



# A systematic review of primary school teachers' experiences with digital technologies curricula

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## Abstract

Many countries around the world have now introduced Digital Technology concepts and pedagogical practices to their primary school curricula to ensure students develop the understanding, competences and values that will enable them to contribute to and benefit from their future labour market and society. This study aimed to explore teachers' experiences with these curricula in order to understand how teachers can be supported to raise their implementation efforts. An analysis of twenty-three studies across eleven countries was undertaken and found there was a lack of consensus of an appropriate age and approach to introducing Digital Technology concepts within primary schools. Teachers' Digital Technology self-efficacy, Digital Technology self-esteem/ Digital Technology confidence was seen to greatly influence their implementation, and many challenges to implementation were discussed. Professional Learning and Development was raised as a solution to boost teachers' confidence and overcome common implementation barriers.

**Keywords** Digital technologies · Information and Communications Technology · Self-efficacy · Implementation · Professional Learning and Development

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## 1 Introduction

Although Computer Science (CS) was first seen in schools in the 1980s, its popularity was short-lived due to the introduction of end-user software and a subsequent emphasis on digital literacy/eLearning/ICTs (Bresnihan et al., 2015; Brown et al., 2014). Fortunately, in the last decade we have seen many countries redeveloping curricula to include technology concepts and pedagogical practices designed to develop students' "knowledge, skills, attitudes and values that [will] enable them to contribute to and benefit from an inclusive and sustainable future" (OECD, 2018a, p. 4) (European Commission/EACEA/Eurydice, 2019; Varoy et al., 2021).

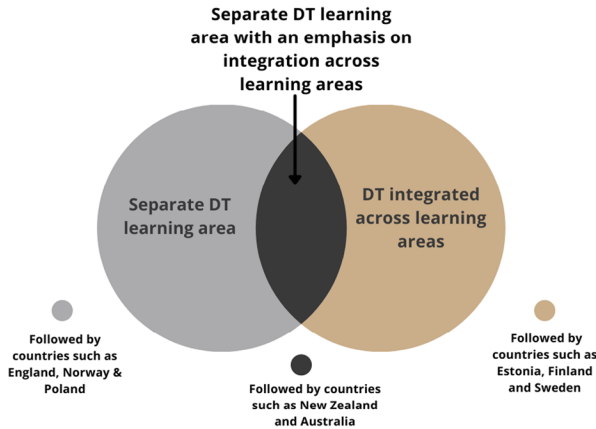
While much of the demand for this resurgence is driven by predicted changes to the labour market caused by general technological advancements, we also face a range of complex global problems, e.g., climate change and ageing populations and find immense pressure is placed on solving these issues through innovative technical solutions (OECD, 2019). With education seen to be the most significant sector for achieving sustainable development goals (UNESCO, 2019), there is additional pressure placed on countries to redevelop and introduce these technology concepts and pedagogical practices to their curricula.

While a range of terms are used globally to describe this redeveloped learning area (e.g.: Computing, Informatics) the term Digital Technologies (DT) is used throughout this article in a general sense to describe the learning area. In the most simplistic terms, DT is learning ABOUT technology, whereas the eLearning/ICT capabilities focus is on learning WITH technology (Ministry of Education, 2018).

More than half of the OECD countries have now developed specific digital education strategies addressing DT goals and priorities, with additional countries prioritising these as part of a broader innovation strategy (van der Vlies, 2020). A range of different approaches to meet these goals have been adopted, with the most common trend to develop curricula which introduce basic DT concepts to primary school students and deliver specific DT courses to secondary school students (Heintz et al., 2016; Krause et al., 2017).

Three general approaches can be seen in a country's approach to introducing DT content to their primary school curricula: (1) content is introduced as a separate learning area, (2) content is integrated throughout other curriculum learning areas, or (3) a separate learning area is created, but the content is taught through other curriculum areas. These approaches are outlined in Fig. 1 with reference to example countries that follow each practice.

Most DT curricula have an emphasis on twenty-first-century skill development such as critical thinking, problem-solving, collaboration, creativity, curiosity, life-long learning, and adaptability (Battelle for Kids, 2019). These are fundamental skills for students to develop alongside their DT knowledge, yet they benefit students across a range of learning areas and are critical components of preparing students for the high-skills information age and demanding labour market of their future (Benade, 2017; Relkin et al., 2021).



