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RESEARCH ARTICLE

Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence

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Abstract This review was designed to further our understanding of the link between teachers' pedagogical beliefs and their educational uses of technology. The synthesis of qualitative findings integrates the available evidence about this relationship with the ultimate goal being to facilitate the integration of technology in education. A meta-aggregative approach was utilized to analyze the results of the 14 selected studies. The findings are reported in terms of five synthesis statements, describing (1) the bi-directional relationship between pedagogical beliefs and technology use, (2) teachers' beliefs as perceived barriers, (3) the association between specific beliefs with types of technology use, (4) the role of beliefs in professional development, and (5) the importance of the school context. By interpreting the results of the review, recommendations are provided for practitioners, policy makers, and researchers focusing on pre- and in-service teacher technology training.

Keywords Pedagogical beliefs · Technology use · Systematic review · Qualitative evidence · Meta-aggregation

Introduction

Current evidence indicates that although the use of technology during the teaching and learning process is steadily increasing (e.g., Berrett et al. 2012; Inan and Lowther 2010), achieving 'technology integration' is still a complex process of educational change. This is

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apparent as the use of technology in schools is still extremely varied and, in many instances, limited (e.g., Spector 2010). Achieving the goal of meaningful technology integration (i.e., using technology to support 21st century teaching and learning) does not depend solely on technology-related factors (Arntzen and Krug 2011; Ertmer 2005; Kimmons et al. 2015; Tondeur et al. 2008a). Ultimately, teachers' personal pedagogical beliefs play a key role in their pedagogical decisions regarding whether and how to integrate technology within their classroom practices (Deng et al. 2014; Inan and Lowther 2010).

Researchers have argued that teachers' classroom practices are highly influenced by their pedagogical beliefs (Fives and Gill 2015; Kagan 1992; Pajares 1992; Richardson 1996). Based on the results of previous research (Ertmer et al. 2015; Hermans et al. 2008; Lin et al. 2012; Zhao and Frank 2003), teachers select applications of technology that align with their selections of other curricular variables and methods (e.g., teaching strategies) and that also align with their existing beliefs about 'good' education. Technological devices such as computers, tablets, or interactive whiteboards do not dictate one's pedagogical approach (Lawless and Pellegrino 2007); rather, each device enables the implementation of a range of approaches to teaching and learning (Tondeur et al. 2008b). In other words, the role technology plays in teachers' classrooms relates to their conceptions of the nature of teaching and learning.

In this respect, research on educational innovations suggests that technology integration can only be fully understood when teachers' pedagogical beliefs are taken into account (Ertmer 2005; Lim and Chan 2007; Liu 2011; Sang et al. 2010a). As noted by Chen (2008), "in a classroom, the teacher perceives and defines a teaching situation, makes judgments and decisions, and then takes related actions" (p. 66). More specifically, on the basis of their beliefs, teachers choose specific instructional strategies and tools, including technology, to incorporate into their classroom practices (Lim et al. 2014; Prestridge 2012; Zhao and Cziko 2001). Although we recognize that technology decisions are not the only decisions influenced by teachers' beliefs, this is the primary focus of this article.

With the call for increased technology integration (e.g., U. S. Department of Education, Office of Educational Technology 2010), it is important to examine the link between teachers' beliefs and teachers' practices. In the last decade, the relationship between teachers' pedagogical beliefs and their uses of technology has been examined extensively (e.g., Ertmer and Ottenbreit-Leftwich 2010; Prestridge 2012; Sang et al. 2010b), but still this relationship remains unclear (Mueller et al. 2008). Given the centrality and importance of teachers' pedagogical beliefs and the lack of a clear understanding about the relationship between beliefs and classroom technology use, the purpose of this qualitative review is to further clarify this relationship. A meta-aggregative approach was used to locate, critically appraise, and synthesize the qualitative evidence base (see Hannes and Lockwood 2011). Before describing this methodology in more detail, we first examine how pedagogical beliefs have been defined in recent educational research.

Background

Defining pedagogical beliefs

It is difficult to describe teacher beliefs in unequivocal terms considering the myriad of ways they have been defined in the literature (e.g. Ertmer 2005; Hermans et al. 2008; Lim et al. 2013). According to Richardson (2003), beliefs are defined as psychological understandings, premises, or propositions felt to be true; whereas, knowledge is referred to

as "factual propositions and understandings" (Calderhead 1996, p. 715). The totality of one's beliefs about the physical and social world, as well as beliefs about oneself, is posited to exist within a comprehensive belief system (Rokeach 1968). In general, beliefs serve as personal guides that help individuals define and understand the world and themselves (Pajares 1992).

Although we hold beliefs about almost everything, pedagogical beliefs refer specifically to the understandings, premises, or propositions *about teaching and learning* that we hold to be true (Denessen 2000). As described by Pajares (1992), "All teachers hold beliefs about their work, their students, their subject matter, and their roles and responsibilities" (p. 314). In this review, we focus specifically on teachers' beliefs about teaching and learning and refer to these as *pedagogical beliefs*. A teacher's pedagogical belief system comprises a complex and multifaceted structure of related beliefs on teaching and learning (Ertmer and Ottenbreit-Leftwich 2010; Hermans et al. 2008). Core beliefs are the most stable and therefore the most difficult to change as they have multiple connections to other beliefs (Richardson 1996). According to Ertmer (2005), core beliefs about the nature of teaching also are resistant to change because they have been formed over many years of experience and have been supported by strong authority and broad consensus. In contrast, beliefs that are more peripheral and more recently formed are more dynamic and thus, more open to change (Fives and Gill 2015).

