Technology Integration in the Most Favorable Conditions: Findings from a Professional Development Training Program

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Introduction: Technology Uptake

The belief that technology in its various instantiations will transform educational practice is very prevalent and dates back for at least a century. The assumption behind the introduction of technology into educational systems was that it will eventually make them more meaningful, interesting, and relevant for students, thereby drastically improving the quality of learning. However, if there is one consistent finding from the past three decades of research on ICT use in education, it is that technology has failed to transform teaching and learning practices.

There are two interrelated problems with technology use. *First*, research indicates that the *extent of technology use* in classrooms is rather low: teachers do not appear to use technology in their practices to any considerable extent (Hinostroza, Labbé, Brun, & Matamala, 2011; Norris, Sullivan, Poirot, & Soloway, 2003; Ward & Parr, 2010; Webb & Cox, 2004; Wikan & Molster, 2011). *Second*, *even when teachers do embrace technology, it gets integrated in ways which sustain rather than transform existing practices* (Condie, Munro, Seagraves, & Kenesson, 2007; Cuban, 2001; Cuban, Kirkpatrick, & Peck, 2001; Donnelly, McGarr, & O'Reilly, 2011; Eteokleous, 2008; Hayes, 2007; Hermans, Tondeur, van Braak, & Valcke, 2008; Li, 2007; Norton, McRobbie, & Cooper, 2000; OFSTED, 2004; Player-Koro, 2012; Prestridge, 2012). On an international level, the SITES 2006 study indicated that ICT adoption does not necessarily mean that traditional practices are abolished

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C. Karagiannidis et al. (eds.), *Research on e-Learning and ICT in Education: Technological, Pedagogical and Instructional Perspectives*,
DOI 10.1007/978-1-4614-6501-0_14,

(Law, 2008). Similar evidence is reported on a national level, e.g., the UK (Selwyn, 2008; Smith, Rudd, & Coghlan, 2008; Yang, 2012) Ireland (McGarr, 2009) and Greece (Vosniadou & Kollias, 2001). The low rate of classroom technology use and the way technology is used to support existing practices are the primary reasons why the vision of transforming education through technology has yet to be realized.

Why has it proven so difficult for teachers to use technologies in their practices? Researchers have sought to determine the reasons behind this technology resistance. More than a decade ago, Becker (2000a, 2000b) identified four enabling conditions for technology adoption: technology access, training, curriculum compatibility, and constructivist beliefs. Ertmer (1999, 2005) attempted to further systematize technology resistance into obstacles that can be distinguished into first-order and second-order barriers. Typically, first-order barriers are extrinsic to teachers while second-order barriers are teacher related.

First-order barriers are beyond the direct control of the teacher and have to do with what is provided by the local and state authorities in terms of technology infrastructure and support structures such as equipment, training, and support. First, *technology access* is one of the main conditions upon which technology integration depends. Several studies report that one of the strongest predictors of technology use is technology access (Becker, 2000a; Eteokleous, 2008; Granger, Morbey, Lotherington, Owston, & Wideman, 2002; Norris et al., 2003). Second, a certain level of *technological competence* is required if teachers are to use technology. A possible lack of technical skills might potentially undermine technology integration. Several studies report that the greater the personal ICT competence the more likely the teachers were to use ICT in their classrooms (Eteokleous, 2008; Prestridge, 2012). Moreover, classroom integration of technology has been predicted by computer experience (Mueller, Wood, Willoughby, Ross, & Specht, 2008; Wood, Mueller, Willoughby, Specht, & Deyoung, 2005). Third, *technical support* can also be a hindrance to technology adoption. Several studies report that access to technical support can be a facilitator of technology use (Hayes, 2007; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Finally, the issue of *leadership* is often stressed as teachers need not only technical but also administrative support. Some studies report that principals and school administrators can play a facilitatory role in terms of technology adoption (Hayes, 2007; Law, 2008).

Technology adoption is clearly contingent on eliminating these first-order barriers. Addressing first-order barriers required lavish funding so as to ensure the availability of resources and training, both technical and pedagogical. Additionally, educational authorities have restructured curricula so as to accommodate technology use and foster technology integration. Progress on all fronts related to first-order barriers has been steadily made over the years (Ertmer, 2005). The underlying assumption that guided much of the thinking was that providing resources and support would somehow naturally lead to greater technology adoption (Ertmer, 1999). It turned out, however, that resources and support were a necessary but not a sufficient condition for technology integration: second-order barriers played a critical role.

Second-order barriers involve teacher beliefs about teaching and learning (Ertmer, 1999). Teacher beliefs about teaching and learning might shape whether and how teachers eventually integrate technology in their classrooms. Therefore, teacher beliefs have been the focus of much attention in the literature (Hermans et al., 2008; van Braak, Tondeur, & Valcke, 2004; see also Baggott la Velle, McFarlane, John, & Brawn, 2004; Ward & Parr, 2010). While addressing first-order barriers was relatively straightforward, addressing second-order barriers proved considerably more challenging (Ertmer, 2005). Generally speaking, second-order barriers have been addressed mainly via professional development training (PDT) programs and activities of many forms.

Professional Development Training on ICT Pedagogy

Ertmer (2005) argued that teachers are likely to think about technology in the same way they think about other educational innovations. Consequently, examining how teachers approach innovations and what makes PDT programs effective might help understand teachers' response to PDT on ICT integration in the classroom. According to the literature on PDT, three properties have been singled out as being critical for its success: form, length, and content. As far as *form* is concerned, many forms of PDT have been found to be effective: workshops (Ertmer, Ottenbreit-Leftwich, & York, 2007; Shriner, Schlee, Hamil, & Libler, 2009), seminars and conferences (Ertmer et al., 2007), independent learning (Gray, Thomas, & Lewis, 2010), school-based professional development by staff (Gray et al., 2010), and personal coaching (Miller & Glover, 2007). When it comes to *length* PDT should be both continuing (Miller & Glover, 2007) and sustained (Garet, Porter, Desimone, Birman, & Yoon, 2001). Finally, with regard to *content*, research suggests that PDT is more likely to be effective if it has a pedagogical rather than a technical orientation (Law, 2008; Law & Chow, 2008b). It is also likely to have an impact if the primary focus is on the academic subject (Garet et al., 2001).