**Fig. 1** Approaches to Introducing DT Concepts to Primary School Curricula. *Note:* Figure compiled from information collated from the following sources: Australian Curriculum, Assessment and Reporting Authority, 2015; UK Department for Education, 2013; Finnish National Agency for Education, 2016; HITSA: Information Technology for Education, 2012; Ministry of Education, 2017; Norwegian Directorate for Education and Training, 2020; The National Agency for Education, 2012; The Republic of Poland, 2009

## 1.1 Benefits

The benefits of DT education span from an individual level to that of society as a whole. At the individual level, students are provided with increased opportunities to develop skills such as personal agency, problem solving, communication and executive functioning (European Commission/EACEA/Eurydice, 2019; Webb et al., 2017). They are given opportunities to apply their knowledge to design, create, test and produce digital solutions to issues that are meaningful to them (Barendsen et al., 2015; European Commission/EACEA/Eurydice, 2019; Reinsfield & Fox-Turnbull, 2020).

Schools are believed to deliver more coherent and relevant learning experiences (Reinsfield & Fox-Turnbull, 2020) which see classrooms improved through heightened student engagement, motivation, and attitudes (Mason & Rich, 2019). Society benefits from creating a labour force that can adapt to changes in the workplace (Barendsen et al., 2015; European Commission/EACEA/Eurydice, 2019) and from having citizens who can design, create, and produce solutions that address ethical, environmental and economic issues (OECD, 2019). Finally, economies are improved through increased economic opportunities brought about by an innovative workforce that can take advantage of trade opportunities (Heintz & Mannila, 2018; Webb et al., 2017).

## 1.2 Challenges

While computational thinking concepts were first taught in education in the 1960s (Rich et al., 2019), DT in its redeveloped form is a reasonably new learning area to both primary and secondary schools (Geldreich & Hubwieser, 2020; Heintz &

Mannila, 2018) requiring teachers to develop new knowledge and understandings of technical concepts often with little prior knowledge to base this on (Vivian et al., 2020).

The foundation of DT requires teachers and students to be digitally competent prior to engaging with the DT curriculum content (Garneli et al., 2015), and whilst there has been an emphasis on teachers' ICT capabilities within education systems for many years now (European Commission/EACEA/Eurydice, 2019) a lack of familiarity with ICTs for both teachers and students has been highlighted throughout the Coronavirus pandemic (van der Vlies, 2020).

Adding further to teachers' challenges is the multifaceted aspect of DT (concepts, skills, principles, ICTs, hardware/software, etc.) and evolving nature of each, which requires teachers to continually upskill to ensure they stay aware of advancements (Johnson et al., 2017; Lindberg et al., 2017; Munasinghe et al., 2021).

Misconceptions surround this learning area due to the changing focus of DT from its vocational Technology beginnings (Funke et al., 2016; Reinsfield, 2018), lack of global agreement on basic concepts within this learning area (Falkner et al., 2019; Garvin et al., 2019), widely recognised male-oriented stereotype (Cheryan et al., 2015; Geldreich & Hubwieser, 2020) and disagreement around the most effective methods to deliver the content (McGarr & Johnston, 2020). Of particular concern is that educators, parents, and students have been seen to develop a range of inaccurate perceptions about the nature and purpose of DT, which affect their attitudes towards teaching and learning DT (Heintz et al., 2016; Hestness et al., 2018; Reinsfield & Fox-Turnbull, 2020; Munasinghe et al., 2021).

Developing the pedagogical approach required to effectively teach DT has also been seen to challenge some teachers set in typically traditional teaching methods (Geldreich & Hubwieser, 2020; Lindberg et al., 2017), and, as yet, there are very few initial teacher education programmes that explicitly teach these pedagogical practices (Cai & Gut, 2020).

Unsurprisingly these challenges have hindered and even ceased some teachers' implementation of the DT curriculum as they attempt to overcome barriers to deliver the content as intended (Munasinghe et al., 2021; Larke, 2019).

This literature review provides a global insight into the state of DT education in primary school settings. It is anticipated the findings will be used to aid decision making around boosting teachers' DT implementation, ultimately better preparing students for their future work, life and citizenship (OECD, 2018b).

