Exploring transformative professional development within K-12 computing education

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Abstract. Many computing educators find themselves teaching a subject that is relatively new to them, making access to high-quality, effective professional development (PD) essential. However computing education research does not always unpack the approach being taken to PD, which may reflect underpinning values and beliefs about teachers' role in the process. The study reported in this paper set out to explore computing PD opportunities using Kennedy's framework of transformative, malleable and transmissive PD, whereby 'transformative' PD refers to approaches that encourage collaborative inquiry and critical professionalism. In the study, 341 computing teachers in primary and secondary education in the UK and Ireland reported on PD they had considered impactful. Results showed that most teachers highlighted transmissive forms of PD as being impactful, primarily delivery-focused training courses, and only 18 teachers described PD categorised as transformative. Most teachers reported that PD was impactful if it built on their prior knowledge. As it is likely that many PD programs are designed around transmissive approaches to PD, we argue that computing teachers should be supported to engage with a broader range of PD opportunities, particularly those that are focused on inquiry and teacher agency.

Keywords: computing education · K-12 education · teacher education

1 Introduction

Professional development (PD) for in-service computing teachers takes many forms, from short training sessions to formal qualifications undertaken part-time. Within general education PD research, the forms and modalities of PD have long been researched, with meta-analyses highlighting that effective PD is likely to be collaborative and sustained over time [8, 15]. Other research has focused on the need for PD to support the development of 'critical professionalism' [4], and the term 'transformative' PD has been coined to describe ways of supporting teacher agency and inquiry [4, 17, 21].

In the field of computing education[3], the notion of transformative PD is not often discussed (an exception would be [25]). The delivery of PD in the form of workshops and training for teachers is common [20], and often around subject knowledge [11]. Computing is a new subject for many in-service teachers, who are likely to request subject knowledge training. However, there has been criticism of PD that implies a deficit in the teacher, rather than drawing on a teacher's strengths and existing experience [16]. In this paper, we were interested to investigate what PD teachers reported as impactful, and to align that to research on transformative PD. The survey-based study described here involved 341 teachers from the United Kingdom and Ireland, with both qualitative and quantitative analysis conducted on the responses. This represents an initial exploration into the way that we conceptualise PD and its benefits for computing teachers.

The five countries investigated in this study - England, Scotland, Wales, Northern Ireland and the Republic of Ireland - vary greatly in population size, from 56.55m (England) to 1.9m (Northern Ireland), and in the way they have implemented computing. Education is a devolved matter in the UK, such that national parliaments and legislatures have responsibility for their respective education systems, the development of curricula and the provision of teacher training. In **England**, Computing has been a mandatory subject for children aged 5-16 since 2014, and an elective subject from age 16 since the 1970s [7]. The National Centre for Computing Education (NCCE) has offered teacher training and resource development in computing since 2018 [29]. **Scotland**'s curriculum was updated in 2016, although computing science has been available as a discrete and elective subject at the secondary level for many years. Pupils have an entitlement from age 3 to 15 to a Broad General Education (BGE) which includes Technologies. In **Wales**, the new 2022 Curriculum for Wales [34] reinforces the societal importance of digital competence as a statutory cross-curricular skill alongside literacy and numeracy for all learners aged 3–16, and the Technocamps project offers training to improve teacher confidence and capability to deliver the curriculum [22]. In **Northern Ireland**, digital skills are included from primary through to upper secondary as part of *Using ICT*. Finally, the **Republic of Ireland** has offered a Leaving Certificate in Computer Science since 2018, with an associated program of PD for teachers.

2 Transformative professional development

Teacher PD is an essential part of improving school performance and learner outcomes [2], and a large field of study that has been researched for decades. Recent work has placed an emphasis on the importance of long-term, inquiry or learner-centered structures that support teachers as they collaboratively develop the professional knowledge they need to use in their own context [3]. In computing, PD courses take many different forms, for example, online MOOC-style PD [26, 35], remotely-delivered but asynchronous courses [24], or face-to-face courses

[3] Computing is a generic term we use throughout to include computer science (CS), computing science, informatics and other CS-related subjects.

of varying lengths [23]. However, equating PD with 'training' alone risks forgetting many other approaches to professional learning that may impact teachers' confidence and classroom practice. Other approaches to PD that have been explored in the computing PD literature include belonging to a community of practice (CoP) or professional learning network (PLN) [31], working towards accredited qualifications [30], peer coaching [6], co-designing activities [14], and action research [5].