In the field of educational technology, teachers' beliefs have been commonly classified into one of two categories: teacher-centered beliefs and student-centered beliefs (Deng et al. 2014; Ravitz et al. 2000). Teacher-centered beliefs are typically associated with behaviorism (Deng et al. 2014) and tend to emphasize discipline, subject matter, and moral standards (Mayer 2003). The teacher acts as an authority, supervising the process of learning acquisition and serving as the expert in a highly structured learning environment. In contrast, teachers with student-centered beliefs tend to emphasize individual student needs and interests (Kerlinger and Kaya 1959; Mayer 2003), and typically adopt classroom practices associated with constructivism and/or social constructivism (Deng et al. 2014). For example, based on a key tenet of the constructivist theory (i.e., knowledge emerges in contexts in which it is relevant) (Bednar et al. 1991), student-centered approaches tend to revolve around students' active participation in authentic disciplinary problems, using real tools of the discipline (Ertmer and Glazewski 2015). As many as 50 years ago, Kerlinger and Kaya (1959) criticized this bi-polar distinction. Their study provided support for the hypothesis that teachers may hold *both* teacher-centered and student-centered pedagogical beliefs. Given this, researchers today are encouraged to consider a multi-dimensional approach to exploring teachers' belief systems (Tondeur and Hermans et al. 2008).

Relationship between pedagogical beliefs and technology use

Teachers' pedagogical beliefs act as a filter through which new knowledge and experiences are screened for meaning and relevance (Kagan 1992). This also applies to teachers' experiences with technology. Researchers have proposed that, in conjunction with the use of technology over time, teachers often change their classroom practices and, ultimately, adopt more student-centered beliefs (e.g., Matzen and Edmunds 2007). However, this is not true of all teachers. This may be because teachers' individual experiences, beliefs, emotions, knowledge, self-efficacy, skills, and motivations can be influenced by their teaching contexts (Stoll 1999). Moreover, teachers' perceptions about, and actions towards changing and developing their teaching methods, including their uses of technology, are

influenced by what they believe represents good teaching and effective learning (Borko and Putnam 1995; Ertmer et al. 2015; Fullan 2001).

Evidence suggests that teachers who hold constructivist beliefs tend to be highly active technology users (Ertmer et al. 2015; Judson 2006). According to Becker (2000), not only do these teachers tend to use technology more frequently than teachers with teacher-centered beliefs, but they also tend to use them in more student-centered ways (i.e., allowing students to select and direct their own uses of available technology tools). More specifically, teachers with constructivist beliefs have been observed to use technology as an information tool (e.g., to retrieve and select information; see Tondeur et al. 2008) and as a means to help students develop higher-order thinking and problem-solving skills (Berg et al. 1998). According to Ananiadou and Claro (2009), teachers with constructivist beliefs use technology to support students' capacity to "apply knowledge and skills in key subject areas and to analyze, reason, and communicate effectively as they raise, solve, and interpret problems in a variety of situations" (p. 7).

Purpose of the study

Based on findings from Inan and Lowther (2010) and Miranda and Russell (2012), teachers' pedagogical beliefs are observed to be strong predictors of their uses of technology. However, findings are not as clear-cut as initially thought. As noted earlier, there is still the general perception that teacher beliefs and practices are uni-dimensional (teacher-centered *or* student-centered), as opposed to multi-dimensional (Kerlinger and Kaya 1959). A multi-dimensional view suggests that teachers hold varying degrees of both kinds of beliefs (Ertmer and Ottenbreit-Leftwich 2010).

Another complexity in this research area relates to inconsistencies between beliefs and practices. As noted by Pajares (1992) and others (e.g., Chen 2008), pedagogical beliefs may compete with other beliefs or external factors and as such, be altered in practice. The specific context in which pedagogical beliefs are applied influences, sometimes to a great extent, the manner in which those beliefs manifest (Ertmer 2005). Frequently, these inconsistencies are attributed to intervening factors that can have both direct and indirect effects on teachers' abilities to translate their pedagogical beliefs into practice, including teacher-related (e.g., competence, motivation, confidence, self-efficacy), school-related (e.g., leadership, policies), and cultural and societal-related (e.g., parental expectations, standardized testing requirements) (e.g., Ertmer et al. 2015; Windschitl and Sahl 2002). The goal of this review is to synthesize the available evidence on the relationship between teachers' pedagogical beliefs and their uses of technology.

Research method

Meta-aggregation of qualitative studies

In this study, we applied a systematic review method to locate, critically evaluate, and synthesize studies about the relationship between teachers' pedagogical beliefs and their classroom uses of technology. Petticrew and Roberts (2008) defined a systematic literature review as an interpretation of a selection of documents on a specific topic that optimally involves summarization, analysis, evaluation, and synthesis of the documents. The advantage of such a systematic review is that it produces a map of the 'bigger picture.'

Systematic reviews can facilitate understanding of a topic, identify common threads across studies, and/or aid in the development of theory (Hammersley 2001; Tondeur et al. 2012).