## 2 Method

A systematic literature review process was undertaken following the transparent method set out by Tranfield et al. (2003). This method has been used by other educational technology researchers such as Sarker et al. (2019), Spiteri and Chang Rundgren (2020) and Mantilla and Edwards (2019) to identify any research gaps and link themes across relevant literature on their studied phenomenon. Designed to ensure decisions are informed by rigorous and unbiased evidence, the review process

**Table 1** The Procedure for Selecting Studies for the Review Based on Inclusion and Exclusion

Inclusion	Exclusion
1. Empirical studies related to the teaching of DT concepts.	1. Studies that do not relate to the teaching of DT concepts.
2. Research involving teacher participants (including pre-service teachers).	2. Research not involving teacher or pre-service teacher participants.
3. Primary school focus.	3. Studies that did not have a primary school focus.
4. Published between 2015 and 2022.	4. Studies published prior to 2015.
5. Contributed to accumulated evidence for one country.	5. Where there were less than two studies per country.
6. At least two studies for each country.	6. Articles were limited to five per country based on relevance to inclusion criteria.
	7. Literature that had not carried out a study, e.g., literature reviews, reports.
	8. Articles that were superseded by a newer publication of the same research.

consists of three stages: (1) planning the review, (2) conducting the review, and (3) reporting and dissemination (Tranfield et al., 2003).

## 2.1 Research design

The iterative planning stage consisted of scoping the research area to define, clarify and refine the literature review based on the aim of the study to investigate primary school teachers' experiences with digital technology curricula. The history of DT from its vocational Technology beginnings was uncovered, and a clear distinction was made between the studied DT phenomenon and the Technology/ICT/eLearning subject.

## 2.2 Inclusion and exclusion criteria

Initial inclusion and exclusion criteria were developed to limit the review to literature related to the teaching of DT (or equivalent) concepts at a primary school level. After initially scoping the research area, exclusion criteria 2 and 7 were added to ensure selected literature provided empirical evidence from teachers' perspectives and that additional weighting wasn't placed on findings from the same research. The final inclusion and exclusion criteria are shown in Table 1.

## 2.3 Search strategy

The review was conducted in June 2021 through the University of Auckland catalogue, Proquest and Science Direct databases. Each database was searched using the following terms ("Digital Technologies" OR "Information Technologies" OR "Digital Literacy" OR "Computing" OR "Computational thinking" OR "Computer Science" OR "Informatics" OR "Informatiks" OR "Computation" OR "ICT" OR

“Information and Communications Technology” OR “Technology” OR “Computational Thinking” AND “school” OR “primary” OR “education” OR “curriculum” OR “teacher” OR “pedagogy”.<sup>1</sup> Further searches were undertaken adding the name of countries that were identified as having DT components within their curriculum to the search string.

After conducting the searches and removing any duplicate articles, the inclusion and exclusion criteria were used to examine the article title firstly, then the abstract and finally the entire article to uncover publications relevant to this review. This process enabled the quick removal of articles that did not meet the specific criteria developed in the planning stage yet was thorough enough to ensure that those that were relevant were not mistakenly dismissed. Many journals were quickly eliminated as the title and abstract suggested they related to eLearning rather than DT.

### 3 Results

Twenty-three articles across 11 countries were found to (1) be relevant to the scope of this literature review as outlined in the selection criteria, (2) have employed high-quality research methodologies and (3) have undergone a peer-review process. A summary is provided in Table 2.

### 4 Findings

The following five themes emerged from the thematic analysis.

#### 4.1 Introduce DT concepts to primary school-aged students

Within the reviewed literature, the following countries were referenced as introducing DT curriculum at a primary school level (or younger); United Kingdom, Poland, Australia, Scotland, Ireland, USA and New Zealand (Duncan et al., 2017; Funke et al., 2016; Sentance & Csizmadia, 2017; Vivian et al., 2020).

Cited benefits of this approach included (1) students learn to be creative with technology (Funke et al., 2016), (2) students are able to develop a positive image of DT before stereotypes and a negative attitude towards DT generally (Bower & Falkner, 2015; Funke et al., 2016), (3) tapping into students' interests by teaching DT skills across learning areas, and (4) increased learning outcomes, self-esteem and motivation (Geldreich & Hubwieser, 2020).

Critics of this approach believe that students at a primary school level do not have the required cognitive abilities (including mathematical and literacy skills) to understand abstract DT concepts (Ng, 2017; Sentance & Csizmadia, 2017). Emphasis was also placed on how primary aged students lacked the psychological skills, social

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<sup>1</sup> Truncation was used on relevant keywords to broaden the results to include various word endings and different spellings.

