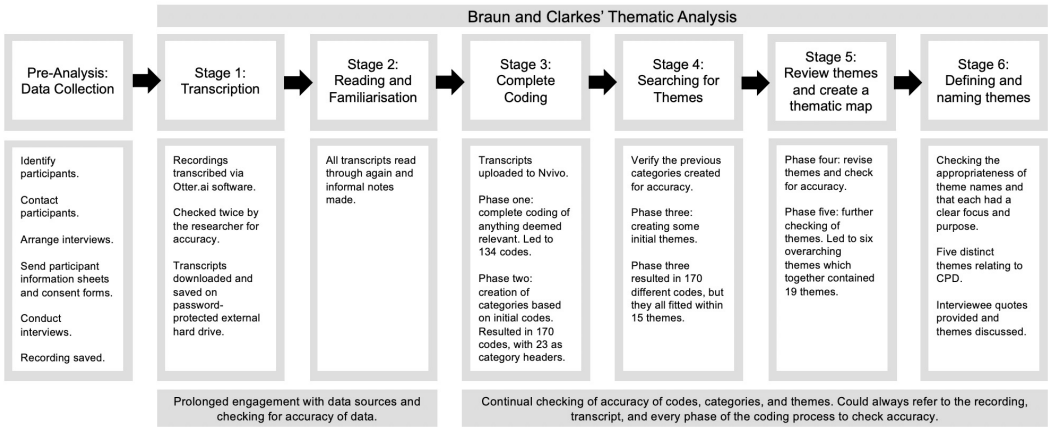

Fig. 1. Thematic Analysis Process. Adapted from [13].

4.5.2 Methodological Integrity. Maxwell draws on the importance of providing an understanding of what happened in qualitative research, as validity pertains to the conclusions reached from an account, not the methods or data used [59]. Hence, throughout the research process there was a prolonged engagement with data sources as suggested by Lincoln and Guba to enhance credibility [55]. Furthermore a chain of evidence was established, so any finding and interpretation could be traced to its original source to check for accuracy [100], with the process of auditing and checking being prevalent throughout the different phases of coding as outlined in Figure 1. By having all transcripts and all five phases of coding on Nvivo, this allowed the researcher to identify how the analysis evolved, and where codes were situated within a wider passage of text. By doing so, this helped ensure accuracy of the codes.

Analysis of the qualitative research relied on what the individual researcher deemed significant, so the analysis may have been influenced by any prior assumptions. Inter-rater Reliability (IRR) was not used as although IRR can help reduce confirmation bias, McDonald, Schoenebeck and Forte highlight how IRR should not be used when developing codes is part of the process, while there are many other methods used to communicate reliability in qualitative research [60]. Therefore, to enhance research reliability and credibility, quotes from interviewees are presented [18] in addition to their interpretation, allowing for readers to draw their own conclusions. Furthermore, to ensure accuracy of the findings, multiple stakeholder perspectives were gathered for each institution where possible, to allow for the triangulation of evidence which can enhance credibility [55]. However, it is recognised that no account can include everything [59], but by showing the context and positionality of the researcher, making the research process transparent, and providing a variety of interviewee quotes, this can enhance research reliability [60].

It should be noted the interviews were conducted as part of a larger study focusing on CS teachers within colleges, that involved asking questions beyond the realms of CPD, such as their choice of computing curricula, and so not every theme was directly related to CPD. However, due to the length and detail gathered from the research, this qualitative piece of research necessitates being divided, with this article solely focusing on aspects related to CPD.

5 FINDINGS AND DISCUSSION

Through the analysis of interview data, five overarching themes were created. This section will present each of these themes with interviewee quotes to provide supporting evidence, and these will be contextualised to existing literature.

5.1 CS CPD Should Address Various Knowledge Domains

This theme highlights what should be covered within CPD. It has been discussed how the most effective CS CPD would cover both PK and CK, in addition to recent sector developments [61, 75], and these different aspects were highlighted by interviewees. For instance, Interviewee 10 (lecturer) explained how CPD has two main aspects:

> 'You need to develop pedagogy and your skills at the same time and never get complacent with either of them. Especially in computing, everyone thinks they know everything.'