The researchers used a meta-aggregative approach, developed in 2001 by the Joanna Briggs Institute (http://joannabriggs.org), which comprises a systematic process of extracting and synthesizing qualitative data. The outcome was an aggregative approach that (1) emphasized the complexity of interpretive and critical understandings of phenomena; (2) recognized the need to ensure that the approach to synthesis is transparent; and (3) ensured that the synthesized statements would be practical and usable (Hannes and Lockwood 2011). According to these authors, qualitative approaches can provide insights into how and why specific pedagogical beliefs and technology uses are linked, or the perceived reasons for the success or failure of interventions or programs in this field.

The increase in volume of available qualitative research in the field of pedagogical beliefs and technology use enables the aggregation of findings, allowing us to synthesize the knowledge gathered from individual studies. The main steps of meta-aggregation, as used in this study, are outlined in our analysis section. Additional examples of the meta-aggregative approach can be found in the Joanna Briggs Library of systematic reviews (http://joannabriggslibrary.org).

Search strategy and inclusion criteria

Initially, identified articles were subject to two criteria for inclusion in the synthesis. First, the research needed to focus on teachers' pedagogical beliefs, and second, the article needed to include some discussion of, or investigation into, how these beliefs related to classroom technology use. The studies included in this synthesis were located through an extensive search of the Web of Science. Opinion pieces, letters, and editorials were excluded. Key words used in the literature search included "ICT," "technology," as well as "pedagogical beliefs" or "educational beliefs" in combination with search filters identifying only qualitative empirical studies. Although the definition of technology can cover a broad range of ideas, when searching within the Web of Science databases, the words "technology," "IT," or "ICT" were used. Furthermore, we restricted our search to include only empirical studies published in English within the 10-year period of 2002–2012. Based on these searches, 77 potentially relevant journal articles were identified by the review team. The review team consisted of the four authors, all experienced in research on the relationship between pedagogical beliefs and technology use in education. The authors duly note their own biases toward student-centered practices, which may be apparent throughout this paper. Ertmer et al. (2015) conducted a review and found that constructivist beliefs lead to uses of technology that support the development of 21st century skills.

In a first screening, the titles and abstracts of the studies were examined by two team members. Exclusions were made if studies did not use qualitative methods or were insufficiently focused on the topic. The insufficiently focused articles tended to concentrate more heavily on generally beliefs about ICT as opposed to educational beliefs. Based on this screening, only 14 studies remained (see Table 1). In some cases, full papers had to be scanned due to poorly structured abstracts.

Analysis

As mentioned earlier, a meta-aggregative approach was used to review the qualitative evidence. More specifically, this approach followed a three-step process, as described by Hannes et al. (2010):

Table 1 Overview of selected studies

First author	Year	Country	Primary data sources	Respondents
1. Chen	2011	Taiwan	Interviews	24 EFL teachers
2. Cviko	2012	Netherlands	Observations, interviews	4 teachers in kindergarten, 73 pupils
3. Ertmer	2012	US	Document analysis, interviews	12 K-12 teachers
4. Donnelly	2011	Ireland	Observations, (follow-up) interviews	7 science teachers and 6 educational stakeholders
5. Lim	2007	Singapore	Analysis of artifact, interviews	19 pre-service teachers
6. Lim	2008	Singapore	Observations, interviews	6 teachers from 2 primary schools
7. Lin	2012	Taiwan	Observations, interviews	3 language art teachers
8. Martin	2008	Singapore	(post-task-) interviews, video and screen recording	16 pre-service teachers
9. Ottenbreit-Leftwich	2010	US	Portfolio review, interviews, observations	8 award-winning teachers
10. Vanderlinde	2010	Belgium	(Follow-up) interviews, document analysis, field notes	School leaders and ICT-coordinators from 3 schools
11. Pedersen	2003	US	(Follow-up) interviews, observations, field notes, focus groups	15 middle school science teachers
12. Hennessy	2005	UK	Focus group interviews	Members of the project teams from 6 schools
13. Levin	2005	Israel	Open questionnaires, observations, interviews	6 teachers, 164 students
14. Windschitl	2002	US	Ethnographic approach	3 teachers

(1) Extraction of findings: Based on the 14 selected studies, we aggregated the original findings on the relationship between pedagogical beliefs and educational technology use. The actual descriptions presented in the results and discussion sections of the selected articles were used to maintain a true representation of the primary studies. This process required repeatedly returning to the original data to verify, contradict, and/or enrich interpretations.

(2) Categorization of findings: We developed a set of categories to represent findings that cut across the studies and had similarity in meaning. The categories included some of the following: "beliefs as perceived barriers of technology use," "linking specific beliefs to types of technology use," or "changing teacher beliefs and technology use."

(3) Synthesizing the categories: We carefully reviewed the set of categories to produce a set of synthesized findings. As a result of this process, we created five statements to emphasize the main effective practices based on the literature that should be addressed by practitioners, policy makers, and/or researchers, including recommendations for a particular direction for the achievement of successful technology integration in education.

The extracted findings were aggregated and synthesized independently by two researchers. All disagreements between the researchers were resolved through discussion among the four authors. In the next section each category and synthesized statement is described and examples are provided.

Results

As noted earlier, 14 studies were included in the review. The studies were conducted in eight different countries: four were from the United States, three from Singapore, two from Taiwan, one from Belgium and the Netherlands, one from Israel, one from the United Kingdom, and one from Ireland. An overview of each of the selected studies, including first author, year, country, and primary data sources, is provided in Table 1.

Based on our analysis, 13 categories were identified; these are presented in the second column of Tables 2, 3, 4, 5 and 6. Finally, the 13 categories (C) are combined into six synthesized statements explicitly related to the relationship between teachers' pedagogical beliefs and their uses of technology in education (see Column 3 of Tables 2, 3, 4, 5 and 6).