**Table 2** Overview of Selected Literature Ordered According to Author Name and Publication Year

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Bower and Falkner (2015) Australia	Pre-service teachers' misconceptions of computational thinking.	Questionnaire.	$n = 38$	Pre-service teachers are not ready to teach computational thinking. They need experience with relevant ICTs, to develop a better understanding of what Computational thinking means and to develop appropriate pedagogical strategies.
Bower et al. (2017) Australia	Impact of Professional Learning and Development on teachers' computational thinking knowledge and pedagogical capabilities.	Pre and post workshop questionnaire.	$n = 69$	Teachers' understanding of computational thinking, the pedagogy behind teaching computational thinking and their computational thinking self-efficacy were improved through the delivery of relatively short targeted Professional Learning and Development. Teachers claimed additional resources, time, and Professional Learning and Development would support their growth even further.
Chang and Peterson (2018) USA	Pre-service teachers' perceptions of computational thinking.	Artefacts and reflections.	$n = 59$	Participants were seen to identify the value and relevance of computational thinking to students, but there were varied responses as to where they felt this learning fits within education. Many computational thinking misconceptions were discovered.
Corradini et al. (2017) Italy	Teachers' conceptions about computational thinking.	Questionnaire.	$n = 972$	While participants understood ICTs are not needed to teach CS and knew computational thinking is not solely coding or using ICTs, many teachers were unable to provide a complete and sound definition of what computational thinking is.

Table 2 (continued)

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Duncan et al. (2017) New Zealand	Teachers' beliefs around computational thinking in primary schools.	Questionnaire.	$n = 13$	When teachers were given adequate support, they were found to be capable of teaching the developed material and overcome their DT misconceptions. Participants discovered benefits of teaching DT such as unexpected opportunities for cross-curricula teaching and enhanced student engagement.
Falkner et al. (2019) Australia, England, Ireland, Italy, Malta, Scotland, USA	Comparison of intended curriculum against enacted CS curriculum with a focus on CS topics and programming languages.	A country report questionnaire and a teacher questionnaire.	$n = 203$	The CS topics teachers were found to teach the most were algorithms, programming, computational thinking and data representation. The topics taught least were Machine Learning and Artificial Intelligence. Teachers were found to teach using both unplugged and visual programming in lower years, with an increase in the number of teachers using text-based programming with students aged eleven and older.
Funke et al. (2016) Germany	Teachers' opinions of the CS education in primary school settings.	Interviews.	$n = 6$	Most teachers felt it is important for students to move past simply using ICTs, but they did not feel confident to teach CS without additional training.



**Table 2** (continued)

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Geldreich and Hubwieser (2020) Germany	Teachers' perspectives on implementing algorithms and programming to primary aged students in formal and non-formal formats.	Interviews.	$n = 40$	Almost all participants felt students should be given the opportunity to learn programming in some form (formal or non-formal formats). The majority of challenges raised by teachers in regard to implementing programming in a formal class setting were practical in nature relating to individual school settings.
Heintz and Mannila (2018) Sweden	Impact of Professional Learning and Development on teachers' computational thinking implementation.	Observations.	$n = 70$	This study found the following: (1) teachers were confident implementing the same lesson provided in the Professional Learning and Development in their own classrooms, (2) teachers were competent at adapting provided material to their own setting, and (3) teachers were reluctant to lead Professional Learning and Development and recruit other teachers within their schools.
Kong et al. (2020) Hong Kong	Impact of Professional Learning and Development on teachers' computational thinking development in relation to programming.	Questionnaire & self-reflections.	$n = 76$	This research found teachers' capacity to implement programming education with a focus on computational thinking skills was improved after completing the Professional Learning and Development. Improvements were found in three of the four technological pedagogical content knowledge (TPACK) dimensions.

Table 2 (continued)

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Larke (2019) England	The motivations and influence teachers have over enacting the CS curriculum.	Observations, interviews, and artifacts.	$n = 4$	Teachers viewed the content of the CS curriculum as: (1) too narrow, (2) too difficult to teach without additional resources, (3) a lower priority than other learning areas, (4) requiring unrealistic student prerequisite skills and (5) not meeting their professional standards. These beliefs caused teachers to neglect the implementation of this learning area.
Mannila et al. (2018) Sweden	Understand teachers' digital competence self-efficacy and training needs.	Questionnaire.	$n = 530$	Participants were most confident with information and data literacy and least confident with respect to programming and copyright/licenses. The findings suggest that personalised training is required to meet the different self-efficacy needs of teachers.
Munasinghe et al. (2021) New Zealand	Teachers' understanding of computational terms related to computational thinking concepts and the impact of Professional Learning and Development.	Pre- and post-Professional Learning and Development questionnaire	$n = 41$	Even when teachers understand the meaning of jargon, there may be issues in teachers' understanding due to the computational meaning being unknown or the context being unclear. Appropriate support was shown to enhance teachers' understanding of the techniques and skills that the jargon refers to.

