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Towards a pedagogical model of teaching with ICTs for mathematics attainment in primary school: A review of studies 2008–2018

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ABSTRACT

This article reviews literature in the field of ICTs in teaching/learning mathematics at an elementary school level. The findings to date in the field of teaching with technology in mathematics classrooms are very conflictual, with some studies indicating that ICTs impact positively on achievement through altering pedagogy, while other studies indicate that the effect on achievement and pedagogy is in fact negative. The current paper seeks to address the conflictual data by analysing a variety of meta-analyses and studies in order to answer the following questions: Does pedagogy alter with the use of ICTs in grade 6 mathematics classrooms and if so, in what ways does it vary? Secondly, does student achievement in mathematics change with the use of ICTs as teaching tools and if so, in what ways does it do so? Findings from the review indicate that student achievement in mathematics can be positively impacted using technology, *depending* on the pedagogical practices used by teachers. Technology on its own appears to have no significant impact on student's attainment. There is a dearth of findings regarding pedagogical variation with ICTs outside of a single meta-analysis that indicates that a 'constructivist' approach to teaching/learning with technology is the most effective approach to developing students' conceptually. Due to this gap in the literature, the paper outlines a theoretical framework for providing a nuanced study of pedagogical variation with ICTs drawing on Cultural Historical Activity Theory and TPACK that can track pedagogical change along various dimensions.

1. Introduction

Almost all schools in the 21st century make use of Information Communication Technologies (ICTs) as tools for teaching. Even in the developing world context, ICTs feature prominently in schools. The assumption underlying the use of ICTs in schools is that they impact positively on student outcomes. However, the extent to which ICTs can achieve this depends on how a computer is used as a learning/teaching tool: that is, how the computer affects pedagogical practices (Li and Ma, 2011; Hardman, 2015). The research regarding the impact of ICTs on altering pedagogy is highly conflicting, with three distinctly different results reported: first, the research indicates that ICTs do not alter pedagogy (Cassim, 2010); second, a body of work suggests that ICTs change pedagogy positively (Webb and Cox, 2004; Bosamia, 2013) and finally, contradicting this finding there is research suggesting that ICTs negatively impact on pedagogy (see for example Hardman, 2015; Baker, 2019). In a bid to gain clarity regarding whether ICTs impact positively on mathematics attainment at primary school and, if so, what pedagogical practices appear most effective to achieve this outcome, the current paper presents a review of ten years of studies conducted in the field. Two research questions are addressed in this paper:

1. Do ICTs impact positively on mathematics outcomes in elementary school and
2. Does pedagogy alter with ICTs and, if so, in what ways does it alter?

2. Theory

2.1. Methodology

While this article is not a systematic review of the literature in the field, I draw on the logic underpinning systematic reviews in order to select the parameters for the review. A systematic analysis enables one to draw conclusions from a wide selection of evidence-based studies (Dewey and Drahota, 2016). All studies within the research parameters are included, across a number of data bases, potentially lessening selection bias and setting out the parameters for other researchers to follow. This allows for what Pittway (2008) defines as the 7 key features of a

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systematic literature review; transparency, clarity, integration, focus equality, accessibility and coverage. These key features of a systematic review inform the current review, which is concerned exclusively with studies from 2008-2018. The need for such a review arises from the fact that of 13 meta analyses located regarding teaching/learning with ICTs in mathematics classrooms, only four fall within the search period of 2008–2018 (Tamim et al., 2011; Higgins et al., 2012; Li and Ma, 2011; Cheung & Slavin, 2013). I note here that the search terms focus specifically on mathematics; the work of Chauhan (2017) is much broader than mathematics but is referenced in the current review in terms of student attainment). The use of ICTs in schools has grown steadily and there is a need to understand what more novel technology, such as mobile telephony or iPads is potentially having in mathematics classrooms. In a bid to develop a pedagogical model capable of outlining how best to teach with ICTs, the review also engaged theoretically with the body of knowledge that comes out of Cultural Historical Activity Theory (Wood et al., 1976; Gallimore and Tharp, 1993; Hedegaard, 2002, 2009; Hedegaard and Chaiklin, 2005; Mercer, 2000a, 2000b; Cazden, 1986, 2001; Wells, 1999; Piaget, 1976, 1977; Engeström, 1999a, b, 1987) . As noted in the abstract, this review is concerned to answer the following question: Does pedagogy alter with the introduction of ICTs in grade 6 mathematics classrooms? The following questions are investigated in this review:

1. How does pedagogy change in ICT based classrooms?
2. What pedagogical practices are shown to be effective in ICT rich environments?
3. What impact does teaching/learning with ICTs have on student attainment in grade 6 mathematics classrooms?

The question guiding this review served as a first instance of a parameter for inclusion/exclusion. Studies not related to mathematics or related to learning mathematics in secondary school and Higher Education were excluded. This is because mathematics becomes much more specialised as one leaves primary school, with teachers specialising in that subject. At a primary level, teachers teach all subjects as well as mathematics and may, therefore, not be as specialised in this content area as high school or higher education teachers. The review also limited itself to the decade of 2008–2018 as there is a body of research available about ICT use in mathematics prior to 2008 and much has altered in the technological field since then. The following steps were followed to retrieve data: Frist I searched only English data bases as I am a first language English speaker. These included, ERIC, EBSCOHOST; HUMANITIES INTL; JSTOR, PsycINFO, Education (A SAGE Full-Text Collection), COMPUTERS AND APPLIED SCIENCES, as well as Google Scholar. We used Boolean operators, parentheses, and wildcards to develop the following query: [(pedagogy) AND math* AND (ICTs* OR intervention* OR treatment*)]. I selected based on the following criteria:

1. Studies fell between 2008-2018
2. They addressed teaching/learning mathematics with ICTs in elementary schools
3. They were in peer reviewed journal articles or books

I excluded unpublished dissertations or theses as I wanted to present a picture of what is published in the field. The grey literature I sourced was located with the assistance of a librarian from Google Scholar. Only one piece of grey literature met the criteria for inclusion. Altogether 37 studies were reviewed, 9 of which were meta-analyses and one which was a systematic review of the literature. The findings from the studies are presented below.

2.2. Findings: teaching mathematics at primary school with ICTs

2.2.1. Math attainment with ICTs at a primary level

In what follows, I address the following question outlined in the introduction: What impact does teaching/learning with ICTs have on student attainment in grade 6 mathematics classrooms?

The research regarding the impact of ICTs on mathematical attainment points clearly to the fact that ICTs, at a primary school level, do indeed impact positively on student outcomes (Tamim et al., 2011; Higgins et al., 2012; Li and Ma, 2011; Cheung & Slavin, 2013; Demir and Basol, 2014; Chauhan, 2017; Slavin et al., 2009; Slavin and Lake, 2009; Rakes et al., 2010). Tamim et al. (2011) performed a second order meta-analysis drawing on 25 meta-analysis over a 40-year period and draw the conclusion that "the average students in classrooms where technology is used will perform 12 percentile points higher" than a student in a more traditional classroom where technology is not used (Tamim et al., 2011: 17). However, one meta-study (Campuzano et al., 2009) indicates that mathematics attainment in primary school is not impacted at all by ICTs. This study is critiqued by Cheung & Slavin (2013) due to what they see a methodological flaw in the meta-analysis. They go on to illustrate in their own meta-analysis of 74 studies that attainment in mathematics is positively impacted by the use of ICTs. Further findings from the meta-analyses reviewed indicate that students with special needs benefit more from technological input than neurotypical students (Li and Ma, 2011; Higgins et al., 2012) and primary school students benefit more from ICT use than secondary school students. Gender, race and socioeconomic status show no significant effects in the use of ICTs on mathematics attainment. Moreover, in relation to mathematics learning, Li and Ma (2011) show that students tested using non-standardised tests as opposed to traditional, standardised tests to measure attainment have more positive outcomes. Tamim et al. (2011) further indicate that computer technology that supports instruction is more effective than technology that offers direct instruction. This points to the importance of the pedagogical basis of ICT use. The authors are clear to highlight that technology on its own has little benefit to the student but rather, how it is used and how it is designed is important in determining whether or not it will be effective in improving student outcomes. This sentiment is echoed by the work of Higgins (2012) who state that "it is therefore the pedagogy of the application of technology in the classroom which is important: the how rather than the what" (3).