Synthesis 1

The relationship between pedagogical beliefs and technology use should be considered to be bi-directional (See Table 2).

Our first two categories illustrate how pedagogical beliefs are related to teachers' technology use and suggest that technology use can lead to the creation of new, reconstructed, or reaffirmed beliefs. More specifically, in nine of 14 studies (S), the qualitative evidence indicated that teachers' experiences with technology were perceived to be an enabler for supporting pedagogical belief change (C1). For example, according to Chen (2011), "advanced computer technologies allow the teachers to practice becoming an innovative teacher as well as a constructivist teacher" (S1, p. 383). The Ertmer et al. (2015) case study also illustrated how 12 technology motivated teachers from the United States experimented, implemented, and refined new approaches to teaching and learning: "*technology gradually reshaped the way I teach*" (S3, p. 431). The findings from these nine studies highlight how some teachers see technology as an opportunity to (1) engage students in learning and to give them more ownership (S4, S5); (2) introduce problem-based learning (S5, S8); (3) experiment with simulations (S12); (4) access authentic digital information (S14); (5) communicate and collaborate with peers, teachers, and parents (S13, S14); (6) provide scaffolds for self-regulated learners (S8, S13); and/or (7) accommodate individual learning (S14). The comments in Category 1 suggest that when teachers spent time in technology-rich learning environments, their pedagogical beliefs shifted from a paradigm that emphasized a teacher-centered approach towards one that emphasized more open-ended, student oriented or constructivist approaches.

In contrast, five studies mentioned that teachers' pedagogical beliefs could be perceived as enablers for technology integration (C2). In one study, Cviko et al. (2012) found that kindergarten teachers who had developmental or constructivist beliefs perceived technology as a tool for supporting learning and had positive expectations for the integration of technology. The qualitative evidence confirmed how the affordances of technology supported teachers' existing constructivist beliefs about teaching and learning including the perceived need to 1) allow students to work in small groups (S3), and 2) encourage students to explore and research new ideas (S6).

Table 2 Findings contributing to synthesis 1

Examples of qualitative evidence	Categories	Synthesis
(…) For these three teachers, technology was a tool that allowed them to experiment, implement, and refine these new approaches to teaching and learning. [S3] She viewed the laptop as a means for her students to accommodate their individual learning needs and for her to orchestrate classroom learning experiences that had been impossible before the laptops [S14]	*Technology as perceived enabler for change (in teaching approaches and beliefs)*	The relationship between pedagogical b eliefs and technology use should be considered to be bi-directional
Higher education EFL teachers who are constructivist-oriented tend to use ICT more. [S1] With respect to the perceptions of the affordances of computers, the five teachers articulated that computers supported their beliefs of teaching and learning. Aik Ling and Ben stated that computers promoted dialogues in the classroom and encouraged 'students to explore and research new ideas and understand the ideas for themselves' [S6]	*Teacher beliefs as perceived enabler for technology integration*	

Based on the evidence in both categories, Synthesis 1 highlights the importance of viewing the relationship between pedagogical beliefs and technology use as being bi-directional. Technology-rich learning experiences have the potential to change teachers' beliefs towards more student-centered, constructivist beliefs, while at the same time, teachers with constructivist beliefs are more likely to adopt technology in student-centered ways within the context of teaching and learning.

Synthesis 2

Teachers' pedagogical beliefs may hinder or prevent technology integration (See Table 3).

In three studies, teachers' pedagogical beliefs were perceived to be an impactful barrier to their educational uses of technology (C3). For instance, the evidence in the Donnelly et al. (2011) study suggested that the open nature of ICT-based resources (e.g., a virtual Chemistry Laboratory) did not match the pedagogical beliefs of a group of science teachers. In this study, teachers with "contented traditionalist beliefs" saw no real need to use technology when "traditional practices continue to work" (S4, p. 1478). This was also illustrated by the study of Lim and Chan (2007), which suggested that because most teachers' personal learning experiences were predominately through direct instruction, they believed that technology was not essential to teaching and learning and that a whiteboard served their educational purposes equally well (S5).

Table 3 Findings contributing to synthesis 2

Examples of qualitative evidence	Categories	Synthesis
Some teachers see no real need to use computers when "traditional practices continue to work" and hence see "no clearly recognised need to change" [S4] (…) Like most of the pre-service teachers, her experiences as a student had been predominately direct instruction, with an emphasis on facts, and ''right or wrong answers''. Anna felt that technology was not essential to teaching and learning and believed that a whiteboard would serve the purpose equally well. [S5]	*Beliefs as perceived barrier of technology use*	The relationship between pedagogical b eliefs and technology use should be considered to be bi-directional
Although they were willing to learn about technology and try it out with their students, they found it hard to fit ICT integrated activities into an already too tight teaching schedule because ICT activities tend to consume more class time than traditional styles of instruction. [S7] In addition to her perception that laptops generated classroom chaos, Julia experienced uncertainty about when to use the laptops and what to use them for. She had little time to learn more about technology. Julia's planning time was consumed with preparations for four different classes, and she gradually acquiesced to the demands of her workload, becoming less concerned with learning how to use the laptop. [S14]	*Perceived barriers related to beliefs and technology use*	

In nine studies, the authors described perceived barriers related to teacher beliefs and technology use (C4). A recurrent theme in this category was the lack of time. For instance, a teacher in the Lim and Chan (2007) study commented that in Singapore a rigid scheme of work and tight block scheduling discouraged her from integrating ICT-based constructivist practices. She explained: "… all these will take up most of the curriculum time so I've no choice but to follow this structured manner of instruction. It's sad because the students don't get the opportunity to be more active in their learning" (p. 822).