While some essential features of successful PDT have been identified, there are still areas of critical importance which are largely unexplored. More specifically, in addition to form, length, and content, *it has been argued that teachers themselves are one of the most critical determinants of PDT success because their previous experiences might influence the outcomes of any in-service training regardless of its form, length, and content*. The argument is that we need to consider what teachers themselves bring to PDT sessions in terms of former experiences and practices (Penuel et al., 2007). For example, Coburn (2004) has convincingly demonstrated that teachers' responses to innovation appear to be mediated by their preexisting world views and practices. Additionally, teachers' local contexts should also be carefully considered when determining the effectiveness of a PDT program, as the demands posed by the contexts of practice make teachers set specific priorities (Penuel et al., 2007). PDT is bound to be interpreted in terms of the existing policies, schedules, budgets, curricula, hardware, software, technical, and administrative support of teachers' local contexts. For instance, Zhao and Frank (2003) found that the more strongly teachers believed that computers were compatible with their teaching styles, the more often teachers reported using computers in their practices.

Many teacher background variables have been systematically explored as predictors of ICT classroom use (e.g., Hermans et al., 2008; Law & Chow, 2008b; Tondeur, Hermans, van Braak, & Valcke, 2008; van Braak et al., 2004; Ward & Parr, 2010). However, teacher background variables have not been systematically investigated as predictors of PDT success even though their significance has been recognized in the aforementioned literature (Coburn, 2004; Penuel et al., 2007). In particular, when it comes to PDT that is related to ICT integration in the classroom, *researchers have rarely focused on how teachers with specific backgrounds respond to PDT*.

But in what ways can teachers belonging to specific groups be important for understanding the effectiveness of PDT for technology integration? As we argue in this work, this is because examining teachers with specific—and more particularly favorable—background properties is one way of determining the possible upper range of technology integration that we can reasonably expect from PDT programs. Technology integration can vary greatly along the sustain-transform continuum. At one extreme, teachers might make no or limited use of technology. In this case, the impact of technology will range from negligible to small. At the other extreme, teachers might use technology a great deal. In this case, depending on the ways technology gets used, its impact might be far-reaching, ultimately leading to the transformation of teaching and learning practices. As the preceding literature review shows, the majority of teachers do not use technology in their practices and those who actually do tend to domesticate it rather than use it to change their practices. *Examining how the most committed, skilled, qualified, or experienced teachers respond to PDT in ICT use is a possible test of success for current in-service PDT programs since it can be a measure of their maximal effectiveness along the sustain-transform continuum of technology use*. In other words, *if PDT stands any chance of achieving our highest aspirations relevant to transforming current educational practices, then teachers with such qualities are the best possible candidates for proving the case for PDTs*.

To the best of our knowledge, *there are no studies on how teacher background properties such as skills, expertise, or qualifications might influence the effectiveness of a PDT*. Consequently, we draw mainly on studies indicating certain teacher background properties as being either highly conducive to technology adoption or closely related to it. It seems reasonable to assume that *the more properties facilitating technology integration teachers have before attending a PDT program, the less ground these teachers would have to cover in terms of learning while attending the PDT*. Our assumption is that teachers with such properties will show the best and most favorable response to PDT as they would have to make less progress compared to other teachers.

ICT Use as a Function of Teacher Background

Only a handful of studies have closely examined specific teacher groups with respect to technology adoption and use. One group of studies focused on *exemplary technology-using teachers to extract those background properties that make them distinct*.

Exemplary technology-using teachers use technology in their practices in innovative, non conventional ways. In such studies the typical focus is on determining what makes these teachers exemplary technology users, documenting their practices, investigating their beliefs and pedagogical philosophies, and determining factors that either facilitate or hinder their efforts to use technology (Angers & Machtmes, 2005; Becker, 2000b; Becker & Riel, 2000; Ertmer et al., 2007; Hadley & Sheingold, 1990, 1993; Leftwich, 2007; Riel & Becker, 2008). This body of research shows that exemplary technology-using teachers are different from other technology-using teachers and other teachers in general in a number of ways. More specifically, exemplary technology-using teachers actively seek more professional development activities than ordinary teachers, take release time to follow such activities, are more willing to take risks and experiment with technology, and overall have a high level of commitment to improving their students' learning through technology (Angers & Machtmes, 2005; Becker & Riel, 2000; Hadley & Sheingold, 1990; Leftwich, 2007; Riel & Becker, 2008). While the contribution of such studies to our understanding of technology integration is critically important, this line of research has not focused on the processes through which these teachers became exemplary. As a consequence, *the personal learning trajectories of exemplary technology-using teachers are unknown, especially in relation to PDT on ICT pedagogy*. However the aforementioned characteristics of exemplary technology-using teachers can work as rough guidelines in an attempt to locate groups of teachers with background properties that maximize the potential of in-service PDT.