2.2.2. Pedagogical change with ICTs-what works?

While the discussion above indicates that technology impacts on attainment in mathematics, it points to the need to understand pedagogy as the dynamic force behind this change. In what follows the following two questions are addressed.

1. How does pedagogy change in ICT based classrooms?
2. What pedagogical practices are shown to be effective in ICT rich environments?

While there is a significant body of research that speaks to mathematical attainment with ICTs, there is a paucity of published studies that investigate variation in pedagogical practices with ICTs. The most detailed engagement with the question of pedagogy and ICTs is arguably that done by Webb and Cox (2004), which is extremely dated. This is particularly problematic when one notes that the findings of positive mathematical attainment caution that this is only possible where pedagogical practices integrate and alter in order to meet students' diverse needs. Even more problematic is the finding in some research (Hardman, 2010, 2015) that the use of ICTs alters pedagogical practices negatively, therefore negatively impacting on students' outcomes. The dearth of research speaking to pedagogical variation with ICTs is problematic, further, in that one of the most significant findings in both historical research and current meta-analyses is that ICT needs to be integrated into pedagogy for there to be any significant gains made with technology (Higgins et al., 2012). Having said this, some studies do point to what effective pedagogy with ICTs should look like, which speak to what must potentially alter in traditional pedagogy for the ICTs to be of benefit. The studies reviewed for this paper variously refer to the most effective pedagogical practices with ICTs as 'collaborative', 'pupil centred' or 'constructivist' (Li and Ma, 2011; Rosen and Salomon, 2007). What underlies these terms is the notion that children are active cognising agents (Piaget, 1976) who learn through structured engagement with more competent others (Vygotsky, 1978) to construct novel knowledge. Pointing to a dearth in findings relating to pedagogy with ICTs is the fact that only one meta-analysis (Rosen and Salomon, 2007) was located for this review and this fell outside of the review date periods selected. However, as it is the only meta-analysis comparing traditional and constructivist pedagogy and is referenced by many other studies (see for example Li and Ma, 2011), it is included in the current paper.

Rosen and Salomon (2007) carried out a meta-analysis on 32 experimental studies where they compared the outcomes of students' mathematical attainment with ICTs in 1) a constructivist pedagogy and 2) more traditional transmission-based pedagogy. For them, constructivist pedagogy is underpinned by the assumption that "real understanding of mathematics can be achieved when learners socially appropriate and actively construct knowledge" (Rosen and Salomon, 2007: 3). While the learning objectives of a more traditional transmission-based pedagogy "is to provide basic math knowledge and skills under conditions of traditional drill and practice learning" (Rosen and Salomon, 2007: 3). This echoes the definition of constructivist vs. traditional pedagogy suggested by Li and Ma (2011) who indicate that traditional pedagogy is teacher centred while constructivist pedagogy is student-centred. However, in neither of these meta-analyses do the authors outline exactly what constructivist pedagogy with computers should could look like. We are left with no sense of what dimensions of pedagogy might differ across the two contexts or indeed, how mediation occurs meaningfully in the constructivist context. Terms like 'teacher and learner' centred become mere rhetorical devices, then, not pointing to actual empirical realities. Taken to its logical conclusion, a radical constructivist view is, in my opinion, deeply problematic for teaching/learning in that it focuses solely on the student's capacity to construct knowledge, often side-lining the teacher's crucial role in this process. I have little doubt that students can indeed construct knowledge empirically, on their own, but what type of knowledge they construct when doing so is a matter for consideration. A 6-year-old who sees a dolphin will classify it as a fish because it lives in the sea, recognising that it has fins like a fish and therefore belongs to that class of animal. This of course, is a misconception; a dolphin has more in common with a cow than a fish. Without being actively taught in a structured manner by a teacher, the child cannot merely arrive at this knowledge on his/her own (Karpov, 2005). While not presenting a detailed definition of what 'constructivist' pedagogy looks like, the meta-analyses, do point to differing effect sizes between traditional and constructivist pedagogy with ICT and this is useful in providing foundation for situating further research.