Interviewees cited a wide range of content CPD should cover. The most frequently cited topic areas desired by interviewees included programming, cyber security, and artificial intelligence/-machine learning. Interviewees discussed how CPD should include CK such as relevant industry standard tools and practices, PK, knowledge of how their college operates, policies and practices, safeguarding, using digital teaching tools, and aligning what CPD to classroom practice. This latter finding supports the recommendations of US based CS CPD studies (e.g. [9, 32, 77]) but in an English FE context, while supporting the recommendations made by the DfE in 2016 [28]. Overall, the variation in what should be covered in CPD is exemplified by Interviewee 22 (senior leader) who stated:

> 'They [computing teachers] need to upskill themselves as that, that sort of dual professional, they need to upskill their their teaching, they need to upskill their ability to educate and what that looks like at HE, but they also need to make sure that their industry skills, their technical skills are absolutely on point.'

A problem is that each CS teacher will have their own background experience, qualifications, and teaching methods. Hence, in line with existing literature, some interviewees stated how CS CPD opportunities need to be tailored to the individual for what they need to improve [77, 79]. For example, Interviewee 13 (senior leader) explained:

> 'One size [of CPD] doesn't fit all. And I get that, but actually everybody's on their journey, and everybody's at different points on their digital journey. And how do you cater for people that are at different points?'

This is a key problem for both CPD providers and educational institutions. A more pressing issue is the institutional factors which must be in place to facilitate the ability for teachers to take part in some CPD activities in the first place.

5.2 CPD Requires Institutional Support

General reviews of CPD highlighted the importance of institution support [23], while the DFE indicated the importance of leadership support for enabling teacher CPD in schools [28]. Interviews verified this is important in an FE context, where interviewees discussed that taking part in CPD during work hours is due to the college and senior leadership supporting them. One senior leader (Interviewee 12) was keen on embedding CPD into normal procedures and how it should be treated no different to teaching. They stated:

> 'We'll be driving that down into the expectations in personal objectives and professional development and review meetings. And so we really say okay, 'well, what are your

> learning goals for you this year?', and this is a, not a, it would be nice if I could do some CPD, but no you're required to in order to remain competent.'

This interviewee acknowledged that if teachers are up to date this could lead to better student outcomes, a view shared by Ofsted [69], and many other interviewees. Interviewee 1 (senior leader) expressed their recommendation that any college needs to have somebody at a senior level with support from the principal (or equivalent) in driving a college strategy forward, while one course leader (Interviewee 31) stated:

> 'What we've done is we've tapped into the National Centre of Excellence for computer science accelerated course and asked for staff as part of their CPD. We made it mandatory for staff to upskill to try and bridge that gap.'

While this shows good support from senior leadership, one lecturer (Interviewee 16) explained how CS departments need to be supported in different ways to other departments as they require resources and equipment to be updated more frequently [92]. When this is combined with the lack of funding present in FE [4, 14], interviews unsurprisingly highlighted resource issues. For instance, Interviewee 14 (course leader) stated:

> 'I don't try and push the cutting edge tech, we can't afford it, we don't have it, and our network might struggle to run it'

While not directly related to CPD, this quote highlights issues of funding, and that without sufficient infrastructure and equipment, teachers may not be able to effectively implement new tools and techniques learnt from CPD, as illustrated by Cooper et al [22]. In keeping with research on the FE sector (e.g. [52, 71]), having sufficient time was deemed by interviewees as a requirement to partake in CPD. Comments included that keeping yourself updated is 'like another job' (Interviewee 27, head of department), 'teachers just simply don't have the time to do that. To upskill themselves' (Interviewee 26, course leader), and 'you can't fit that all in' (Interviewee 10, lecturer). Darling-Hammond indicated how reduced teaching loads and financial subsidies is one way to encourage CPD uptake for teachers [25], and given the funding and time constraints for CS lecturers in FE, factors like these are required. However, if CPD is free, there is still the cost to the college of having to cover that teachers' lessons. Furthermore, even with time and funding, due to the vast array of topics within CS, and how fast technology changes, some interviewees explained how they still need to do some learning in their own time, which was the case for Interviewee 5 (lecturer):

> 'We have, like, CPD days and times as well. And okay, yeah, that that helps, of course, a lot. But, you know, you would still need to have you still need to take some of your own time.'

One senior leader (Interviewee 28) was explicitly asked about the time and funding allocated for CPD for teachers, and even they as the most senior person in the college, admitted they do not give staff time, but they should be allowed more time:

> 'We don't give staff here time. But we do have a fairly significant CPD budget, which we allow people to apply for. And largely, you know, most people get what they want, within reason. It's just more down to the teacher's individual ability and energy in order to be able to do that... I do think that teachers should be slightly unshackled. To allow them to give them some more time and energy to focus on the things we've just been talking about, rather than some of the stuff that they have to do at the moment, the bureaucracy and the assessment methods.'