Kennedy [16, 17] developed a framework of models of PD using a spectrum from transmissive to transformative PD (see Figure 1).The first level of PD, transmissive, includes approaches such as training, deficit models and the cascade model, which "attend primarily to occupational aspects of professional learning" [12, p.165]. The second level,'malleable', includes models such as award-bearing PD and CoPs, indicating that these types or models of PD can be used to different ends depending on the intended (or unintended) purpose [17]. The spectrum indicates an increasing capacity for autonomy and teacher agency in the transformative direction. The third level of PD, 'transformative' is focused on collaborative professional inquiry, defined as:

> *"... all models and experiences that include an element of collaborative problem identification and subsequent activity, where the subsequent activity involves inquiring into one's own practice and understanding more about other practice, perhaps through engagement with existing research"* [17, p. 693]

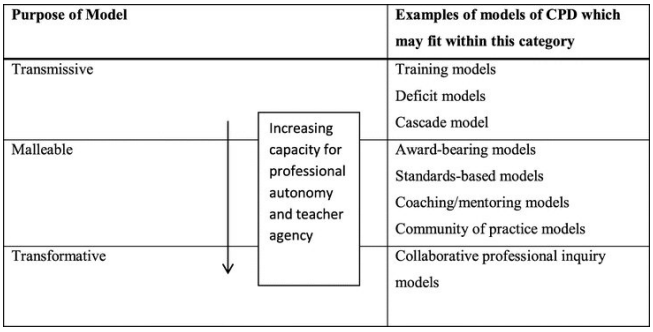

Fig. 1. Spectrum of PD models [17]

Other researchers give different descriptions of what constitutes transformative PD. Mockler [21] describes transformative PD as that which aims for the transformation of society, in that teachers learn to support students to think critically. Sachs chooses to categorise PD as *retooling*, *remodelling*, *revitalising* and *reimagining* [28], with 'reimagining' described as transformative in its intent and practice; teachers are individually and collectively equipped to act as "shapers,

promoters and well-informed critics of reforms" [28, p.160]. In their review of transformative PD, Boylan et al. [4] assert that although transformative PD is yet a small field, its importance lies in its focus on the critical professionalism of the educator. It therefore provides a valuable lens through which to examine computing teachers' reporting of their own PD experiences.

Research in computing PD has already emphasised the importance of PD that is based on inquiry and communities of practice (e.g. [13, 27, 31]). Although not explicitly labelled as 'transformative', it exemplifies PD that supports teachers as critical professionals. The study in this paper aimed to investigate the extent to which teachers in a specific set of countries accessed these opportunities and found them impactful. Thus, the research questions are framed as follows:

RQ1 What professional development opportunities do computing teachers in the UK and Ireland describe as impactful to their practice?
RQ2 To what extent can teachers' impactful experiences be described as transformative PD?

3 Methodology

The study was conducted via the development, distribution and analysis of a survey, based on **ME**asuring **T**eache**R** **E**nacted **C**omputing **C**urriculum (METRECC), a validated survey instrument developed by an international Innovation and Technology in Computer Science Education (ITiCSE) working group in 2019 [10]. METRECC was designed to measure aspects of the experiences of computing teachers around the world and since 2019 has been used with teachers in 14 different countries. The METRECC survey is openly available for researchers to use.[4]

3.1 Data collection

The METRECC survey was localised for UK and Ireland teachers [32]. To answer the RQs, three new questions were added to METRECC as follows:

1. Description of one PD activity that had the greatest impact on one's teaching in the last 12 months (free text).
2. Length of the PD activity (free text).
3. Factors that contributed to the PD being impactful (16 check boxes).

Other questions about PD for teachers included in the survey related to (i) participation in a range of PD types (10) in the last 12 months, (ii) barriers to participation in professional development, and (iii) localised questions for teachers in England, Wales and Ireland about their participation in national initiatives. Because these questions relate to participation and not impact, they are not the focus of this study but are reported elsewhere [18].