Rosen and Salomon (2007) found that, when tested against constructivist-appropriate criteria, students in a constructivist-based ICT lesson performed better than those in a traditional ICT based lesson. This meta-analysis is interesting in that it suggests that a constructivist-based pedagogy with ICTs leads to better attainment that a more traditional pedagogical approach. However, as the study is a meta-analysis and is concerned with experimental comparisons, the paper does not outline exactly what pedagogical practices work best in a constructivist pedagogy or indeed, how these differ, along which pedagogical dimensions, from a more traditional approach.

These findings are slightly more elaborated in a report by the Education Research Centre (2010) who propose a view of teaching with technology that takes note of Shulman's PCK (1987) as informing pedagogical practices as well as a constructivist view of teaching which they refer to as a didactic view. For them "The basic principle of the didactic view of learning and teaching was that knowledge is not something given *out there*, so to speak, but something to be explained …[…]…Knowledge is not a given, the theory says, but built up, and transformed, and – such was the watchword – *transposed*" (Chevellard, 2007, p.132, emphasis as original). How exactly one achieves this is slightly vague in their document. While there is little argument in psychological and educational settings about the primacy of teachers in developing students' knowledge, surprisingly few ICT studies focus exclusively on pedagogy with computers (Webb and Cox, 2004 are a notable exception here, but their work is very early in the 21st century). A concern with improving performance is the focus of much of the discussion, especially in relation to mathematics classrooms. There are, however, some key historical studies in the field that focus particularly on how ICTs influence pedagogy in schools. This research supports the findings by Rosen and Salomon (2007), indicating that the most popular type of software available for use in schools is termed 'constructivist' software (Becta, 2000, 2001, 2007) and the most prevalent use of this software plays out in a 'constructivist' environment. As we have seen above, what exactly is meant by constructivism can be quite opaque. However, historically, this term draws from the Piaget (1976) and Vygotsky (1978) notions of learning as an active process, requiring participation from the child.

Piaget (1976; 1977) theory indicates that children learn actively through a process of assimilation, where they understand novel information in terms of pre-existing cognitive functions, and accommodation, where these existing structures shift because the novel knowledge clashes with what is already known. In a teaching scenario, this requires that children are afforded opportunities to interact with objects in order to develop their knowledge structures. The process, pedagogically, underlying this is called cognitive conflict and relies on the children being subject to a process of disequilibrium, where previous structures are insufficient to understand novel knowledge and must therefore shift and grow to accommodate for this knowledge (Flavell, 1963). While recognising the importance of teaching in cognitive development, for Piaget (1977) teaching is a necessary but not sufficient explanation of cognitive development and development must necessarily precede learning. Conversely, Vygotsky (1978, 1986) places teaching at the heart of cognitive development, indicating that learning leads to cognitive development, if it is properly organised. For Vygotsky, good learning, learning that leads to development, requires mediation, or structured guidance, of scientific/schooled concepts, within a unique social space called the Zone of Proximal Development (ZPD). The primary mediating tool, according to Vygotsky is semiotic mediation. Much research to date has indicated that Vygotsky's work is empirically sound in relation to learning/teaching in schools (Daniels, 2001; Hardman, 2005; Wood et al., 1976; Gallimore and Tharp, 1993; Hedegaard, 2002, 2009; Hedegaard and Chaiklin, 2005; Mercer, 2000a, 2000b; Cazden, 1986, 2001; Wells, 1999). These, then, are the theoretical foundations underpinning constructivist ICT programmes. For our purposes, this type of software can be understood as requiring some level of active construction on the student's behalf. The understanding of pedagogy as involving active, cognising agents engaged in problem solving in a mediated context leads to the following description of pedagogy mobilised in this review: *a structured process whereby a culturally more experienced peer or teacher uses cultural tools to mediate or guide a novice into established, relatively stable ways of knowing and being within a particular, institutional context in such a way that the knowledge and skills the novice acquires lead to relatively lasting changes in the novice's behaviour, that is, learning* (Hardman, 2008: 69). A description of what constitutes pedagogy, while theoretically based, needs to be operationalised if one is to study pedagogical change with ICTs in an actual classroom. Cultural Historical Activity Theory (CHAT) provides a necessary situating of human actions within the context in which they unfold and in the rest of the paper, this is explored as a framework for elaborating pedagogical change in ICT based lessons.