Another issue preventing teachers taking part in CPD was a lack of awareness of CPD opportunities from both institutions and individuals. This was not something highlighted in the literature review but from the sample of interviewees it was found some teachers may not be

aware of what they should be updating themselves on, and hence, what CPD opportunities may be available. One lecturer (Interviewee 11) simply stated 'opportunities don't arise', while another teacher (Interviewee 4) explained this in more depth:

> 'If you don't know what you don't know, then you don't know what you need to know if you know what I'm saying. So because they've [teacher colleagues] both taught at FE for so long and don't really understand where industry is at. Well I'm just you know, five years out of industry now so I'm kind of, not on cutting edge anymore. If you don't know where industry is at it's very difficult to know what you need to learn.'

Despite this interviewee perspective, there are resources available for CS teachers teaching those aged 16-18 (e.g. see [95]), but interviewees did not mention them.

5.3 CPD Should be Engaging

Interviewees discussed the engagement of those taking part in CPD. Macia and Garcia in their review of CPD indicated a key problem for CPD is a gradual lack of teacher engagement [56], while in the specific context of CS CPD in the US, McGill et al highlighted how interest of teaching CS is important for taking part in CPD [61]. The findings of this study support these assertions in an English FE context, as it was found that if a teacher wants to learn and develop, they will be more willing to engage in CPD, and to seek out opportunities. Those interviewees who were earlier into their careers were generally keener on learning new things and keeping up to date with industry changes than those closer to retirement. In fact, three teachers stated how they would like to pursue a PhD. One lecturer (Interviewee 4) stated:

> 'I'm thinking of doing my PhD, my PhD that I'm thinking of doing is trying to work out why FE [Further Education] can't teach to the level that the industry is requiring.'

This quote draws upon the personal interest for learning and some of the problems present within the education sector for CS teachers. This personal interest is likely to be a driving factor in whether any form of CPD is successful, as otherwise a teacher may not be as engaged. Some interviewees discussed how CPD with awards and accreditation's attached to them tend to lead to increased engagement. For example, one head of department (Interviewee 31) discussed how CPD opportunities with a qualification attached to it provides 'a bit more motivation', while one senior leader (Interviewee 13) stated:

> 'We worked at looking at how we develop their [teachers] CPD, some of like the online training packages. So Microsoft has a suite of badges and looking at how we can empower them to say, 'Well, you know, if you ever left here, if you ever went on to somewhere else, you could say that you're certified Microsoft teacher'.

While additional qualifications may benefit the individual, CPD with an award or accreditation attached to it tends to be a longer commitment and have associated costs. The college would therefore have to decide whether that development opportunity is worthwhile. Still, many interviewees discussed how they keep up to date with sector developments and showed a clear passion for computing and teaching and learning. For example, one course leader (Interviewee 9) explained how many of their staff engage in personal pursuits such as coding or web development and stated how 'Some of it it's a passion'. This situation was almost identical at other colleges too, with Interviewee 29 (lecturer) outlining how they are applying to the British Computer Society to access CPD opportunities, while others were doing the same but through reputable publishers such as ACM and IEEE, as in the case of Interviewee 20 (lecturer) when asked about how they stay relevant:

> 'That's a really good question. So I think because I'm a member of the Institute of Engineering and Technology, that's good. So I'm getting magazines, I'm getting periodicals.

> I'm pretty much a geek, really. So I think that helps, I think, if you're a geek outside. So I do a lot of coding, a lot of web development in my own spare time. And I think I can bring some of that into the, into the classroom.'

However, some interviewees explained how while learning new tools and software is a good thing, if that software is not allowed where they work, or they do not have the resources to run that specific software effectively (e.g. due to poor infrastructure), this can result in them feeling less engaged in the CPD as they cannot apply their learning to their teaching.

5.4 CS CPD Should Involve a Combination of Activities

A key aspect of CPD discussed was the wide variety of methods in how it took place, and how different each type of CPD was structured. Many interviewees believed that for CS, 'CPD has to be part of the job', due to the ever-changing nature of the subject area. It was evident there was not a one size fits all approach and taking part in different types of CPD were more beneficial. This is not a surprise, as mix of both online CPD and face-to-face learning has been described as being more appropriate [39], with CPD using a range of techniques and including opportunities to reflect as more effective [80]. Some interviewees discussed how they have attended formal face-to-face training courses with mixed reviews. Some referred to taking online courses such as those from Udemy or Code Academy, while some stated how watching videos on YouTube, reading class textbooks, or asking questions on forums are their ways of engaging with CPD. While online sources were deemed as most accessible, with interviewees referring to how useful online sources and textbooks are to gain CK, they were not always considered beneficial, especially if outdated, or if they did not adequately cover how to teach a certain topic (i.e., PK and PCK). For example, one lecturer (Interviewee 19) said:

> 'You've got the textbook, which is out of date, almost as soon as it's been printed, really... they give you a scheme of work for every unit, which is diabolically useless, really. And you know, and, you know, the resources just aren't there.'