Table 2 (continued)

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Ng (2017) Hong Kong	How to upskill pre-service teachers to teach coding education.	Case study.	$n = 10$	Participants mastered basic coding skills and were able to design and reflect on learning activities after a short amount of Professional Learning and Development. The learning of coding using a sequential program of logical concepts was found to be appropriate.
Pargman et al. (2020) Sweden	Understanding the tensions teachers face when learning to teach computational thinking.	Reflective notes.	$n = 200$	Teachers experience three types of tensions while undertaking computational thinking Professional Learning and Development. These tensions relate to understanding the content and scope of Computational Thinking in a primary school setting, connecting programming to their own unique setting and understanding the rationale behind teaching computational thinking.
Pears et al. (2017) Sweden, Finland and Lithuania	Teachers' perspectives of computational thinking and computing.	Questionnaire.	$n = 213$	In-service teachers were found to be competent in managing the transition to the new curriculum, yet many teachers were experiencing a lack of support, particularly in relation to accessing teaching materials.
Reinsfield and Fox-Turnbull (2020) New Zealand	Using networks of expertise to upskill Technology teachers.	Interviews, meetings and online tasks.	$n = 3$	The Professional Learning and Development was found to assist teachers' perceptions and understandings of the nature of Technology as a curriculum subject. Teachers described the pressures around student achievement and alignment of their teaching with the new curriculum content.

Table 2 (continued)

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Rich et al. (2020) USA	Measure teachers' value, self-efficacy and teaching beliefs about coding and Computational Thinking.	Questionnaire.	$n=245$	Teachers' teaching efficacy for computing increased the most as they taught coding while significant increases were also seen in their self-efficacy for coding and computational thinking.
Rich et al. (2021) USA	Impact of Professional Learning and Development on teachers' knowledge and efficacy beliefs for coding and computational thinking.	Questionnaire.	$n=127$	Teachers' confidence in coding and computational thinking increased from the beginning of the Professional Learning and Development to the end one year later. The largest growth was seen in basic coding concepts with teachers still lacking confidence in more difficult concepts (variables, functions etc) after the year of Professional Learning and Development.
Sentance and Csizmadia (2017) England & Ireland	Teachers' perspectives on challenges and strategies when implementing the Computing curriculum.	Questionnaire.	$n=117$	40% of challenges teachers faced were directly experienced by teachers, 38% related to difficulties faced by students and 16% related to resource constraints. The successful strategies used by teachers when implementing the Computing curriculum were categorised into the following five themes: (1) unplugged type activities, (2) contextualisation of tasks, (3) collaborative learning, (4) developing computational thinking, and (5) scaffolding programming tasks.

**Table 2** (continued)

Reference & Country	Focus of study	Design Assessment measures	Sample size	Outcomes/findings
Vivian and Falkner (2019) Australia	Teachers' confidence about algorithms and programming using the TPACK framework.	Online support group posts and pre and post course questionnaire.	$n = 124$	A significant relationship was found between teachers CS confidence and their Technological Knowledge, Content Knowledge, Technological Pedagogical Knowledge, and Technological Content Knowledge.
Vivian et al. (2020) Australia, England, Ireland, Italy, Malta, Scotland, USA	Teachers' CS self-esteem.	Questionnaire.	$n = 56$	The following differences in CS self-esteem were found: (1) female teachers reported significantly lower CS self-esteem than male teachers, (2) primary teachers were found to have lower levels of CS self-esteem than secondary teachers, (3) teachers with no CS teaching experience reported significantly lower CS self-esteem than their peers and (4) teachers with less than 3 years' experience teaching CS had negative CS self-esteem.
Yadav et al. (2017) USA	Pre-service teachers' perceptions of computational thinking and how it can be implemented within their classrooms.	Questionnaire.	$n = 134$	Pre-service teachers with no previous exposure to computational thinking were shown to have a very basic understanding of computational thinking. Common misconceptions around computational thinking were that it is simply problem-solving or logical thinking and requires the use of computers.

skills, problem-solving skills and resilience to complete complicated DT skills and interact safely with ICTs (Sentance & Csizmadia, 2017; Larke, 2019; Ng, 2017). Furthermore, they suggest that many primary school teachers lack the foundational knowledge on which to build their understanding and teach DT effectively (Falkner et al., 2019; Vivian et al., 2020), which causes challenges for governments in ensuring both in-service and beginning primary school teachers are fully supported to implement the DT curriculum (Falkner et al., 2019).

## 4.2 Integrate DT concepts across learning areas

The literature review revealed 12 articles that discussed the approach of integrating DT across learning areas, as outlined in Fig. 1.