2.2.3. Towards a pedagogical framework for studying ICT use: A cultural Historical Activity Theory framework

Pedagogy is generally defined as the art, science or act of teaching (Webb and Cox, 2004; Watkins and Mortimer, 1999). It is, therefore, the practice that one observes in a classroom. However, pedagogy is not limited solely to what one can observe; a teacher has certain ideas, beliefs and content knowledge that informs how s/he selects what is to be taught as well as how to teach it. Shulman (1986) referred to teachers' Pedagogical Content Knowledge (PCK) as that knowledge that informs how they are to teach as well as what they are to teach. This knowledge is largely invisible to the observer. Shulman's work indicated that knowledge of pedagogical context as well as curriculum knowledge was important in determining how a teacher taught. Investigating pedagogy, therefore, requires that one study a teacher's ideas, beliefs and attitudes towards teaching as well as observing his/her practices in a classroom context.

2.2.4. Pedagogical change with ICTs- CHAT and TPACK

The question that now arises is how best to study the complexity of pedagogical change with ICTs? While Vygotsky (1978, 1986) postulated that tools (for him, primarily language, signs and symbols) could develop a child cognitively; in the 21st research is now clear that indeed, tools such as language and indeed potentially, ICTs, alter the brain because of neuroplasticity, which indicates that synaptic connections in the brain are reorganised due to learning or injury (Doidge, 2007; Sasmita et al., 2018). For Vygotsky (1978) the child is developed cognitively by a more competent other who mediates their engagement with a problem-solving task, using language, predominantly, as a cognitive tool. After his untimely death, Vygotsky's work was further developed by Leontiev (1981) with a specific focus on how practical activity serves a developmental purpose. This work in turn has been added to by Yrjo Engeström (1987) in his Cultural Historical Activity Theory approach to studying expansive, or evolutionary learning in work settings, where entire activity systems alter with the use of tools, along different sites or nodes in the activity system. Engeström focuses on an activity system as a basic unit of analysis, rather than focusing solely on an individual, as the individual's actions, thoughts and beliefs, are afforded or constrained by the system they act within. An activity system is represented as a triangle for ease of use; what is notable is that there are various nodes in the system and three mediating relationships in the activity.

If we look at Fig. 1 above, we can see a graphic representation of human action in an activity system. The **subject** is that person (individual or group) that is the focus of the investigation. The rules of the system afford and constrain behaviours, and these can be tacit as well as explicit. For Engeström (1999b), **mediating artefacts** are tools and signs employed by the subject to act on an object. Tools alter the external world and signs alter the subject psychologically. This is in keeping with Vygotsky's notion of tools and signs. However, in a later chapter in *Perspectives in Activity Theory* (1999b) Engeström suggests that making a distinction between tools and signs is not useful, as internal cognitive tools can become externalised in an activity and external tools can similarly, become internalised during an activity. Indeed, something as obviously practical as a hammer can alter the subject cognitively as well as altering the nail which it strikes. Hence, the firm distinction between practical external tools and internal psychological tools, which derives from Vygotsky's work, is not maintained by Engeström. In this article, we can conceive of ICTs as tools that alter the system, depending on how they are used. Mediating artefacts/tools are used by the subject to act on the **object** of the activity. The object is that problem space that motivates the activity. The outcome is achieved through acting on the object. **Division of labour** refers to the roles that members of the system enact, and the **community** refers to all those involved in working on a shared object. If we relate this to a classroom that is using ICTs, we could imagine the following: the subject is the teacher, who uses ICTs (tools) to act on the object (mathematical understanding) of students using ICTs (mediating artefacts) to produce mathematically competent students (outcome). This happens against a background of each participant taking on a specific role (perhaps teacher teaches, student responds) in a community that shares the common object. The activity system is governed by **rules** to allow and constrain certain actions. It is important to note that an activity system does not exist in isolation as indicated in Fig. 1 above. Human action is too complex for a single activity system to exist at any one time (Daniels, 2001). By means of an exemplar; I teach specific content at a university and am part of an activity system that focuses on this content. However, I am also a parent and inhabit that activity system too and similarly I am a member of the academy, yet another activity system, that affords and constrains what I can do in my lessons. Viewing pedagogical practices as activity systems enables us to analyse them according to the various nodes outlined above.