[4] https://csedresearch.org/resources/evaluation-instruments/tool/?id=185. Data relating to the current study will be made available as supplementary material.

The survey was open to respondents in England, Scotland, Wales, Northern Ireland and Ireland in February and March 2022. Purposive sampling was used to identify computing teachers, using methods including mailing lists, newsletters, blog posts, social media, promotion through school and teacher networks. Snowball sampling was also used with participants encouraged to share the survey with other computing teachers. The whole survey was completed by 512 teachers, with 359 entering responses for the three additional questions. The overall findings are reported elsewhere [32].

3.2 Data analysis

The data relating to the type of PD found to be impactful was coded using a phronetic iterative approach [33] that drew on Kennedy's framework. The initial intent was to use the nine models from Kennedy's 2014 article (see Figure 1) deductively when coding. It was clear that we were not able to definitively determine which model we could ascribe so inductive coding was used to develop codes for the PD, which were aligned to Kennedy's models where appropriate, and subsequently assigned to the three top-level areas of transmissive, malleable and transformative. Two of the three researchers worked together to determine the coding scheme over three iterations, until consensus was reached. Length of engagement with PD is also relevant to its effectiveness and potentially transformative nature [8], so the teachers' answer on length was used to further refine the coding. A third researcher then coded a 15% sample of the data with an interrater agreement via Cohen's Kappa calculated as $\kappa = 0.86$ indicating strong agreement [19]. The final coding scheme used for analysis is shown in Table 1.

Having allocated all statements to categories and types of PD, we compared them with the following teacher characteristics: experience of teaching CS, age, gender, and qualification level. Teachers also selected factors that supported their description of impactful PD and these were also compared with the types. Descriptive and inferential statistical analysis were used to investigate the relationships between these variables. Specifically, Chi-squared tests for independence were used to compare categorical variables with cellwise residual analysis [1] alongside Kruskal-Wallis tests with Dunn's pairwise comparisons for ranked variables [9].

4 Results

Of the 359 responses to the questions about impactful PD, 341 remained once 'none' or equivalent answers were excluded. Most teachers responding were from England (75.4%) with all other countries represented. Teachers wrote between 1 and 97 words (M=9.58, SD=10.76). The length of the PD described as impactful varied from one hour to a year. Table 1 shows the breakdown of transmissive, malleable and transformative PD against the coding scheme.

Most of the PD reported as impactful was classified as *transmissive* (63.5%). This included 158 (46.5%) instances of training, which ranged from face-to-face training events of several hours to lengthier online courses:

Table 1. Impactful PD categorised by Kennedy's types

Type	Coded	n	%
Transmissive	Training	158	46.5%
	Achievement of certificate	48	14.1%
	Using curriculum resources	8	2.4%
	Training others (cascade)	2	0.6%
	Sub-total	**216**	**63.5%**
Malleable	Self-study	31	9.1%
	Participating in a network/community	29	8.5%
	Accredited qualification	17	5.0%
	Mentoring/observation/coaching activities	14	4.1%
	Attending conference	8	2.4%
	Collaborating within department or school	5	1.5%
	Mentoring others (specifically)	2	0.6%
	Examining for awarding body	1	0.3%
	Sub-total	**107**	**31.5%**
Transformative	Creation of curriculum resources	5	1.5%
	Engagement with research	5	1.5%
	Participation in research projects	4	1.2%
	Leading a network/community	2	0.6%
	Practitioner research or inquiry	2	0.6%
	Sub-total	**18**	**5.3%**

> *"I have attended online webinars . . . which have focused on the teaching of computing with their materials. It has been really useful to get more PD about basics of computer science especially the vocabulary and also ideas for how to start with the youngest pupils."*

The type of PD in which teachers have participated is clearly dependent on what is offered. The NCCE [29] has been set up to deliver PD in England, including certified courses, and accounts for many of the experiences that teachers found impactful. Similarly, in the Republic of Ireland, a number of courses and workshops are made available to support the delivery of the new Leaving Certificate and other courses:

> *"Attending the different CSInc workshops that are held online. Great presenters and the material is delivered with energy that makes you interested."*

We distinguished between teachers achieving a certificate (transmissive) and those undertaking accredited qualifications (malleable), using the criteria that achieving a certificate represented participation in a shorter period of training, and a qualification had to be formally assessed and involve some self-directed activity. We noted that a number of teachers were working towards qualifications,including Master's degrees, university-led modules with accreditation, and leadership qualifications that would take months or years to achieve:

"I have just completed an MA Education, this included research on PRIMM."