Advocates for this approach claim DT lends itself well to be integrated within other learning areas because (1) there are many connections with mathematics and problem-solving concepts (Duncan et al., 2017; Funke et al., 2016), (2) it enhances learning in other areas, (3) it aids students' competency development, (4) it has a smaller impact on classroom time than the creation of a whole new subject area would (Bower et al., 2017; Duncan et al., 2017), (5) planning and integration is simple as students generally have the same primary teacher across learning areas (Duncan et al., 2017; Vivian & Falkner, 2019) and (6) this approach aids teachers' understanding that DT skills are transferable beyond the DT learning area (Chang & Peterson, 2018; Duncan et al., 2017).

Alternatively, Bower and Falkner (2015) claim teachers require specific pedagogical skills to integrate DT within learning areas effectively, and Chang & Peterson (2018) suggest current teachers have not been given guidance to develop these skills and are not prepared to teach this way. Larke (2019) raised further concerns regarding teachers' abilities to translate the curriculum into lesson plans that meet the learning objectives for both DT and the learning area DT is being integrated with.

Additional concerns were raised against this approach due to the (1) undervaluing of DT as a distinct discipline on par with Maths or English (Bower & Falkner, 2015; Larke, 2019), (2) belief it gives rise for teachers to develop misconceptions about what DT really is (Corradini et al., 2017) and (3) belief it can lead to aspects of DT becoming lost (Bower & Falkner, 2015). Finally, Pears et al. (2017) claim that developing curricula that integrate CT components requires long term systematic work to ensure its effective implementation.

## 4.3 Factors impacting DT implementation

The major factors described in the literature to influence teachers' development of DT knowledge and DT implementation were found to fall into the following six themes: (1) support, (2) curriculum, (3) Professional Learning and Development, (4) teacher, (5) limited DT research and (6) resources. Like the work of education researchers Lamb and Branson (2015), Valsiner's (1997) zone framework was used to analyse the factors and themes uncovered in this review.

Vygotsky's (1987) Zone of Proximal Development theory is commonly used in education to recognise the learning that occurs when students master new skills and concepts (often with support) that have not previously been studied but are still within their reach. Valsiner's (1997) zone theory builds on this by recognising that the quality of learners' Zone of Proximal Development varies widely. Valsiner extended Vygotsky's Zone of Proximal Development theory to include the Zone of Free Movement (ZFM) and Zone of Promoted Action (ZPA), which consider, respectively, the goals and actions of the learner as well as their social setting (Goos, 2009). This theory assumes that learning takes place within the intersection of all three zones, as shown in Fig. 2.

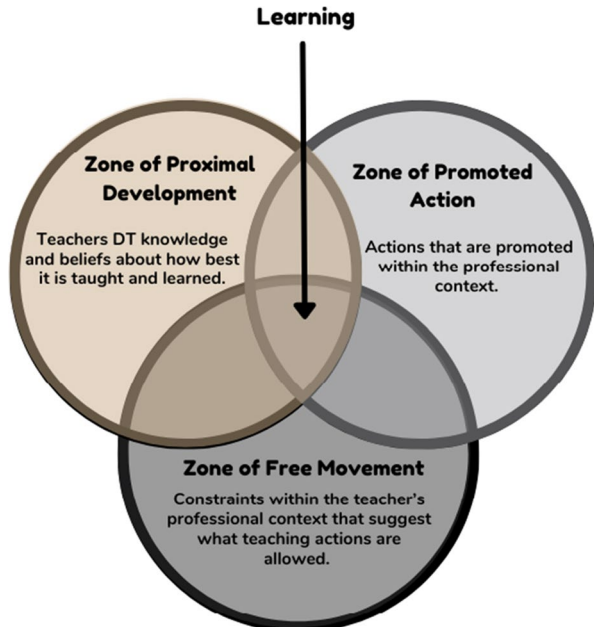
Table 3 categorises the factors found in the literature review to impact teachers' development of DT knowledge and DT implementation into Valsiner's (1997) three zones. The teacher as learner definition of zones often applied in educational research to investigate teachers' response to change was used within this analysis (Bennison & Goos, 2013).

Analysing the reviewed literature using Valsiner's Zone lens provides an outline of the varying facets influencing teachers' development of DT knowledge and their implementation efforts. It highlights the holistic support that teachers need to develop their DT knowledge and boost their implementation.