A further achievement of CHAT lies in its ability to track change within and between activity systems by focusing on 'contradictions' that arise within and between systems. Contradictions can be understood as 'double-binds' where actors in and across systems experience cognitive dissonance, leading to change. These dynamic sites of change are not necessarily positive; the introduction of ICTs into a school, for example, representing a novel tool, can disrupt relations within and between activity systems leading to contradictions that can impact negatively on pedagogy (Hardman, 2008, 2015).

While CHAT's description of human action as encompassing activity systems provides a strong basis for studying pedagogical change, one node in the system that could be developed further is the subject node. While Engeström (1999a, b) obviously appreciates the importance of the subject's beliefs and ideas in relation to their actions within the activity, he does not elaborate on this in relation to ICT use (although see Lim &

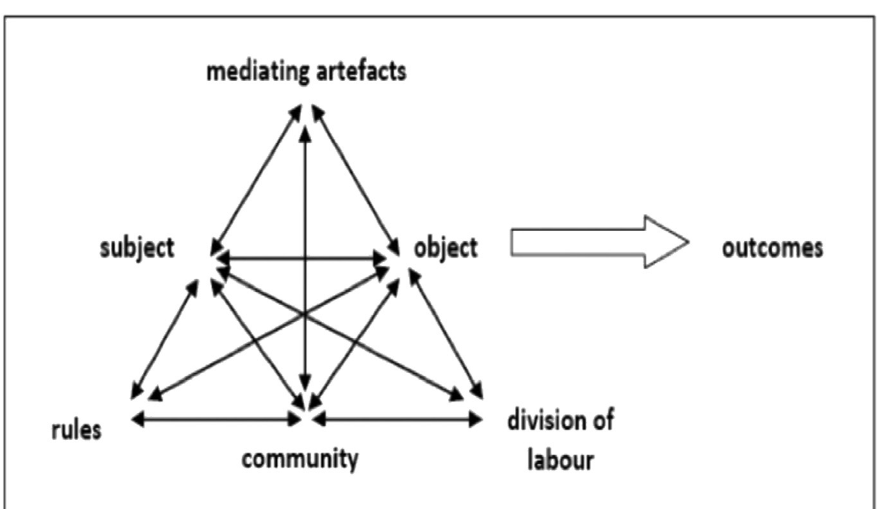

Fig. 1. The activity system.

Chai, 2004, who do go some way to developing this using Engeström's work). Here I will introduce the notion of TPACK as a model for developing the subject position more fully to enable a deeper framework for studying pedagogical change with computers.

2.2.5. TPACK and CHAT-fleshing out the subject

Built on Shulman (1986) model of PCK, Technological Pedagogical Content Knowledge (TPACK) adds the dimension of technology to Shulman's initial model (Mishra and Koehler, 2006). As noted above, pedagogy is extremely complex and studying it requires more than merely observing a teacher teach: one needs to know also how that teacher thinks and what beliefs and ideas impact on their teaching. Mishra and Koehler (2006) add the dimension of technological knowledge to Shulman's original work, highlighting how effective pedagogy with ICTs requires that a teacher is able to integrate technology into a lesson and must, therefore, be familiar with why they select certain technology to teach certain topics as opposed to others. The TPACK model describes an integrated connection between content knowledge, pedagogical knowledge and technological knowledge (Srisawasdi, 2014; Voogt et al., 2013), illustrating the complexities of teachers' thinking in the 21st century in relation to the use of technology. This complexity arises in large part because technology does not have a specific use; a pen for example has a specific use that is transparent and over time, the fact that a pen is a novel technology becomes largely forgotten and its use becomes habitual. ICTs however, are protean (they can be used in many different ways), opaque (how they work is not immediately observable to the user) and they are inherently unstable as they are subject to continuous change (Mishra & Koehler, 2006). This model recognises the interaction of three forms of knowledge in pedagogical decision making (Koehler, 2014):