One group of teachers with special background properties which might be important for technology integration are teachers with constructivist beliefs. Several studies have indicated that exemplary technology-using teachers are also highly likely to employ a constructivist, student-centered approach to teaching (Becker & Riel, 2000; Dexter, Anderson, & Becker, 1999; Hermans et al., 2008; Matzen & Edmunds, 2007; van Braak et al., 2004). Overall, a systematic relationship between constructivist approaches to learning and technology use has been reported in the literature: constructivist beliefs are correlated with a higher rate of technology adoption. While the relationship between constructivist teaching philosophies and technology use has been well established in the literature, *how exactly teachers who are very familiar with constructivist teaching and learning in a given subject area or grade level respond to in-service PDT on pedagogical uses of ICT has not been explored.*

Another group of teachers with specific background characteristics that might be important for technology integration are teachers of high academic qualifications. Compared to ordinary teachers, teachers who hold postgraduate degrees have by definition a higher degree of specialization. Riel and Becker (2008) found that a particular area in which professionally engaged teachers are differentiated from other teachers is that they have invested more in their own education and master's degrees were considered to be an indication of such an investment. As Riel and Becker (2008) report, professionally engaged teachers were more likely to (a) have a constructivist teaching philosophy and (b) use ICT more frequently and differently than other teachers (e.g., more tool applications, wider variety of applications). *Although specialization might influence how teachers respond to PDT, how teachers with a high degree of specialization, such as master's or Ph.D. degrees, respond to PDT has not been investigated.*

Focus of the Study

Overall, *there is a knowledge gap in terms of how specific teacher groups respond to in-service PDT on ICT pedagogy*. The present multiple case study aimed to examine how one such group of teachers responded to a PDT program on ICT pedagogy. More specifically, our target was a group of three primary school teachers who participated in an in-service PDT program offered by a University Training Center (hereafter UTC) in Greece. These teachers were selected among the other participants in the PDT program because they deviated maximally from the average teacher in several ways. First, they had a high degree of expertise in the field of science education as they all held relevant Ph.D. degrees. Second, they had a record of academic publications in refereed journals, having authored or coauthored scholarly papers in the area of science education. Third, they were all very experienced, as their teaching experience ranged from 10 to 20 years of service. Fourth, none of them were ICT novices as they all had previously used ICT in their teaching practices. Finally, two of them had participated in national funded research projects which aimed to support science teaching with ICT while the third earned her Ph.D. in a Teacher Education Department in Greece with a reputation for targeting ICT in the teaching of science. For these reasons, *the three teachers had backgrounds which clearly set them apart from the general teacher population*.

Given that these teachers participated in an in-service PDT program, their backgrounds were highly relevant for two main reasons. On the one hand, *their specialization in science education ensured that they were, by definition, among the most theoretically sophisticated teachers in terms of constructivist teaching philosophies and pedagogies*. Based on the literature reviewed above, they were the most likely to respond favorably to technology integration given that constructivist beliefs are related to classroom technology use (Becker & Riel, 2000; Dexter et al., 1999; Hermans et al., 2008; Matzen & Edmunds, 2007; van Braak et al., 2004). On the other hand, *the fact that the three teachers held not only master's but also Ph.D. degrees indicates a very high level of specialization*. Thus, based on the findings of Riel and Becker (2008), this specialization would greatly facilitate in-service PDT training on ICT pedagogy. Therefore, *we assumed that from the whole teacher population these three participants were the most likely to respond favorably to PDT not just on a superficial but also on a substantial level*. In fact, we would go as far as to argue that teachers of such backgrounds represent the ideal audience for seeding technology innovation concepts.

Given that the three teachers who participated in the PDT held constructivist teaching philosophies and had high academic qualifications, this multiple case study examined how they integrated technology in their practices along the sustain-transform continuum.

Given the design challenge of creating instructional scenarios, implementing them in their classrooms, reflecting on them in the context of the PDT, and then revising their initial instructional scenarios the following research questions were addressed:

1. *How did the teachers integrate technology in their designs?*
2. *Where is technology integration situated on the sustain-transform continuum?*

3. *What were teachers' reflections on their designs?*
4. *How did the teachers revise their initial designs?*

The first question aims to provide an account of technology integration in the context of their practicum so as to map out how the different technologies were prescribed to be used. The second question explored whether technology integration supported established practices or transformed them into new directions. The final two questions mapped out the teachers' responses by way of reflection or redesigning to the design challenge, its implementation, and the feedback they received in the UTC.

Method

Participants and Setting

Following the general European Union (EU) policy guidelines, the Greek authorities have adopted a two-level PDT program for primary and secondary teachers. In 2000 the Greek Ministry of Education (MoE) initiated a large EU-funded PDT program of teacher in ICT (see Demetriadis et al., 2003; Jimoyiannis & Komis, 2007, for a comprehensive account of this program). The program had an explicit technological literacy orientation and aimed to develop teachers' ICT skills and competences. It had a total duration of 50 h and was conducted at special school-training centers (STC). Thousands of teachers participated in this ICT training that continued through most of the decade.

In 2007 the MoE established EU-funded UTCs in academic institutions around the country (Jimoyiannis, 2010, provides a detailed account of this program). The objective of these UTCs was to provide high-quality in-service PDT in the area of pedagogical technology integration across the curriculum. The PDT curriculum involved pedagogical issues regarding technology integration in all academic subjects and grade levels. Each PDT program lasted for 350 h and spanned a period of 6 months. All primary and secondary teachers who had successfully completed the former training program were eligible for participation and could apply for a position. After completing the UTC in-service training programs, the participants could take a centralized exam and, if successful, become official ICT mentors in their respective academic subjects. Following the cascade model which was adopted for this PDT program, these teacher mentors would then provide pedagogical ICT training for their fellow teachers in local STCs (see Fig. 1).

Starting in late 2007, three main in-service training programs were offered at the UTC of the University of Thessaly, the authors' host institution. The present work draws on data collected from the third in-service training program (2011–2012). This program followed the general guidelines for successful PDT in terms of form (lectures, seminars and workshops, independent learning, and personal coaching through mentors), *length* (it was extensive covering 350 h and spanned a period of 6 months), and *curriculum* (clear pedagogical rather than technical orientation).