Time pressures were often expressed in terms of the demands of required standards-based testing. In four of the selected studies, participants explicitly stressed that teacher-centered approaches to technology use (e.g., drill-and-practice software) better prepared their students for examinations (S4, S6, S8, S12). Interestingly, based on the comments of a few teachers, not all students were perceived to be ready to learn from a technology-

integrated constructivist approach as they were generally not self-directed and were more used to being "spoon-fed" (S4, S5).

Another barrier that hindered teachers' adoption of student-centered technology use was the perceived lack of control. For example, a teacher in the Windschitl and Sahl (2002) study arranged the classroom desks into six groups of three to facilitate the desired group interactions, but rearranged the desks back into rows in order to assert her authority. In addition to her perception that "laptops generated classroom chaos, Julia [the teacher] experienced uncertainty about when to use the laptops and what to use them for" (S14, p. 187, see also S5).

Categories 3 and 4 both address the theme of how teachers' pedagogical beliefs and related barriers hindered classroom uses of technology. Our Synthesis 2 statement suggests that in order to understand how to achieve meaningful technology integration in our schools, a better understanding is needed of the interrelated factors that potentially impact the desired outcome.

Synthesis 3

A multi-dimensional approach is necessary to address the relationship between pedagogical beliefs and technology use (See Table 4).

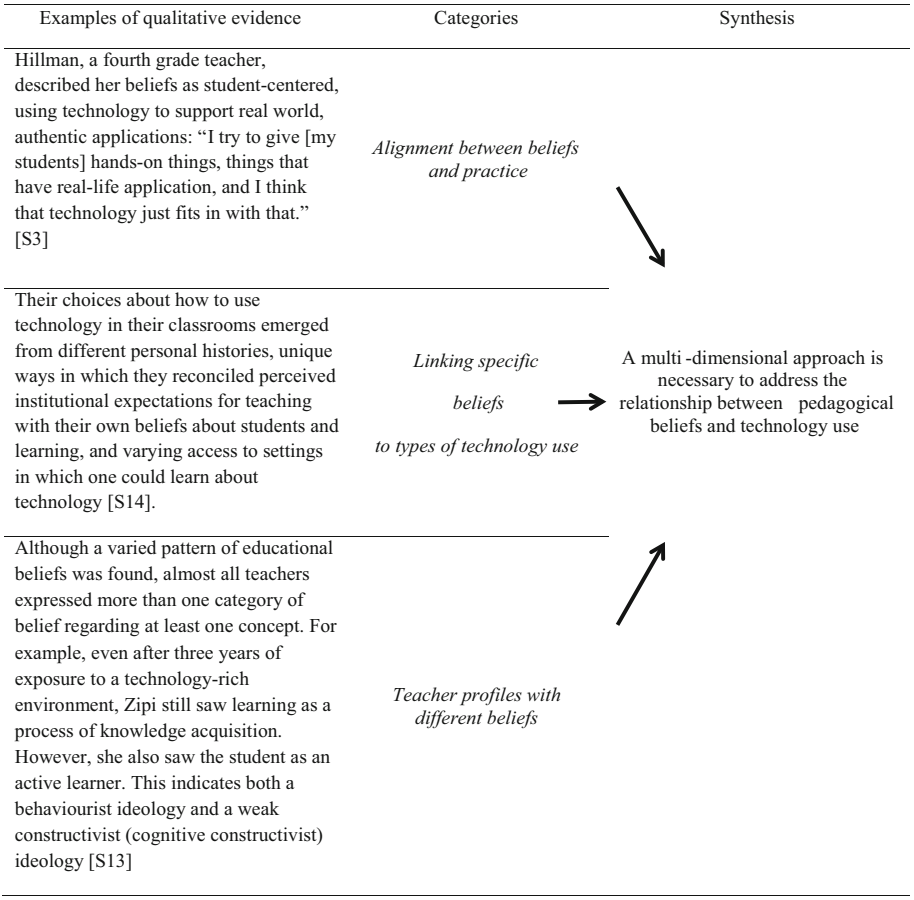
Based on the collected evidence (in seven of the selected studies), teachers' pedagogical beliefs were observed to align with their educational practices (C5). For instance, teachers in Pederson's and Liu study (Pedersen and Liu 2003) were more likely to use programs that were consistent with their student-centered beliefs. In another example of close alignment between beliefs and practices, Hillman, a fourth grade teacher from the United States, described her beliefs as student-centered, using technology to support real world, authentic applications: "I try to give [my students] hands-on things, things that have real-life application, and I think that technology just fits in with that" (S3, p. 431).

Closely related to Category 5, Category 6 highlights that specific pedagogical beliefs are associated with specific types of technology use (observed in six studies). Teachers whose pedagogy was characterized by teacher-centered beliefs frequently used technology in ways that emphasized skills acquisition (e.g., Martin and Vallance 2008), whereas those with constructivist orientations also tended to use technology for the attainment of more open ended (higher-order) learning objectives (e.g., S8). In the study by Lim and Chan (2007), teachers with constructivist orientations used technology as a problem-solving tool. For instance, Penny explained that students could search the Internet for information, enter and analyze data mediated by a spreadsheet application, and represent the relationships and ideas symbolically or visually. These findings support the theme that teachers' beliefs about teaching and learning are related to the way they use technology in their classrooms (e.g., S2).