Reflection as part of CS teacher CPD has been internationally recognised as good practice (e.g. in US high schools [15, 67], and in English schools [85]), but only six interviewees discussed reflection. One lecturer (Interviewee 29) explained how reflection is a key component of their teaching practice, where they watch their own recorded sessions to see what went well (or not), and combine that with student feedback so they could improve:

> 'Reflection is is the fundamental part of it. It's all well and good identifying all the needs of the students and planning your curriculum. But if you can't reflect, you know, in action while you're delivering or after the session, to figure out what went well, what went badly, you're not actually improving your own teaching, you're just delivering the same content over and over again.'

A key point raised here is how any CPD should feedback to improving teaching and helping students, which is frequently highlighted as important for CS CPD, albeit in other educational contexts (see [42, 67, 77, 80, 99]). Similarly, some interviewees discussed how they have benefited from observations, both in terms of gaining feedback on their own practice or observing other colleagues' lectures. Furthermore, some interviewees discussed observing colleagues who teach other subjects to gain a wider perspective on pedagogical approaches. This cross-curricula approach was favoured by a small number of interviewees. For instance, Interviewee 25 (lecturer) stated:

> 'I do observe a lot of lessons. So I found in the past, that could be quite helpful, to identify good practice, you know, things that I can perhaps develop, you know, and it can be a good way of, I suppose, identifying some of the skills that perhaps you

> wouldn't always get, you know, not not observing. And so for example, things such as use of technology, how technology can be used in other areas, not just IT.'

Working with others was discussed more generally in terms of networking and collaboration with teachers from other institutions. Interviewee 25 (lecturer) explained how they do 'a lot of sort of cross college work with various other colleges', while Interviewee 31 (course leader) stated 'I like to sort of just reach out to my networks'. Reviews of international practice have recommended how professional learning support networks should be established where teachers can engage with peers in their subject [23, 25, 56], while there is a wide body of research on the importance of CoP for US CS teachers (see [22, 40, 64, 76, 80]). However, research on the English FE sector has neglected whether support networks and CoP are important for CS teachers, instead detailing a more generalised picture [31, 39]. However, interview findings address this research gap, as it is evident support networks and CoP should be established for CS teachers within English colleges. For example, Interviewee 10 (lecturer) expressed that:

> 'Building a community of people that teaches similar things together, I think is really important. Something funded perhaps by the ETF [Education and Training Foundation], where we can meet every quarter, for example, somewhere neutral, have a few talks about some of the pedagogical developments... we need teachers to get together and be able to experience the different opinions, beyond chain resources and things. So if that's an online platform, if that is something created by central government, or contracted out to develop, I think we need something that brings computer science and computing teachers together.'

Networks can refer to industry links, with some interviewees at all levels discussing how teachers obtaining industry experience and building links with employers is important. Some interviewees discussed the benefits of being able to work in industry for a short while during the academic year. These interviewees were predominantly teachers who worked at colleges offering T-Level qualifications, so they benefited from the government funding available at the time for institutions offering T-Levels to allow them the opportunity to up-skill. However, even those colleges not offering T-Levels tried to ensure staff had the opportunity to up-skill in some capacity. For instance, one senior leader (Interviewee 15) explained:

> 'It's mandatory for every single teaching member of staff in the [college] to have a back into industry day, you're not allowed to not to, we encourage more than the absolute minimum in all instances.'

5.5 CPD Should be Measurable

Harland and Kinder discussed nine outcomes of CPD [45], while Guskey later discussed how CPD should bring a change in classroom practice, teacher knowledge, and student learning outcomes [41]. However, these can be difficult things to measure, and regardless of the structure and content of CPD, a key issue highlighted by a small number of interviewees was the difficulty of measuring the effectiveness (or impact) of CPD. For example, one senior leader (Interviewee 1) said:

> 'They're [teachers] supposed to go out into industry and update their, their subject knowledge. Whether that happens or not, is another matter altogether.'