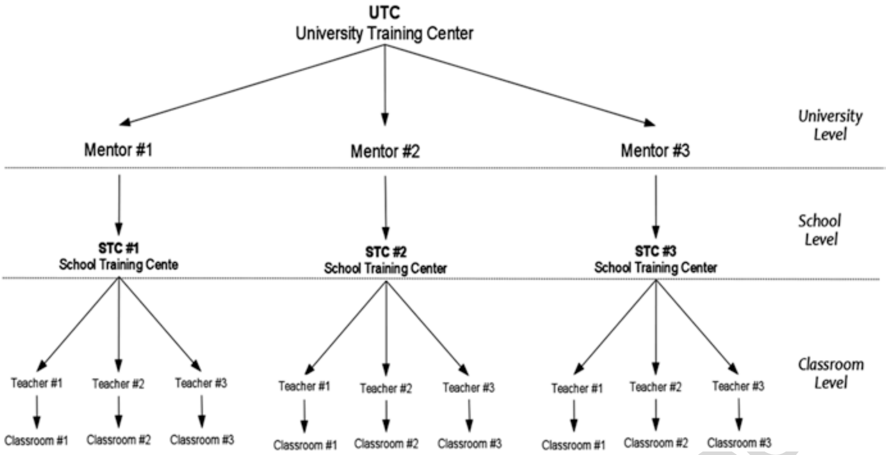

Fig. 1 A cascade model of PDT

A total of eight primary teachers signed up for the third in-service training program. In this work we focus on three of these eight teachers because they naturally formed a group of teachers with very special backgrounds.

PDT Curriculum

The in-service PDT program offered at the UTC in the University of Thessaly comprised a general part and a subject-and-grade-level specific part. The former had a broad, introductory goal and addressed issues related to educational policy in the EU and Greece, history of educational technology, learning theories, and how they relate to educational software, taxonomies of educational software, technical and administration issues related to the school ICT laboratories, and adult education. This general part lasted for 160 h and provided the foundation upon which the second, subject-specific part could build. The second part which lasted for 190 h focused on how to specifically integrate technology in the teaching of various academic subjects and grade levels. Both subject-specific and general-purpose software tools were introduced. Particular emphasis was given to technology integration according to the research literature for each academic subject. To this end, a number of experts specializing in the teaching of academic subjects were contracted as teachers. Following the MoE mandates to ensure the highest possible quality of training, only university staff or Ph.D. holders of various specializations were eligible to teach at the UTCs. In addition to the theory (i.e., general and subject-specific part), the training program also included a short 30-h practicum section. As part of the requirements of the practicum section, the participants had to implement two of their instructional scenarios (a) in their own classrooms and (b) in collaborating STCs. Four teacher ICT mentors who had already successfully completed previous versions of the University of Thessaly UTC in-service PDT program were also hired contracted to mentor the planning and reflection components of the practicum section.

Design, Procedures, and Data Collection

[AU4] [AU5] Following the rationale of qualitative methodology (Lincoln & Guba, 2000), the present study was conducted as a multiple case study (Yin, 2009). The study was designed as a case study in an attempt to understand how teachers of constructivist philosophies and high academic qualifications responded to an in-service PDT program on ICT pedagogy. In this multiple case study design, each teacher was treated as a separate case in order to determine common underlying patterns through replication.

The overall procedure followed is depicted in Fig. 2. The teachers attended the 350-h in-service PDT program which involved both theory and practical applications of ICT across the curriculum. The *theory* section was concluded with the design of ICT-based instructional scenarios. These instructional scenarios were put to practice in the *practicum section*. Each teacher selected two of the instructional scenarios designed in the course of the training and implemented them in their classrooms. The practicum section was followed by a feedback session where the teachers shared their experiences with the group and received feedback and suggestions from their fellow teachers, the teacher ICT mentors, and the authors. In the *reflection* session which followed, the teachers were asked to revise their instructional scenarios in light of their experiences and the feedback received.

Due to the nature and focus of the study, many different types of data were collected in the course of the PDT. For the purposes of the work reported in this chapter, we draw on the following data sources:

(a) *Instructional scenarios.* As artifacts, instructional scenarios were of primary interest as they embodied a teaching plan. The participating teachers developed several instructional scenarios, following a detailed template that was provided as part of the requirements of the training program. The teachers had the freedom to create any instructional scenario, in any subject, using any of the ICT tools available, in any way they saw fit. Following the theory and practice guidelines of the PDT, the main requirement was that the integration of technology in their designs would have to have high added value.

(b) *Group discussions.* Whole-group discussions were also of primary interest as it is during these that the teachers provided explicit accounts of their instructional scenarios, thereby disclosing the rationale behind their designs. Group discussions were held during the feedback session and took place at the UTC with the authors and the ICT-mentor teachers. These group discussions were tape-recorded, and large portions were transcribed verbatim for further analysis.

Fig. 2 Overview of the procedure

(c) *Revised instructional scenarios*. Revised instructional scenarios were meant to embody teachers' reflections following the implementation of instructional scenarios in their classrooms and the feedback session that followed. By reflecting on the elements the teachers perceived as problematic, revised instructional scenarios helped pinpoint the "corrective" measures needed. The revised instructional scenarios were also formally required for evaluation purposes.

(d) *Participant observations and field notes*. In the course of the practicum and reflection sections, the authors took various notes of informal communications with the participants (e.g., personal e-mails, informal discussions), questions posed in the practicum section, and problems which surfaced in planning and teaching. All such observations and notes were then combined with the rest of the data to facilitate the analysis.

Data Analysis

Instructional scenarios and revised instructional scenarios were the data sources through which we addressed the first two research questions. They were analyzed following established qualitative data analysis procedures. For each teacher case, this involved data reduction, data display, conclusion drawing, and verifications (Miles & Huberman, 1994). Each instructional scenario comprised several activities, and for the purposes of this work we used the instructional activity as our main unit of analysis. Following a qualitative content analysis approach, we initially used rough descriptive categories to classify technology use in each instructional activity, arriving at general profiles of ICT use per instructional scenario. Subsequent passes led to successive generalizations and mutual agreement between the researchers on the main categories of technology use in the teacher designs. The categories used are described next. These categories were used as indicators of constructivist theoretical underpinnings for the teachers and as a means of assessing which constructivist principles found their way to the instructional scenarios.