#### 4.4 DT misconceptions

More than half the reviewed articles described DT misconceptions and gender/racial stereotypes held by teachers, students, caregivers, and the wider community. The underlying causes of confusion around the purpose and importance of DT were attributed to the evolution of technology from its vocational beginnings (Reinsfield

**Fig. 2** Valsiner's Zones. Note. From "Exploring numeracy teacher identity: An adaptation of Valsiner's zone theory" by Bennison & Goos (2013, p. 4). Copyright 2013 by Crown AARE



**Table 3** Factors Impacting Teachers' Development of DT Knowledge and/or DT Implementation Categorized by Valsiner's Zone Theory

Zone	Identified factor impacting teachers' development of DT knowledge and/or DT implementation
Zone of Proximal Development	<ul style="list-style-type: none"> <li>• ICT knowledge and self-efficacy</li> <li>• DT knowledge and self-efficacy</li> <li>• Twenty-first-century pedagogical knowledge and beliefs</li> <li>• Reflection on practice</li> <li>• Curriculum interpretation</li> <li>• Level of DT misconceptions</li> <li>• Beliefs, attitudes, and dispositions towards DT</li> <li>• Awareness of available DT support</li> <li>• Beliefs around benefits of DT to students</li> <li>• Ability to apply DT learning across learning areas</li> <li>• Role of DT has evolved from its vocational beginnings</li> </ul>
Zone of Free Movement	<ul style="list-style-type: none"> <li>• Access to ICTs and teaching materials</li> <li>• Access to technical support</li> <li>• Students abilities, motivations and behaviours</li> <li>• Available time to: undertake DT Professional Learning and Development, plan for DT implementation, implement DT in the classroom, take risks implementing DT, and reflect on DT implementation.</li> <li>• Curriculum requirements</li> <li>• Technical curriculum</li> <li>• Available funding for ICTs and Professional Learning and Development</li> </ul>
Zone of Promoted Action	<ul style="list-style-type: none"> <li>• Shared consensus on DT outcomes, concepts and terminology</li> <li>• School leaders: understanding of the DT curriculum, prioritisation of DT, expectations of teachers' DT implementation, initial and continual support of teachers' DT practice</li> <li>• Promotion of internal and external partnerships</li> <li>• Pre-service teacher DT education</li> <li>• Access to Professional Learning and Development</li> <li>• Environment where change is supported and risk-taking is promoted</li> <li>• Support from teaching colleagues, e.g., communities of learning</li> </ul>

& Fox-Turnbull, 2020) and the newness of the topics for many teachers (Duncan et al., 2017). Other misconceptions described throughout the reviewed literature related to beliefs that (1) DT is just programming (Duncan et al., 2017), (2) DT is simply teaching “with” technology (Bower et al., 2017; Falkner et al., 2019; Yadav et al., 2017), (3) computational thinking is only relevant to the CS learning area (Chang & Peterson, 2018), and (4) computational thinking is just problem solving (Yadav et al., 2017). Additionally, the jargon associated with this learning area was seen to contribute to teacher and student misconceptions and misunderstandings of technical aspects (Munasinghe et al., 2021).

Concerningly, the review revealed that teacher misconceptions often led them to interpret and introduce DT ideas incorrectly, miss picking up student misconceptions (Duncan et al., 2017) and, in some cases, not implement the DT curriculum at all (Munasinghe et al., 2021; Larke, 2019). Funke et al. (2016) described the long-term impact of these misconceptions on high schools and universities, who are



required to counteract students' misunderstandings and stereotypes towards CS in order to generate demand for this important learning area.

While the importance of addressing DT misconceptions was dominant throughout all the relevant literature, only four articles provided potential solutions. Bower et al. (2017) and Duncan et al. (2017) both believed teachers' misconceptions were best addressed within DT Professional Learning and Development. Yadav et al. (2017) stated that connecting teachers to skills and resources was the most appropriate approach to dispel misconceptions and Funke et al. (2016) believed introducing DT concepts to students at an early age would help to foster a positive image of DT before misconceptions and stereotypes had a chance to develop.

#### 4.5 Teachers' DT self-efficacy/DT self-esteem/DT confidence

Within education, teachers' DT self-efficacy, self-esteem and confidence have been shown to effect long term change due to the influence they have on teachers' motivation (Mannila et al., 2018), behaviour (Bower et al., 2017; Mannila et al., 2018), commitment to teaching DT (Bower et al., 2017; Rich et al., 2020), and perseverance and resilience in the face of adversity (Mannila et al., 2018; Rich et al., 2021). Vital to this technical learning area, Vivian & Falkner (2019) found teachers with higher DT confidence used technical language and referenced learning objectives more than those with lower levels.