Similarly, another senior leader (Interviewee 2) stated how it is 'difficult to monitor or gauge the effectiveness of CPD'. While metrics such as hours or days spent can be used, these are simplistic measures which show the time someone spent on CPD, not on whether that time spent was worthwhile, or whether it leads to improved classroom teaching. Another senior leader (Interviewee 22) described this problem explicitly:

> 'You could very easily say 'right, everyone has a target of X number of hours of professional development they have to do in a year. It has to be measurable. It has to be evidenced, it has to have you know, you need to check in and check out when you're doing it and at the end of the year, we've got a lovely spreadsheet that tracks across and your name will go green if you've done enough professional development'. Obviously those sorts of techniques and those strategies tell us what someone has done, actually, it tells us how long someone spent doing something, it doesn't tell us if it's had any impact, if it's had any benefit to them, or their students or, indeed, to us as an organization.'

Hence, CPD should have some sort of evaluation metric, whether through evaluating teacher self-efficacy as illustrated by McGill et al [61] and Ravitz et al [79], or monitoring classroom practice before and after an intervention. However, despite the challenges of measuring impact and effectiveness, to neglect CPD based on its difficulty to measure would be naive, and not taking into consideration the benefits CPD can provide. CPD can happen in many ways, but it needs certain contextual elements and characteristics to be effective, and what works for one individual and college may not be suitable elsewhere.

6 ACESI GUIDELINES FOR CS CPD

This section details a set of guidelines which outline the characteristics for effective CS CPD in the context of CS teachers in the 16-18 sector. The guidelines, titled the ACESI Guidelines for CS CPD (see Table 2), were created by combining interview findings and existing literature, where ACESI is an acronym for the five various characteristics within the guidelines.

The first part (A) is for adoption characteristics, these are contextual factors and barriers which exist that may present CPD from taking place. The second part (C) is for the content characteristics CPD activities and opportunities should have. The third part (E) represents engagement characteristics, while the fourth part (S), refers to how the CPD should be structured. Finally, the fifth part (I), represents the impact of CPD, detailing what CPD should aim to achieve. All of the thirty guidelines outlined in Table 2 indicate whether that guideline was mentioned by either of the three stakeholder types interviewed, and whether it has been highlighted in existing literature.

6.1 Adoption Characteristics

There are barriers preventing CS teachers taking part in CPD. These have been defined as 'adoption characteristics'. Adoption characteristics are factors that should be present for CPD to take place in the first place (i.e. be adopted), irrespective of how beneficial CPD may be. They are largely contextual factors related to the institution (or teachers) who would be engaging with CPD. Three of the these adoption factors were mentioned by each stakeholder type interviewed and by both generic CPD literature and CS CPD literature. These related to having sufficient time, funding, and senior leadership support for CPD. While these are barriers and link to having institutional support, there are ways these barriers can be reduced. For instance, Darling-Hammond suggests financial subsidies are one way to address issues of funding for CPD [25].

Another point raised by each stakeholder type and in literature was the importance of teachers having a personal interest and passion for the subject, as they would be more likely to engage in CPD. Without this interest, teachers are unlikely to take part in and be engaged with CPD [77]. Hence, CPD providers should consider ways to ensure teachers are interested and engaged in CPD, whilst indicating the importance of recruiting teachers who are interested in their own development. A related adoption characteristic was having an institutional culture of development and growth that helps facilitate CPD. This has been mentioned in general CPD literature [34], and