In contrast to the evidence that supports Category 6, evidence in Category 7 suggests that teachers' pedagogical beliefs, as described in five of the qualitative studies, can not always be classified into one single category (e.g., S6, S8, S12). That is, teacher profiles included multiple beliefs and approaches towards technology. In the study by Levin and Wadmany (2005), for instance, most teachers were observed to change educational lenses depending on the context, thus demonstrating multiple views rather than uni-dimensional beliefs. As such, different types of technological applications, in combination with different belief profiles, can lead to quite different outcomes (S13).

In the studies mentioned above, the authors criticized the bi-polar distinction often made between teacher-centered beliefs and more student-centered educational beliefs and have

Table 4 Findings contributing to synthesis 3



turned their attention, instead, toward a multi-dimensional description of the belief system (Synthesis 3, Table 4). The qualitative evidence analyzed for this review supports the idea that the technology integration process is an individual process, unique to each teacher.

Synthesis 4

A better understanding of the role of pedagogical beliefs is needed for teachers to benefit from professional development aimed at increasing educational technology use (see Table 5).

Professional development was a main theme in the majority of studies reviewed. In eight of the 14 studies, the findings indicated that changes occurred in the beliefs and educational practices of the participating teachers after participating in professional development (Category 8). Generally, the qualitative findings showed that at the beginning

Table 5 Findings contributing to synthesis 4

Examples of qualitative evidence	Categories	Synthesis
Comparing the technology-mediated lesson plans and the microLESSONS, there was a change in teachers role from a knowledge dispenser to a facilitator, students role from knowledge receiver to knowledge constructor, and technology's role from tools to assist students in receiving knowledge to tools that facilitated knowledge construction. [S5]	*Changing te acher beliefs and technology use*	A better understanding of the role of pedagogical beliefs is needed for teachers to benefit from professional development aimed at increasing educational technology use
Although teacher A learned how to find useful resources from the Web and use them to create multimedia materials to suit her instructional purposes, her teaching style remained teacher-centric. (…) With this activity, teacher A did not show significant advance in either the pedagogy or technology dimension; therefore, her ICT integration status remains the same [S7]	*Resistance to changing beliefs and practices with new technologies*	

of interventions most teachers expressed teacher-centered beliefs compared to more varied beliefs after the interventions (e.g., S13). For example, in the Levin and Wadmany (2005) study, the respondents focused more on facilitating student understanding at the end of the program as opposed to simply covering content in a technology rich environment, as noted at the beginning of the study. Also in the Lim and Chan (2007) study, there was a change in teachers' roles, "from a knowledge receiver to knowledge constructor, and technology's role from tools to assist students in receiving knowledge to tools that facilitated knowledge construction" (p. 483). An examination of the artifacts developed in this study suggested a change from a more teacher-centered set of pedagogical beliefs to more student-centered beliefs. However, the authors questioned if the change was due to the need to meet the expectations and fulfill the assignment requirements rather than to a real change in pedagogical beliefs.

Generally speaking, pedagogical beliefs are relatively stable and typically long-term professional development is needed in order to change teachers' pedagogical beliefs and practices. For example, the Levin and Wadmany (2005) study showed that after a three-year period of teaching and learning in a technology-based environment, changes occurred in the beliefs and practices of the six participating teachers.

Another issue emerging in four of the 14 studies related to teachers' resistance to changing beliefs and practices with new technologies (Category 9). Despite their engagement in professional development geared toward using technology in constructivist ways, some teachers continued to regard teaching as a process of knowledge transmission

(see S13, S14). For example, a teacher in the study by Windschitl and Sahl (2002) cited her busy schedule as a reason for maintaining her teacher-directed instructional strategies (see Category 4). According to a middle school teacher in the United States, "standardizing the curriculum included homogenizing the learning experiences" (p. 195).

Categories eight and nine both address issues related to strategies for supporting changes in teachers' pedagogical beliefs and technology-supported practices (Table 5). Clearly, as noted by the results of several studies, not all teachers will benefit from a professional development intervention (Synthesis 4). This leads to the next theme, which addresses the role of context in teachers' adoption and implementation of technology in their classrooms.

Synthesis 5: a consideration of the school context is needed to address the complex relationship between teacher pedagogical beliefs and technology use (see Table 6)

The influence of context on pedagogical beliefs and technology use was a key theme in eight of the 14 studies (Category 10). More specifically, school characteristics such as policy planning, technology support, or peer support seem to play an important role. With respect to peer support, several studies showed that pedagogical beliefs can be reinforced

Table 6 Findings contributing to synthesis 5

Examples of qualitative evidence	Categories	Synthesis
In the lower grades, the school promoted the use of ICT within a teacher-centred vision on education, especially in mathematics and languages classes. For the higher grades, the school promoted the use of ICTwithin a student-centred vision on education (e.g. ICTas a presentation and communication tool). [S10] During my last twelve years, we have tried so many things: group learning, problem-based learning, discovery learning, ... but they all didn't work in the school system [S6].	Influence of (school) context on ICT use and teacher beliefs	A consideration of the school context is needed to address the complex relationship between teacher pedagogical beliefs and technology use
The findings highlight how some teachers see ICT as an opportunity for them to do something new and interesting with their students in terms of how the students learn while other teachers feel it is beyond their control to do anything about the types of ICT resources they have within their classroom [S4]	Different teacher beliefs profiles within a school	

by colleagues and that sharing ideas about technology use can stimulate student-centered teaching with technology (e.g. S14). However, some researchers noted that teachers report having few conversations about the role of technology in their classrooms and mention the school culture as a barrier (e.g., C3). Interestingly, the findings also demonstrate how students' negative attitudes and poor ICT skills can hinder student-centered technology integration (S12). This can also be related to the variable of grade level: "In the lower grades, the school promoted the use of ICT within a teacher-centred vision on education, especially in mathematics and languages classes. For the higher grades, the school promoted the use of ICT within a student-centred vision on education" (Vanderlinde et al. 2010).