1. T*echnology tools*. This category included the various types of software tools used such as stand-alone software or network applications (e.g., web browser). This category assessed the presence of a constructivists' preference for a multitude of information sources so as to address students with different proclivities and intensify the social embeddedness of the information provided. Although a stand-alone software may indeed be specially designed in addressing particular disciplinary needs, the current availability of easily accessible learning resources through the Web makes them natural candidates for lessons addressed to digital natives.
2. *Information modality*. This category addressed the types of content that the technology made available and included text, images, video, and audio. This category assessed the importance of providing information of different modalities so as to supply multiple different representations of information.

3. *Information context*. This category described the nature of the information sources used, distinguishing between educational and authentic sources. It assessed the extent to which authentic information resources and real-time data possibly of local and personal interest were employed in the instructional scenarios. Although including information in the context of school necessitates distancing from the official sources by learned communities, the bulk of information available on the web by varying sources of expertise makes it practically feasible to assess authentic information sources.
4. Students' role in *technology use*. This category referred to who used technology (student vs. teacher), whether technology was used as a tool to process information (yes/no), the locus of choice of technology tools and sources (student vs. teacher), the locus of choice relative to how technology tools were used (critical decisions regarding technology use were made by the students vs. the teacher), and the mode of technology use (individual vs. group use). This category assessed various indicators of constructivist concerns for promoting student agency in the learning process. From a constructivist learning viewpoint, (a) students rather than teachers are expected to be the main users of technology, (b) students are expected to use technology as a tool to process information rather than simply consume information, and (c) students are supported in making the choices regarding technology use.
5. *Technology function*. This category examined the specific role technology played in terms of learning for every instructional activity. Technology was used for providing information, providing representations (without manipulation by the students), and providing opportunity for limited simulation (manipulation demands were minimal).

This category assessed the constructivist tendency to harness the potential created by the access to rich information sources and to strong tools for data exploration (e.g., to assess rich information sources, to synthesize information from various—often divergent—sources, to use real-time data to draw conclusions) and to use the visualization affordances of the technology (e.g., to conceptually facilitate the transition from abstract to the concrete, to use multiple representations perhaps in parallel to student manipulation). Finally, since all instructional scenarios were related to science education, it also assessed the presence of technology uses that are in sync with current constructivist learning environments in science education which capitalize (a) explorations of a physical phenomenon in ways impossible in real life, (b) experimentation (hypothesis formation and testing), and (c) developing science process skills.

Each instructional scenario activity was assessed with respect to the categories mentioned above. All six instructional scenarios we analyzed were related to science education, four belonged to earth science, one to physics, and one to environmental studies. The analysis of the transcriptions of the group discussions and the participant observations and field notes focused on themes pertinent to the third research question, i.e., *how the teachers reflected on the design challenge and its implementation.* On the one hand we examined if teachers thought that their designs reflected significant departures from their current practices. On the other hand, we looked at whether they experienced the design of instructional scenarios as a challenging activity. These data were triangulated with the teachers' assessment comments about the implementation of their instructional scenarios that were included in their instructional scenario reports.

Results

Technology Integration

The first question focuses on how the teachers integrated technology in their designs. The instructional scenarios were the main data sources used to answer in this part of the analysis. In order to identify patterns, each instructional scenario for every teacher was treated as a separate case. Despite differentiations, the analysis of the instructional scenarios revealed similar patterns of technology integration. Due to space limitations, one instructional scenario per teacher was randomly selected and is presented here.

Tables 1, 2, and 3 present the results of the analysis of one lesson that each teacher planned and carried out in the practicum section with respect to the categories of technology tools, information modality, information context, and technology func-

Table 1 Teacher A: Grade: 6; academic subject: science; unit: physics, analysis, and synthesis of light

Technology tool	Information modality	Information context	Technology function
Web browser	Text, image	Educational	Information provider
Web browser	Video	Educational	Information provider
			Representation provider
Web browser	Text, image	Authentic	Information provider
Web browser	Animation	Educational	Limited simulation
Web browser	Text, image, video, animation	Educational	Information provider
			Representation provider
			Limited simulation
Web browser	Video	Authentic	Information provider

Table 2 Teacher B: Grade: 4, academic subject: environmental studies, unit: the weather

Technology tool	Information modality	Information context	Technology function
Web browser	Text, image, tables, charts	Authentic	Information provider
Web browser	Text, images, tables, charts	Authentic	Information provider
Web browser	Text, image	Educational	Information provider
Stand-alone software	Text, image, animation	Educational	Information provider
			Representation provider

Table 3 Teacher C: Grade: 6, academic subject: geography, unit: day–night cycle

Technology	Information modality	Information context	Technology function
Stand-alone software	Animation	Educational	Limited simulation
Stand-alone software	Image	Educational	Representation provider
Stand-alone software	Animation	Educational	Information provider Limited simulation

tion. Each lesson was actualized within two periods, which is approximately 90 min. Each table row represents the different instructional activities in each lesson.

As can be seen in Tables 1, 2, and 3, technology use involved (a) digital learning resources and (b) interactive software applications. More specifically, taking into consideration all of the designs, technology use was characterized by the use of both general-purpose tools (such as a web browser) and the use of special-purpose educational software. The browser was primarily used for accessing information on the World Wide Web and, to a lesser extent, for running web-based simulations and animations. Although Web 2.0 sources (blog, wiki) were used in two cases by teacher A, they were employed as information sources and the students were not involved with the more constructive functionalities of these tools. The other type of technology use involved stand-alone educational software. It should be noted however that the stand-alone software that was used was the result of research work aiming towards addressing student misconceptions in the relevant natural science domains. Overall, the browser reigned as the main software tool as it was dominant in designs of two out of the three teachers.

In terms of modality, Tables 1, 2, and 3 show the presence of not only the textual mode but also visual modes. Visual modes included realistic videos, simulations, realistic videos that were annotated, realistic images, and charts. This variety is in accordance to the professed constructivism of the teachers. On the other hand auditory modes have attracted less attention.

In terms of authenticity, only some of the information sources used were authentic ones. The majority of the sources were educational, i.e., were tailor-made for educational purposes. Moreover even the authentic sources that were used were authoritative in nature, thus coming as close as possible to univocal educational sources. However the sources were appropriately selected so as to suit the targeted students' age range.