Table 2. ACESI Guidelines for CS CPD

	GUIDELINE	INTERVIEWS [a]			CITATIONS [b]		
		SL	CL	L	US	OC	GL
A	01) Sufficient time for CPD - CPD is in line with teacher schedules	x	x	x	[80]	[66]	[52]
	02) Support by senior leadership - CPD benefits are outlined clearly	x	x	x	[22]	[85]	[23]
	03) Sufficient funding available - CPD includes financial subsidies	x	x	x	[22]	[42]	[25]
	04) Institution awareness of CPD - CPD should be marketed effectively	x	x	x			
	05) Institution culture of development/growth	x	x				[34]
	06) Teachers have personal interest/passion - Ensure CPD is engaging	x	x	x	[61]	[56]	[53]
C	07) Content is tailored to the individuals' current knowledge needs	x			[77]	[62]	[28]
	08) Content is tailored to what is applicable to the classroom	x	x	x	[80]	[24]	[25]
	09) Develops relevant computer science content knowledge	x	x	x	[67]	[86]	
	10) Develops pedagogy knowledge	x	x	x	[61]	[86]	[52]
	11) Develops computer science pedagogical content knowledge	x	x	x	[78]	[65]	
	12) Develops knowledge of software and tools		x	x	[9]	[47]	
	13) Develops awareness of industry/sector developments		x	x	[83]	[75]	[28]
E	14) Include awards/accreditation's if possible (e.g. Cisco certification)	x	x	x	[22]	[85]	
	15) Include access to new resources, software, and tools		x	x	[64]	[65]	
	16) Include opportunities to form new networks and meet new peers		x	x	[22]	[24]	
	17) Has clear goals, objectives and relevance of why CPD is required			x	[61]	[56]	[23]
S	18) Involves a combination of techniques	x	x	x	[37]	[56]	[39]
	19) Takes place over a period of time, not a one-off occasion	x			[99]	[66]	[53]
	20) Includes follow-up support				[67]	[42]	[28]
	21) Includes opportunities for collaboration and sharing good practice	x	x	x	[37]	[86]	[25]
	22) Has opportunities to develop/partake in communities of practice	x	x	x	[64]	[24]	[28]
	23) Include opportunities for observation, feedback, and mentoring	x	x	x	[37]	[86]	[25]
	24) Includes classroom-based practice activities		x	x	[67]	[97]	[44]
	25) Has reflection embedded into the activity or event	x	x	x	[15]	[12]	[28]
I	26) Influences classroom practice and student learning outcomes	x	x	x	[32]	[12]	[69]
	27) Develops a teachers' knowledge base	x	x	x	[37]	[24]	[41]
	28) Develops a teachers' confidence (self-efficacy)	x			[37]	[62]	[45]
	29) Enhances institution ability to offer new courses and/or topics	x	x				
	30) Formulation of new networks and communities of practice		x	x	[37]	[24]	

[a] SL = Senior Leader, CL = Course Leader, L = Lecturer

[b] US = US based CS CPD literature, OC = Other country based CS CPD literature, GL = General literature re: CPD

by senior leaders and course leaders during interviews, but not lecturers. Finally, awareness of CPD opportunities was one aspect not highlighted in the literature review but by each interviewee type, and so this serves as a unique contribution of what else may be important when designing CPD. To address this lack of awareness, it is suggested that when designing CPD consisting of workshops and events, these events should be marketed effectively and through the right channels.

If the six 'adoption characteristics' are present, the barriers of taking part in CPD may be reduced. This would position a college in a situation where they are more willing and able for staff to take part in CPD. Although not all CPD consists of workshops, events, and courses, an implication for practice is that providers of such CPD opportunities must consider these adoption characteristics in the design of CPD above everything else for it to be plausible for teachers to take part. While this is relevant for CS teachers in English colleges, further research would be required to verify whether this is the case in other educational settings. Nevertheless, readers are encouraged to consider how these guidelines may apply elsewhere in their own contexts and where 'fuzzy generalisations' can be made [8].

6.2 Content Characteristics

Content characteristics refer to what must be present within CPD regarding topics and content. In line with existing literature, interviewees from each stakeholder type outlined how CPD should be tailored to what is applicable in the classroom, and should cover CS CK, PK, and CS PCK. Hence, this study contributes to knowledge by augmenting the wide body of literature which discusses the importance of these characteristics (e.g [65, 67, 78, 83, 99]), but in the unique educational setting of English colleges. There are also two content characteristics highlighted as important for CS CPD in literature but only mentioned by course leaders and lecturers. These were developing knowledge of software and tools [9], and awareness of sector developments [75].

6.3 Engagement Characteristics

Engagement characteristics are characteristics of CPD which are likely to increase the likelihood of teachers wanting to take part in CPD, but also, their engagement during the process. Some interviewees commented that if teachers are not engaged, they are unlikely to realise the potential of the opportunity presented to them. It is suggested CPD should have clear goals and objectives [23], since if teachers are going to adopt new beliefs or methods of teaching into their practice, they need to understand how these translate into classroom practice [34]. Although this aspect was found in both general CPD and CS CPD literature, it was only lecturers who mentioned this aspect during interviews, presumably as they are the main stakeholder type specifically involved in CS CPD.

Other characteristics that enhance engagement are opportunities to form new networks and meet new peers, and to gain access to new tools and resources. This is often in the resemblance of a tangible product for teachers so they may feel as if they are 'getting something' from CPD in addition to the learning. These characteristics were not discussed by senior leaders, or in generic CPD literature. It is likely that forming new networks and gaining access to new software and tools is an aspect of CPD more important for the CS community, with the interview findings supporting US based CS CPD literature [22, 64], but in the context of English colleges. Nevertheless, teachers should be engaged with CPD for it to be effective, and therefore CPD should be designed in a way that enhances engagement.