Additionally, the qualitative findings highlight the importance of school policies. According to Hennessy (Hannes et al. 2013), a conscious effort is needed at the institutional level to create opportunities, particularly with a cross-curricular subject like ICT, and to clarify departmental responsibilities. The departments in this study tended to operate independently in many cases and opportunities for sharing knowledge about what pupils were doing in different subjects seemed to be limited (S12). In the study by Vanderlinde et al. (2010), the role of technology was grounded in a shared vision of 'good' education in all three schools that were examined, although the definition of "good" varied from school to school. For instance, while stakeholders of school A stressed that class-based instructional needs must precede pupil's individual technology use, school B stakeholders emphasized that students should use technology for independent and creative work. In this way, technology use was more teacher-centered in school A and more student-centered in school B (S10).

Our analysis also revealed that teachers working in the same school did not necessarily share the same pedagogical beliefs (Category 11). For example, some teachers in the study by Cviko et al. (2012) had strong transmission beliefs, some had strong constructivist beliefs, and others acknowledged possessing both orientations (see also S10). In this respect, stakeholders in one school in the Vanderlinde et al. (2010) study "acknowledged the importance of both orientations and did not favor one specific educational orientation" (p. 10) in terms of its vision for educational technology use. This aligns with the results of the study by Levin and Wadmany (2005) indicating that educational change involving information technology is an individual process, unique to each teacher, even when working with groups in a supportive and dynamic learning community (S14). In summary, the main synthesis of the qualitative data for Categories 10 and 11 includes the desirability of building a coherent and supportive school community of practice, which embraces a vision of a "good' education, that is, one that integrates meaningful technology use (Synthesis 5).

Discussion

In this systematic review we aggregated available qualitative evidence on the relationship between pedagogical beliefs and educational technology use, resulting in five synthesized statements. The first synthesis suggests that the relationship between pedagogical beliefs and technology use comprises a bi-directional relationship. Based on the selected studies, the integration of technology within classroom educational processes has the potential to change teachers' beliefs towards more student-centered, constructivist beliefs. Technology is viewed as a way to motivate teachers to experiment, implement, and refine new

approaches to teaching and learning (Donnelly et al. 2011). This is in line with the review by Ertmer et al. (2015), who suggested that constructivist beliefs lead to uses of technology that support the development of 21st century skills. Based on this synthesis, it is important to note that learning to teach with technology is an iterative process: beliefs lead to actions, which, in turn, lead to the development of reconstructed or reaffirmed beliefs (Haney et al. 2002).

Apart from an illustration of a beliefs-practice relationship, the current study highlights the potential for teachers' pedagogical beliefs to act as a barrier to technology integration (Synthesis 2). The evidence suggests that teachers with more teacher-centered beliefs do not perceive technology as being essential to the teaching and learning process (e.g., Lim and Chan 2007). Synthesis 2 also suggests that a better understanding is needed of the interrelated factors that potentially impact teacher beliefs and technology use. Recurrent barriers include the lack of time, a rigid schedule of classes, and examination requirements (e.g., Windschitl and Sahl 2002). These findings confirm that time pressures and an examination-oriented society tend to lead to teacher-centered approaches to technology use (Lin et al. 2012). Although several educational authorities (for an overview, see Voogt and Roblin 2012) have suggested more student-centered uses of technology (such as those targeting 21st century skills), many of the identified obstacles are still subject to the implicit and explicit rules of our educational systems. Surprisingly, even some students in the selected studies were perceived not to be ready to learn from a technology-integrated constructivist approach (e.g., Lim and Chan 2007.

However, technology can also be beneficial to teachers with teacher-centered pedagogical beliefs (Tondeur and Hermans et al. 2008). Several authors reported that teachers find value in using technology when it aligns with their current pedagogical approaches (Lim and Chan 2007; Tondeur et al. 2013). Therefore, regardless of teachers' pedagogical approaches, technology should be introduced in ways that align with teachers' current approaches, thus appealing to their values and increasing the likelihood that teachers will integrate and use technology. In this respect, the collected evidence emphasizes the importance of a multi-dimensional approach to addressing the relationship between pedagogical beliefs and technology use (Synthesis 3): many of the teacher profiles described in the 14 studies included multiple beliefs and approaches towards technology use. Levin and Wadmany (2005), for example, suggested that most teachers could not be classified as holding one pedagogical orientation, but rather seemed to change educational lenses depending on the context. Nevertheless, our findings also suggest that specific pedagogical beliefs are associated with specific types of technology use (Martin and Vallance 2008). In other words, there generally seems to be a close alignment between pedagogical beliefs and practice (Pedersen and Liu 2003).