Finally, with respect to the category of students' role in technology use, the results do not show much variation. In all of the designs, technology was exclusively used by the students who collaborated in small groups to complete the assignments. However, technology tools and sources were explicitly selected by the teachers. Moreover, the ways both the technology tools and the information sources were to be used by the students were highly prescribed by the teachers through worksheets. The worksheet was the main tool through which the teachers tried to balance some freedom of choice for the students with a detailed specification of the technology use. Finally, technology tools were mainly used as a gateway to information, not as tools to process data and information or otherwise transform it.

On the whole, the designs of the instructional scenarios were influenced by constructivist principles. The students were the main users of various information sources and simulations in ways that facilitated the expression of their alternative conceptions and a reality check of these conceptions. Nonetheless, two constraining factors characterize most of the categories:

(a) Limitations of openness: Capitalizing on Web 2.0 functionalities, accessing conflicting information sources, and accessing people outside the walls of classroom are all nonexistent in the teacher designs.
(b) Limitations of students' agency: How and for what purpose technology is used are prescribed by the teacher, and any source of challenge (like conflictual information) is avoided.

Technology Integration Along the Sustain-Transform Continuum

The second research question focused on the technology leverage for implementing science education instructional scenarios that were clearly going past current practices in Greece. The initial instructional scenarios and the revised ones were the main data sources for this analysis. Teachers' reflections were also used as a secondary data source but are reported in detail in part c of this section. The main functions of technology can be seen in the rightmost column of Tables 1, 2, and 3. More specifically, when situating the function that technology performs in the context of the instructional scenarios we arrived at two main categories that express the leverage of technology: *accessibility* and *visualization*. The first refers to making accessible content which would be inaccessible without technology. The second refers to the visualization of physical phenomena and models in the context of providing 2D/3D static or dynamic representations as well as other forms of representation.

The first main function that technology played in the designs involved making inaccessible information easily tangible. For example teacher B used a meteorological site run by a state agency to make accessible to students real-time data on the current weather in different sites in Greece and Europe. Undoubtedly, using technology to access information which would be inaccessible through other means utilizes the potential of technology to add currency, relevance, authenticity, multimodality, and interest to one's teaching. Overall, the teachers used the information resources to enrich the curriculum content which had to be delivered. *On the other hand technology was not used to support engagement with students'* own concerns and questions. Moreover, once the information was accessed no further demands of creative craftsmanship either in processing the information or in interpreting the information were put on the students. The absence of conflictual or difficult-to-interpret information was further minimizing opportunities for this craftsmanship to be needed.

The second main technology function involved visualization. Instructional scenarios, worksheets, presentations of the instructional scenarios, and reflections on the instructional scenarios all centered on some form of presentation to the students.

As the analysis of the instructional scenarios suggests, although technology was used by the students themselves, *technology was largely used for demonstration purposes* in order to "show" something as clearly as possible, so that (a) student misconceptions are eradicated through cognitive conflict and (b) students are provided with crucial external representations that facilitate the understanding of the intended concept or process. For example, in the course of an instructional activity teacher C asked the student to stop a simulation showing coordinated representations of the Earth and its position relative to the Sun at specific time intervals. After each simulation freeze, the students had to answer specific questions which were given in the worksheet. Undoubtedly, visualization *is one of the main strengths of technology*, and it is understandable why the teachers made such an extensive use of technology-enabled visualizations. On the whole, the teachers did take into consideration students' alternative conceptions and constructed sequences of predefined experiences alternating raw production of students' ideas with *the "corrective" experience of superb visualization afforded by technology*.

When considering the whole corpus of the instructional scenarios the following common patterns emerged. First, simulations appeared in the teachers' designs, but their use was extremely limited. For example, in the case of the coordinated representations time was the only variable that could change. Moreover the directions in the student worksheets specified the specific values of the time variable where the students were instructed to freeze the simulation. Consequently, while on the surface the students appear to be actively controlling the simulation, from a learning point of view nothing much would have been different had the teachers used a video projector for a whole-class display of the simulation and had they posed similar questions to the whole class.

Second, technology use by students for constructing hypotheses or transforming and representing knowledge or managing the tasks was extremely sparse. There is only one exception to this pattern, teacher C, who on one occasion used GoogleEarth to create limited opportunities of manipulation and provided students with a genuine inquiry question. However the conditions were unfavorable (time allowed, place of the activity in the overall design) and rendered such an inquiry practically impossible.

Third, technology-enabled visualizations seemed to compete with physical artifact-enabled visualizations as if the two were struggling to occupy the same slot in the script of the didactical sequence. There are several manifestations of this. On the one hand, simulations were used sequentially and not in parallel with more traditional "experiments." For instance, teacher A introduced a simulation quite some time after a relevant experiment. On the other hand, teachers underplayed the visualizing and representational affordances of hands-on artifacts (such as the globe, construction, and manipulation of 3D artifacts). The teachers did not use the opportunity to combine digital simulations with the use of hands-on artifacts; instead, they showed an extreme faith on the efficiency of digital visualization as a learning tool. Finally, technology was often used (especially by teachers B and C) to stage a guided presentation of the features of the visualized physical model and to compare these features with selected and heavily transformed pseudo-authentic digital materials. In this final case digital reality took the place of physical reality both in terms of the experimental means and of the observations.

Teachers' Reflection on the Design Challenge and its Implementation

The third research question centered on teachers' reflections on the whole PDT experience and specifically looked at the teachers' perceptions of the design challenge and its implementation.