- Technological knowledge (TK) includes not only knowing different kinds of hardware and software, but also knowing how to use them (Angeli and Valanides, 2009).
- Technological content knowledge (TCK) requires that the teacher knows the ways in which the technology and content are linked and how ICTs can be used to alter subject matter.
- Technological pedagogical knowledge (TPK) entails knowing how the use of ICTs affords and/or constrain certain pedagogical practices as well as knowing how one can change one's approach to teaching using technology (Ward & Benson, 2010).

Voogt et al. (2013) argue that the TPACK model needs to be seen not as an individual characteristic of a single teacher, but rather, as part of a wider system. For this they draw on Engeström's CHAT (1987) to elaborate a notion of pedagogy as socially situated. While their argument provides an interesting account of TPACK and especially of collaborative learning as situated, it does not go into depth about how pedagogy can be studied by linking TPACK and CHAT. For this article, I argue that TPACK can be seen as a part of the teacher's subject position (in an activity system) and should be investigated when mapping out any pedagogical activity with ICTs.

2.2.6. What is acquired through pedagogy? Scientific and everyday concepts

According to a Vygotskian perspective (1978, 1986; Hedegaard and Chaiklin, 2005) pedagogical practices, properly structured in a mediated manner, lead to the acquisition of what he terms ‘scientific’ concepts. These are not to be confused with concepts relating solely to the field of science but should rather be seen as academic concepts that are abstract and necessarily need to be taught. Vygotsky (1986) distinguishes between everyday concepts that a child can learn spontaneously and scientific concepts that a child learns through guided instruction. It is important to note, however, that these two separate types of concepts are dialectically entailed; the child understands the scientific in terms of his everyday and the everyday develops into abstraction through linking with the scientific (Chaiklin & Hedegaard, 2013). The task of an effective teacher then, is to link scientific and everyday concepts in a manner that makes them meaningful to the child. For Hedegaard, scientific concepts embody theoretical knowledge and ‘Theoretical knowledge can be conceptualised as “symbolic tools” in the form of theories or models of subject-matter areas that can be used to understand and explain events and situations in (concrete life activities) and to organise action’ (Hedegaard, 2002: 30). This theoretical knowledge needs to be linked to the child's everyday lived experiences enabling them to analyse their context (Chaiklin and Hedegaard, 2013). How theoretical knowledge is achieved, is clarified by Hedegaard in her double-move, which requires that ‘…the teacher guides the learning activity both from the perspective of general concepts and from the perspective of engaging students in “situated” problems that are meaningful in relation to their developmental stage and life situations’ (Hedegaard, 1998:120). ICTs, I would argue, are well placed to serve as tools to do this as they provide access to the child's lived experience in a way that a static textbook, for example, does not.

3. Conclusion

So where are we going on the path of teaching mathematics with technology? Findings from this review indicate that ICTs can impact positively on primary school mathematics performance provided that a constructivist pedagogy is used as opposed to a traditional transmission-based pedagogy. However, what exactly a constructivist pedagogy looks like in a classroom is not well operationalised in the literature reviewed. While the evidence suggests that pedagogy does indeed change with ICTs, the exact nature of this change remains opaque. To address this gap in the literature this paper has set out a theoretical framework for studying pedagogy with ICTs drawing on CHAT as a framework for situating human action within an activity system, allowing for someone to investigate pedagogy along the various dimensions outlined by CHAT, viz.: mediating artefacts; subject; rules; division of labour; object and outcomes.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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