Another key issue relates to professional development (PD) for technology integration, as highlighted by Synthesis 4. The synthesis statements address issues related to how to facilitate alignment among teachers' pedagogical beliefs and technology-supported practices (Martin and Vallance 2008). Based on the available evidence, not all participants benefited from professional development interventions. This is in line with the findings that teachers' pedagogical belief systems comprise a complex and multifaceted structure of related beliefs (Ertmer and Ottenbreit-Leftwich 2010) that are difficult to change (Richardson 1996). If the goal of the PD effort is to change teachers' beliefs, evidence suggests that long-term professional development is more likely to promote such a change (Levin and Wadmany 2005).

For example, a long-term professional development program, which builds on (pre-service) teachers' existing beliefs and practices and is reinforced through on-going inquiry,

may offer a promising approach (Sang et al. 2012). This approach is in line with recommendations from other researchers who stress the importance of professional development as an iterative process, aimed at extending and updating the professional knowledge and beliefs of teachers in the context of their work (e.g., Kopcha 2010; Tondeur et al. 2016). To illustrate, Kopcha (2010) suggested using a systems approach to student-centered technology integration, incorporating mentoring and communities of practice. The model begins with individualized mentoring and culminates with the creation of a teacher-led community of practice using school specific resources to sustain continued development toward student-centered technology uses. Similarly, several authors have suggested involving teachers in collaborative design as an effective strategy to develop digital resources in line with teachers' pedagogical beliefs (Voogt and Roblin 2012). According to Voogt et al. design teams also provide opportunities for teachers to reflect on each member's personal competence and beliefs regarding the reform. These types of initiatives also have the potential to bolster teachers' self-efficacy, which in turn has been found to influence teachers' beliefs (Holden and Rada 2011).

This leads to the role of the school context in supporting teachers' efforts to integrate technology. Synthesis 5 includes the desirability of a supportive school environment, which includes school policies that are based on the development of a vision of a "good' education that incorporates the meaningful integration of technology (e.g., Vanderlinde et al. 2010). Apart from adopting a school vision focused on student-centered education, Hannes et al. (2013) argues for a conscious effort at the institutional level to implement such a vision (for instance create opportunities, clarify departmental responsibilities, etc.). As one example, Watson et al. (2012) described the importance of enacting a district-wide effort in order to implement student-centered technology uses. Furthermore, they recommended that a shared vision be created among all stakeholders (e.g., board members, parents, teachers, administration) in order to create sustainable and successful educational reforms that integrate technology.

Limitations of the study and suggestions for future research

This review study used a meta-aggregation approach to explore the relationship between teachers' pedagogical beliefs and technology use. Despite using recommended procedures (Hannes and Lockwood 2011), methodological choices lead to inevitable limitations in the process (Hannes et al. 2013). For instance, we excluded studies about teachers' beliefs about the role of technology in education. Moreover, the search strategy was hindered by the existing conceptual confusion in the field regarding pedagogical beliefs (Hermans et al. 2008). Such issues may have influenced our synthesis findings.

Nevertheless, this type of review provides a richer account than can be obtained by one single qualitative study (Hammersley 2001). For instance, the findings provide a clear overview about how contextual characteristics (school culture, grade level, student population) influence the adoption of pedagogical beliefs and technology use in practice. In this respect, the results also demonstrate that the findings in this area cannot simply be generalized. For example, some findings are specific to the context of secondary education (e.g., Hannes et al. 2010). Yet, in higher education, teachers' belief profiles and technology uses might be different (e.g., Lin et al. 2012). Simplifying the complex relationship between pedagogical beliefs and educational technology use was a difficult process that reduced the importance of the contextually of the results. Clearly, we have to assume that pedagogical beliefs and technology uses in classrooms are different in different parts of the world. Future research should consider the relational use of technology in view of teachers'

pedagogical beliefs and school cultures (Krug and Arntzen 2010), national and local curricular organizations, and the societal characteristics of educational systems.

By including other forms of evidence from different types of research, mixed-methods reviews are also important to address, as they can maximize the findings (Joanna Briggs Institute 2014) in the field of pedagogical beliefs and technology integration in education. To illustrate, the mixed-methods model enables us to integrate quantitative estimates about the impact of pedagogical beliefs on professional development for ICT integration, augmented by a qualitative understanding about how pedagogical beliefs can be related to teachers' professional development. Also, longitudinal studies investigating changes in pedagogical beliefs in relationship to how technology is used in classrooms could lead to new insights. The relationship between teacher beliefs and educational innovations, such as technology integration, is complex and therefore any outcomes from an identified change are likely to be produced through an involved chain of events.

Conclusions

A meta-aggregative approach was used to locate, critically appraise, and synthesize the qualitative evidence base on the relationship between teachers' pedagogical beliefs and their uses of technology. By aggregating findings from multiple studies we provide compelling evidence that is not observable when viewing results from a single study. As such, the results can be described as patterns in the literature, which have the potential to move both our theory and practice forward. More specifically, the results presented in this review study fuel the development of theory concerning the complex relationship between teachers' pedagogical beliefs and educational innovations, with a special focus on technology. Past programs aimed at increasing technology integration in education have often failed due to a mismatch between the educational change and the meanings attached to that change by those involved in the instructional process. Consequently, the process of effective technology integration should not be facilitated as a stand-alone event, focusing solely on technical skills. Based on the results of this study, teachers' beliefs about "good" education should be a critical dimension in professional development programs that support teachers learning about the meaningful use of technology in education.

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