Technology integration as a challenge

Overall, the teachers did not experience the designs in the practicum section of the PDT as a real challenge. This is not surprising given their high level of expertise. As teacher A noted in the discussion of the reflection session:

> I have been using ICT in my teaching before this [PDT] program. I was certainly using ICT in Science Education which is a subject I know really well. So, it's not that I learned something new that I've just started using in my teaching…That doesn't mean I did not profit somehow from attending the PDT. It [ICT] was more useful for other [academic] subjects. But here [science education], since I taught in a domain that I know well, I feel that I would have still delivered even if I had not attended the PDT (Teacher-A)

Here the teacher clearly delineates what she thought of the PDT, stressing that she did not find it informative enough in her domain of expertise. Overall, the teachers who participated in this study were very confident with their theoretical underpinnings in science education and often cited relevant sources in their reflections. For example, in the following excerpt, teacher A explains the theoretical guidelines that guided their designs:

> From the point of view of current approaches to Instruction in the Natural science, learning is not just acquiring information but a continuous process of resolving of inner cognitive conflicts. Those conflicts are created and resolved through active participation, communication and interaction between the student and the learning and social environment in the classroom (Teacher-A)

This statement clearly reflects the constructivist convictions of the teacher, reflecting both the nature of science learning and an instructional approach to science teaching.

In another occasion teacher C articulated his own stance about when the use of ICT may be productive, largely corroborating our conclusions (section on "Technology Integration Along the Sustain-Transform Continuum" above) about the added value that teachers attributed to technology

> … my conclusion regarding the use of ICT or what we call "digital resources" etc. is that you aim to use ICT whenever you have no particular or no other ways of representation, alternative ways of representation, presentation of a new concept or phenomenon and the second way [of ICT use] is to use ICT in conjunction with the experiment etc. what we call multiple representations, that is as an complementary medium, as a supplementary tool to promote better understanding (Teacher-B)

Teachers' openness to change

Given that the main functions of technology involved information access and visualization, in the group discussion session the authors suggested other ways of technology integration, linking back to the theory and practices of the PDT program. It was pointed out to the teachers that technology might have been well integrated in their designs, but this integration was limited with respect to the potential of technology to support new forms of teaching and learning. Teachers' responses to our proposals were completely unexpected. Not only did they defend their designs but also claimed that both their designs and the ways technology was integrated in these designs were nothing short of exceptional. From our point of view, it was puzzling that the teachers did not seem to be open to suggestions and refused to even consider other proposals for contemplating new ways of technology integration which would have resulted in a more substantial level of technology use, a level that would have entailed a change in the teaching practices. *In an effort to ground the discussion in a concrete way and since visualization was a pivotal point in all of their designs,* each participant was asked to explicitly describe the function of visualization in terms of learning for his/her design. While the UTC training program provided a broad conceptual framework for understanding technology use across the curriculum, *the teachers approached visualization ad hoc in their designs; that is, they neither examined visualization in terms of a learning theory or a specific conceptualization of learning nor did they consider the special mediating role visualization was to play in their students' learning*. It was as if visualizations themselves would somehow provide most of the support needed by the students leaving teachers with the task of selecting and pacing the appropriate technological tools to supply the visualizations in a "just-in-time" fashion. Therefore, *there appeared to be dissociation between the concepts presented in the training curriculum and the concepts the teachers invoked to explain why exactly they chose to use technology in the ways they did*. Essentially, they conceived technology as a gateway to information, fitting a slot in the science education teaching script that they had mastered as opposed to addressing the technology's learning functions and the role of technology in mediating the learning of science content.

Teachers' Revised Instructional Scenarios

In addition to designing instructional scenarios, the PDT also involved implementing these scenarios in real-world settings and the teachers tried them out in their classes in the practicum section of the program. Due to the PDT design, the teachers were asked to reflect on their experiences and to describe in detail how they would change their designs based on their experiences with (a) the actual technology use in their classes and (b) the feedback they received in the reflection session. More specifically, they were asked to revise their instructional scenarios as they see fit so as to achieve the maximum level of technology added value for the same learning objectives. The resulting accounts of technology use would be idealized, free from any sorts of constraints (time, curricular, infrastructure, student background knowledge, etc.). *The analysis of these "idealized" instructional scenarios indicated that the teachers stood by their original designs. The only changes made were minor* *ones and were unrelated to technology use or function per se*. Consequently, information access and visualization remained the main technology functions in the revised instructional scenarios.

Discussion

The last century has been characterized by recurrent visions of transforming education through various technologies. The high hopes that technology integration into teaching practices would lead to their transformation have not been validated (Condie et al., 2007; Cuban, 2001; Cuban et al., 2001; Donnelly et al., 2011; Eteokleous, 2008; Hayes, 2007; Hermans et al., 2008; Li, 2007; Norton et al., 2000; OFSTED, 2004; Player-Koro, 2012; Prestridge, 2012). Teachers either resist using technology or use technology to sustain rather than transform their practices (Donnelly et al., 2011; Law & Chow, 2008a; Player-Koro, 2012). This failure to transform education through technology has been attributed to first- and second-order barriers (Ertmer, 1999, 2005). As research shows, first-order barriers are a necessary but not a sufficient condition for technology integration. Therefore second-order barriers need to be addressed, and one of the main tools to address them has been teacher training, both preservice and in-service. While there is a substantial body of research on what makes professional development effective, the importance of factors related to teachers' backgrounds has not been thoroughly explored yet (Coburn, 2004; Penuel et al., 2007). The present work contributes to this knowledge gap by examining how a group of teachers who had constructivist teaching philosophies and high academic qualifications responded to an extensive in-service PDT program on ICT pedagogy. The special characteristics of the teacher participants provide a measure of the limits of PDTs as a means to promote technology integration in educational practices in transformative ways.