Throughout the articles within the literature review, many factors were seen to affect a teachers' DT self-esteem/self-efficacy/confidence, including teachers' background skills, knowledge, confidence, their beliefs around DT (Rich et al., 2020; Rich et al., 2021), experiences teaching DT (Bower et al., 2017), support from parents, students, school leadership teams, opportunities to observe other teachers (Bower et al., 2017; Vivian et al., 2020) and their self-evaluation of what is 'good enough' (Vivian et al., 2020).

Vivian and Falkner (2019) noted that females (comparative to males), primary teachers (comparative to secondary teachers), and teachers with no CS teaching experience (against those with CS teaching experience) had lower CS self-esteem than their counterparts with the differences attributed to the newness of CS to primary schools and teachers' lack of experience with this learning area.

Manilla et al. (2018) discovered that teachers were seen to hold similar levels of self-efficacy across all digital competency areas, e.g., teachers with low DT self-efficacy had low competencies across all DT areas and vice versa. This led them to claim that teachers with different self-efficacy (low, medium, high) have very different learning needs that are not met by one-size-fits-all Professional Learning and Development. Conversely, Duncan et al. (2017) and Rich et al. (2021) found that teachers' confidence did, in fact, relate to the specific DT concept investigated, with Rich et al. (2021) finding teachers were less confident in their knowledge of functions, conditions, variables, abstraction and decomposition.

Rich et al. (2021) found that, after undertaking a yearlong Professional Learning and Development course teachers experienced increased confidence for teaching CT and coding. Supporting this, teachers taking part in Bower et al.'s (2017) research

initially reported that the biggest impact on their DT implementation was a lack of confidence teaching CT, whereas, after attending a one-day CT workshop, this had shifted, and they claimed insufficient resources was now their biggest challenge.

Teachers' DT self-esteem has also been shown to increase alongside students' success with DT learning, suggesting that (1) teachers should give implementation a go even if they lack confidence with this learning area and (2) Professional Learning and Development should be long-term and allow opportunities for teachers to concurrently teach DT with their students (Rich et al., 2021).

Collectively these studies outline the urgent need to raise teachers' confidence to teach DT through the provision of Professional Learning and Development and resources in order to provide students with learning opportunities reflective of the twenty-first century (Bower et al., 2017; Rich et al., 2021).

## 5 Discussion and conclusion

DT education has the ability to develop students' understanding, competencies and beliefs to ensure they can benefit from and contribute to the complex society and demanding labour market of their future. This literature review found numerous challenges unique to DT impacting teachers' implementation and a lack of consensus on appropriate approaches to introducing these concepts to primary school curricula.

This review highlighted that DT learning increases primary school students' creativity, confidence, attitudes, and interest in DT (Bower & Falkner, 2015; Funke et al., 2016; Geldreich & Hubwieser, 2020), although concerns around primary aged students' ability to comprehend particular DT concepts (Larke, 2019; Ng, 2017; Sentance & Csizmadia, 2017) and fears primary school teachers lack the ability to effectively implement the new curriculum were raised (Falkner et al., 2019; Vivian et al., 2020).

While following a cross-curricula approach was believed to result in enhanced learning across multiple areas of students' lives (Chang & Peterson, 2018; Duncan et al., 2017), it does require specific skills for planning and teaching (Bower & Falkner, 2015; Corradini et al., 2017; Larke, 2019; Pears et al., 2017) to ensure DT concepts are not lost, underrepresented, or misinterpreted (Bower & Falkner, 2015; Larke, 2019). Concerningly, Chang and Peterson (2018) believe teachers are yet to be given the necessary support to develop this pedagogy.

This literature review found the majority of factors influencing teachers' DT implementation come from a personal level rather than from within teachers' social setting. Relating this discovery with the work of Bower et al. (2017) and Duncan et al. (2017) leads us to believe that the most efficient way to support teachers' implementation is by addressing challenges and misconceptions through Professional Learning and Development. This literature review found very little research that analysed the type of Professional Learning and Development delivered, and no literature was found that compared different models of Professional Learning and Development or the long-term impact of the Professional Learning and Development on teachers' implementation. Further studies are needed to understand the effect of

different Professional Learning and Development models on teachers' DT implementation to inform decision making around boosting teachers' implementation.

This literature review provides a thorough examination of primary school teachers' experiences with DT curricula across eleven countries and provides an understanding of the issues impacting teachers' implementation. It recognises the role education and DT curricula, in particular, has in preparing students to be active and contributing participants in a sustainable future and highlights recommendations on how teachers' implementation can be supported further.

## Declarations

**Competing interests** The authors report there are no competing interests to declare.

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