6.4 Structure Characteristics

Structure characteristics refer to how CPD is delivered and what it involves. In line with literature, interviewees from each stakeholder type outlined how CPD should involve a combination of techniques, and include opportunities for collaboration, sharing good practice, developing CoP, observation, feedback, mentoring, and reflection. Therefore, these findings support CPD literature but in the unique educational content of English colleges. However, there were some characteristics which only some stakeholders mentioned. For instance, the importance of CPD involving classroom-based activities was not mentioned by senior leaders. Conversely, senior leaders were the only stakeholder who outlined the importance of CPD taking place over a period of time. Nevertheless, lecturers and course leaders did discuss how sufficient time is required for CPD. Interestingly, although follow-up support was cited by the DfE [28] and CS CPD literature [42, 67], no stakeholders mentioned this characteristic.

Out of all of the structure characteristics, opportunities where lecturers can collaborate with others and build their networks were seen as particularly beneficial. The emphasis on networks or a CoP is frequently mentioned as something CS teachers wish to have and is seen as beneficial [14, 39, 52, 56]. Hence, a key implication for practice is that a greater emphasis should be placed on building collaborative networking opportunities for CS teachers.

6.5 Impact Measurement

Once CPD is able to take place, it is recommended some of the guidelines from content, engagement, and structure should be met for CPD to be effective. For example, CPD could have the most relevant content and be structured in the most perfect way but if a teacher does not engage in the CPD or they are forced to engage in it, they are unlikely to learn as much as they could have, thus rendering the CPD a wasted endeavour. Equally, if a teacher is engaged in the CPD and it is structured well, but the content is not relevant to CS or it is unlikely it can be applied in the classroom, this form of CPD will not be applicable. However, defining what leads to effective CPD requires identifying what the intended impact of CPD is or should be. Ofsted [69] and Guskey [41] both outline that the impact of CPD should be influencing classroom practice, student learning outcomes, and developing a teachers' knowledge base. All stakeholder types interviewed mentioned these should be aspects of measuring CPD impact. However, developing a teachers' confidence (and self-efficacy) was only mentioned by senior leaders, whereas forming networks and COP was only mentioned by CS lecturers and course leaders, and in CS CPD literature. This reiterates the increased importance placed on this characteristic by the CS teacher community, in that it is an outcome of CPD, not just part of the process. Furthermore, a more unique contribution to knowledge is the finding that one impact of CPD should be the ability to offer new courses and topics.

Finally, defining the impact of effectiveness of CPD can vary depending on ones' perspective. What a college defines as effective CPD may differ to individual teachers who may have their own personal goals or measures of effectiveness. For example, if a teacher cannot apply what they learnt from CPD into the classroom, but they now feel more confident, have established collaborative networks, or increased their future career prospects, they may view the CPD as having a meaningful impact. However, colleges may be more inclined to view CPD effectiveness as its impact on student grades, the value for money for the CPD, and whether they can now distribute staff more effectively or offer new courses of study.

7 LIMITATIONS OF THE STUDY

If this study was replicated, it would not be possible to have the exact same outcome, as the interviewee perspectives provided are a product of their time and the context surrounding each individual. Similarly, if the study was replicated with other participants, this would involve different perspectives and worldviews which may result in similar, additional, or contrasting findings regarding CPD for CS teachers. Another limitation is that the interpretations are subjective, and there is the potential for researcher bias. Hence, a description of the researcher and a detailed overview of the research process has been provided, while sample quotes are provided so readers can make their own interpretations. It could be argued that another limitation is the sample did not have an equal representation, whether via stakeholder type, or demographic information such as by gender. Conducting further interviews may have allowed for a more thorough analysis, and potentially other findings to be realised, but data saturation was occurring with the sample used.

Another potential limitation is that interviewees placed a larger emphasis in their discussion on how CPD should be structured, and what kind of content should be covered in CPD such as PCK, as opposed to specific content areas such as python programming, or cyber security. Therefore, the ACESI guidelines for CS CPD provide a more generalist view of the characteristics for CS CPD in a college setting for those teaching students aged 16-18, as opposed to for all CS teachers. Hence, future research would be required to verify whether this set of guidelines is valid for those teaching CS for other age groups, or for teaching in other subject areas.

8 IMPLICATIONS FOR CS CPD

8.1 Contributions to Knowledge and Practice

The FE sector has typically been an area of neglect in research [6, 69], despite colleges (the main FE provider) being earmarked by the UK government as being crucial in addressing digital skills gaps [6, 30, 47]. Greatbatch and Tate state research regarding CPD in the FE sector would be helpful [39], and this includes identifying how FE teachers engage in CPD, any barriers that exist, and what forms of CPD are most beneficial [39]. This article explicitly addresses these areas by making an empirical contribution to knowledge through exploring the perspectives of what CPD for CS teachers should entail from employees (n=32) from colleges in the South West of England.