Also in the malleable category, we included participating in a network (8.5%) and self-study (9.1%) with a number of examples given:

"Sitting and tinkering with micro:bits, MakeCode Arcade has had the greatest impact in the last 12 months."

Only 18 statements were classified in the transformative category, including participating in a research project, engaging with research in another way, or leading a group of teachers in a network. One response refers to participation in a co-creation research activity around culturally responsive teaching in computing:

"A ... PD activity that has greatly helped my teaching is being part of a working group in helping to produce culturally relevant guidelines for the CS curriculum to be used by fellow CS educators. "

Another response from a primary teacher refers to the setting up of a network for other teachers:

"... computing network group set up, to have regular training updates, discussions and share ideas and resources with one another. "

Considering the reasons given for PD being impactful (Table 2), the most common factor given was that it built on prior knowledge (n=288, 84.46%) followed by PD with coherent structure (n=221, 64.81%) and the content being appropriate to teachers' subject teaching needs (n=221, 64.81%). Less than half of the impactful PD activities focused on pedagogy (n=163, 47.80%) or assessment (n=106, 31.09%).

We investigated coded PD types against factors for why PD was impactful using a series of post-hoc Chi-Squared tests. We found significant associations between certain PD types and a range of factors. For transmissive PD experiences, teachers were more likely to state that they had a coherent structure (4.0, $p < .05$) and that they provided opportunities for active learning (3.5, $p < .05$). Conversely, teachers were less likely to suggest that transformative PD experiences had a coherent structure (3.1, p$<$.05) or that they took place over an extended period of time (2.7, $p < .05$). Teachers were more likely to report that participating in professional learning networks provided networking opportunities (4.4, $p < .05$), while self-study PD opportunities were less likely to do so (4.1, $p < .05$). Using curriculum resources and mentoring and coaching activities were more likely to take place in school settings (4.2, $p < .05$ and 3.8, $p < .05$, respectively). Finally, pursuing formal qualifications or certified PD courses was more likely to take place over an extended period of time (5.7, $p < .05$ and 3.3, $p < .05$, respectively); conversely, participating in professional learning networks was less likely to take place over an extended period of time (3.6, p$<$.05).

Finally, as teacher responses were part of a larger survey, we were able to investigate the relationship between impactful PD type and other responses, including age, gender, CS teaching experience, phase of teaching and highest qualification. No significant findings were noted.

Table 2. Number of teachers who selected each factor, ordered by most popular responses

Factors that made PD impactful	***n***	**%**
It built on my prior knowledge	288	84.46
It had a coherent structure	221	64.81
It appropriately focused on content needed to teach my subjects	221	64.81
It provided opportunities for active learning	191	56.01
It provided opportunities to practice/apply new ideas and knowledge in my own classroom	185	54.25
It addressed pedagogy	163	47.80
It provided networking opportunities	152	44.57
It took place over an extended period of time (e.g. several weeks or longer)	147	43.11
It provided opportunities for collaborative learning	146	42.82
It adapted to my personal development needs	129	37.83
It addressed assessment of student learning	106	31.09
It focused on innovation in my teaching.	102	29.91
It provided follow-up activities	95	27.86
It took place at my school	33	9.68
It involved most colleagues from my school	11	3.23
None of the above	2	0.59

5 Discussion

We sought to answer the following questions: *RQ1) What professional development opportunities do computing teachers in the UK and Ireland describe as impactful to their practice?* and *RQ2) To what extent can teachers' impactful experiences be described as transformative PD?*. We were interested to find out whether teachers reporting their experiences of PD were engaging in the kind of PD that scholars have been describing as transformative, for example whether they were engaging in collaborative inquiry [17] or critical professionalism [4].

For RQ1, we found that while teachers described a range of activities, nearly half answered the question by describing a particular training course or workshop. They also found benefits in other activities classified as malleable, including PLNs, engaging with colleagues, working towards qualifications, and mentoring activities. When we investigated whether there was any particular relationship with the other data that we had collected in the rest of the survey, such as the qualifications held by the teachers, the length of time they've been teaching, computing, their age, their gender and the reasons that they had chosen those particular types of PD to report as impactful, we didn't find any significant relationships. Correlations between type of PD and factors that supported their choice were not surprising, apart from the relationship between length and transformative PD, which may have been due to the small sample. Overall, if the type of PD teachers are choosing is not related significantly to those factors it could well be driven by what is being delivered locally. It is encouraging that teachers are finding courses and workshops to be impactful and beneficial to

their practice. Further research is needed to investigate the extent to which this type of PD might transform teaching in the longer term.

For RQ2, we identified 18 teacher statements that we could align to the notion of transformative PD as described (e.g. by [28, 17, 21]). Four teachers participated in research projects run by universities, two had carried out their own practitioner research projects and five had more generally engaged with research; this represents being more inquiring about the subject of computing. As there were only 18 responses that we could code as one of the transformative approaches to PD, the analysis that could be conducted around why these types of PD had impact was limited. Further research is needed to investigate the types of PD that are made available to teachers in each of the five jurisdictions.

In their review of transformational PD, Boylan et al. discuss purpose, agency, sociality and knowledge as four characteristics that can be used in analysis [4]. The development of the sociality aspect of transformative PD can create increased trust between teachers and with communities [4] and we saw evidence of this in the creation of networks and peer engagement, although we aligned with Kennedy in classifying some of this as 'malleable'. In terms of knowledge, being engaged with research can constitute a more critical analysis of pedagogy and curriculum, although we did not see any evidence of engagement with social justice issues. From our data, we were not able to ascertain specific *purposes* of the transformational PD, or to observe the development of teacher agency.

Increasingly, computing is a subject which is seen at the forefront of discussions around social and ethical issues, including privacy, bias, decision-making, and internet safety. As these topics become core elements of curricula, it is important for teachers to engage in inquiry and to develop criticality about the nature of computing education. If we are going to break down barriers and make the subject inclusive for all, then what we teach, what resources we use, what examples we use, and how we assess, are all areas with which teachers can critically engage. Education in some jurisdictions may be situated in a political backdrop that has systemically reduced teacher autonomy [21]; discussion of this issue is beyond the scope of this paper.

Transformative PD may include trying new pedagogy in the classroom, investigating research into subject-specific pedagogy or actively establishing networks to facilitate collaborative inquiry among peers. Such forms of PD may be less easy to scale as they involve experimentation, discussion and reflection, but are important if young people are going to be able to participate in an increasingly technological society, with an understanding of its benefits and risks. Through a transformative teaching profession we can develop "critical, literate, socially aware citizens with a strong sense of their own civic responsibility" [21, p.738].

One limitation of the study was that the questions were added to an already lengthy survey, meaning that teachers' responses were not as detailed as we might have liked. The rationale for such a design was to investigate the relationships between impactful PD and other characteristics; however as reported, there were no significant findings in this regard. Further research involving interviews or

focus groups would facilitate a more in-depth analysis and enable exploration of the ways in which teachers perceive PD offered to them and its impact.

6 Conclusion

This paper represents an initial attempt to consider computing PD through the lens of transformative PD, supporting increased teacher agency, autonomy and criticality. Computing is a subject interfacing with societal, ethical and political discourses, and computing education encompasses its impact, as well as the basic principles of the subject. The results from this study indicate that only a small number of computing teachers in the UK and Ireland report finding transformative PD impactful, with the majority reporting that an instance of PD classified as transmissive had the most benefit to their teaching and learning. The results are clearly dependent on the type of PD offered. Given that teachers new to computing are likely regarded as having a deficit in subject knowledge, PD opportunities may be largely restricted to delivery-focused workshops and courses. With a growing interest in transformative PD and the way in which it supports teacher agency and critical teacher professionalism [4], and given that more teachers will have experience of computing teaching as it becomes embedded into the curriculum, we suggest further research is needed to investigate the effectiveness of computing PD that increases autonomy and agency, such as engaging with research and inquiry-focused professional networks.

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