A detailed literature review on CS CPD has been provided which outlines six main characteristics of effective CPD. These areas were (1) knowledge development and application to classroom teaching, (2) self-efficacy development and measurement, (3) observation, feedback and reflection, (4) collaboration and communities of practice, (5) sufficient time, and (6) institution support. However, as suggested by Kennedy [51], a large proportion of teacher CPD literature reports on examples of initiatives in local or national contexts. This is especially the case with the emerging body of work from the US. While many of the interview findings augment CS CPD literature but through the unique educational context of English colleges, there are some unique findings from this study.

The unique findings of this study include that one impact of CPD is that it should enhance an institutions' ability to offer new courses and topics. This was not discussed as an outcome of CPD in the literature reported. Furthermore, for CPD to take place, interviewees revealed the importance of having awareness of CPD opportunities and the importance of an institutional culture that fosters development and growth. This article has outlined the importance of adoption characteristics for CPD, and while many of these characteristics are contextual, the nature of these characteristics is likely to be applicable in many educational settings. Additionally, through the combination of interview findings and literature, it is suggested a knowledge of software, tools, sector developments, and the opportunity to form new networks and CoP are more important in CS CPD than in other subject areas. This is because of the rapid rate of change of the subject area, and due to how many CS lecturers are often working in isolation [43, 99]. Hence, CPD should include these aspects where possible, and CS lecturers should seek out CPD opportunities where these characteristics are present.

As another contribution to knowledge, the ACESI guidelines for CS CPD (Table 2) contextualises and combines interview data and literature. These guidelines all sit within one of the five domains of adoption, content, engagement, structure, and impact characteristics. For each of the thirty guidelines, it is indicated whether these guidelines were outlined by each of the stakeholder types interviewed, and whether that factor is present in literature. As stated by Webb et al [96], the approaches available for CPD for CS education is an important area for research, and in response to this, the ACESI guidelines portray a rounded set of guidelines of what may be important for effective CS CPD for those teaching students aged 16-18.

If CPD providers consider these guidelines in the design of CPD opportunities, those opportunities should be more aligned with the needs of CS teachers within FE institutions. While it could be suggested that the more factors that are present, the more effective CPD will be, this does not mean each guideline shown in Table 2 should be present. For example, each college, course, and teacher will differ and therefore there is not a one-size fits all approach to CPD, and this is a clear implication for practice. Additionally, while the results of this article are not generalisable, it is hoped readers can understand where the findings may be applicable to their own educational contexts, and where similarities may occur. However, future research would be required to verify this.

8.2 Recommendations for Future Research

It is plausible the ACESI guidelines could be applicable to other subject areas such as mathematics and engineering, which are often combined within the same faculty as CS. Hence, it could be assumed the characteristics of effective CPD are similar, but future research would be required to investigate whether the ACESI guidelines are applicable in other subject areas. Furthermore, the ACESI guidelines could be improved by using the guidelines as a basis for future research investigating which characteristics and elements are deemed the most important in specific circumstances, or for specific topic areas.

The interview findings indicated the need for more collaborative networks between colleges or opportunities where CS lecturers can engage in shared CoP. Only some interviewees mentioned organisations such as the British Computing Society (BCS) or Computing at School (CAS), and given the number of organisations which try and help improve CS teaching and offer help for teachers, it is surprising so few of these organisations were mentioned. However, these organisations may find the ACESI guidelines beneficial to use as a baseline of some of the factors that should be included in programmes of CPD. Hence, future research could consider the perspectives of CPD providers such as these organisations in addition to those such as the Education and Training Foundation, the Association of Colleges, the Institute of Coding, or the National Centre for Computing Education. By obtaining perspectives from CS CPD providers, a more holistic view of CS CPD could be realised more effectively.

8.3 Conclusion and Achievement of Research Question

To conclude, this article set out to answer the following research question: 'What are the characteristics of effective continuing professional development for computer science teachers in the 16-18 sector?' This article has achieved answering this research question through a structured literature review of CPD for CS teachers, and an analysis from a qualitative study of teachers and senior leaders perspectives resulting in a set of thirty guidelines (see Table 2) for CS CPD. However, technology is constantly changing and CS teachers will need to continually adapt, and therefore, CPD will need to adapt. While the created guidelines are indicative of what CS CPD should involve, further research is required to ascertain the most effective ways each of the created guidelines can be implemented in practice for different contexts.

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