Due to both the teachers' characteristics and the design of the PDT they participated in, there were no first-order barriers hampering technology integration. With regard to second-order barriers, *these teachers were science education experts and science education is a field where constructivism is championed more than any other educational field* (Duit & Treagust, 1998). It should also be noted that in Greece most Ph.D. dissertations in science education adopt some version of the constructivist paradigm. As the literature shows, teachers who have constructivist beliefs are more likely than other teachers to use technology and also tend to use it in more student-centered ways (Becker & Riel, 2000; Dexter et al., 1999; Hermans et al., 2008; Matzen & Edmunds, 2007; van Braak et al., 2004). On the other hand, one of the potential barriers to technology integration is the time and effort required by teachers to adopt an innovation (Hayes, 2007; Penuel et al., 2007; Sandholtz & Reilly, 2004; Tyack & Tobin, 1994). Teachers are often reluctant to embrace an innovation because there is a lot of work involved in adopting it. In our case, however, the teachers were already accomplished, i.e., had a sound theoretical foundation which in principle should require minimal work and effort on their part regarding technology integration. Overall, because the teachers did not have much theoretical ground to cover, we expected that their responses to PDT would be very positive in two principal ways. First, in terms of technology integration, we expected that *technology would be instrumental in the success of a lesson.* Second, we expected that *technology would not be a mere add-on to current teaching practices but it would leverage them leading to transformations*.

The *former* was fully corroborated by our findings as *the teachers integrated technology in their lessons in a fitting way, closely following the general principles of constructivist learning*. Firstly, the students themselves were the main users of technology. That did not mean the use of technology for drill and practice purposes as is common for novice teachers to do. A wide assortment of digital learning resources was used in the instructional scenarios, giving them currency and relevance. These means were effective in promoting student engagement and facilitated the students' recall of relevant prior knowledge. Secondly, collaborative work and learning were promoted as the students worked in small groups to complete the assignments. Students were indeed prompted to discuss the information and visualizations provided by technology, and certainly some questions could be solved through the joint effort of the students. Thirdly, technology was instrumental for the actualization of these designs and served the teachers' goal of achieving conceptual change in the science topics targeted in each lesson. The teachers themselves reported positive results through assessments they had embedded in the instructional scenarios and realized during the implementation of their designs. Based on teachers' backgrounds and expertise, such high levels of technology integration were hardly surprising and, as corroborated by their own comments, were to a certain degree mastered before following the current PDT program.

The latter, however, was *not supported by our findings. The analysis of the instructional scenarios and in particular the specific technology functions the teachers used indicate that technology was assimilated into their current practices.* To illustrate the nature of this assimilation, we will consider in some detail the dominant instructional paradigm of current science education practices in Greece. More specifically, this paradigm is an adaptation of the model of the "inquiry-scaffolding teaching method" (Schmidkunz & Lindemann, 1992, as reported in Αποστολάκης et al., 2006). [AU7] The science education teacher books for grades 5 and 6 elaborate on this didactical model and provide the general guidelines for its use. According to the rationale covered in the teacher books, each lesson follows a specific sequence because

> students' participation in inquiry is not unguided, but follows specific stages and is guided through specific actions, so as to be practically realizable. At every point the teacher can follow how students learn (Αποστολάκης et al., 2006, p. 32).

This sequence includes a first stage where the teacher transforms the subject he/she has to teach into an initial question or problem. Relevant prior knowledge is brought forth, and students are supported in proposing their ideas ("hypotheses") about the solution to the problem. Student misconceptions surface at this stage. Then the students perform one or more experiments that the teacher has selected for them. As the teacher book suggests, during this phase the teacher should not be too intrusive, allowing students to "really engage in inquiry." However, the time constraints of the implementation indicate that the authors of the teacher guide consider the experiments so well chosen that the students are either expected to arrive themselves at the intended conclusions or that they will be easily convinced by the arguments provided by the teacher. In the next stage, the teacher book proposes to hold a discussion through which the class arrives at the intended interpretation of the experiment and gradually towards answering the initial problem. There is no providence for the cases where students might propose new ideas that could be tested through alterations to the experiments or through new experiments. While the experiments do address students' misconceptions, they do not leave much space for student initiative and creativity in the unfolding of the inquiry. During the closing part of the lesson the teacher guide recommends that students compare their final answers with the ones they gave initially. In the final stage proposed by the teacher book, students should work on teacher-assigned exercises that are expected to lead to a deeper understanding of the science material covered.

As outlined in the teacher guide above, the dominant science education paradigm in Greece is strongly concerned about the pacing of the instruction, trying to balance its constructivist theoretical underpinnings and the appropriation of conceptual change literature with constraints that are inherent in the Greek educational system. Therefore it does not take into account students' own needs and the scaffolding demands placed on the teachers should they choose to support these needs. Out of the four main ICT affordances that Webb (2005) outlined in her review of science learning with ICT-rich environments, this dominant paradigm is compatible only with two: (a) promoting cognitive development and (b) relating science to students' own [AU8] experiences and data in the broader real world. The other two affordances namely

> increasing students' self-management and enabling them to track their progress so that teachers' time is freed to focus on supporting and enabling students learning; and facilitating data collection and presentation of data that helps students to understand and interpret the data, and additionally frees students' time so that they have more time to focus on developing conceptual understanding (Webb, 2005)

are not compatible with the concern about teacher control expressed in the above model. This view is in line with other literature proposals for using ICT in science education. For example, Chang (2013) argued that addressing student needs is probably a main factor in successful scaffolding of science learning through simulations. On the other hand, Osborne and Hennessy (2003) noted the critical role ICT can play for introducing students to scientific inquiry, for developing hypothesis formation and testing, for advancing science process skills, and for solving open-ended problems through various technological tools.

The examination of instructional scenarios against this backdrop leads to the conclusion that the teachers incorporated technology in their existing practices. There are two main indications of this. *First, the way that information was used in the instructional scenarios expressed a strong concern for efficiency in time management: all the information aimed to direct students towards the intended "correct" interpretation*. Even in the cases where authentic sources were used, they were as "school like" as possible: they were used in ways that would not demand judgment and evaluation, only the selection of bits and pieces of relevant information (for an alternative way of using information sources see Bell, 2000). Real-time, detailed, complex, and authentic data sources were utilized in ways that looked more like a guided tour. Finally, Web 2.0 resources were only used to access authoritative information indicating an entrenched practice that avoids introducing real-life conflict in the classroom. *Second, technology was exclusively used in order to provide authoritative information*. There is a striking similarity here between this technology role and the role "experiments" play in the "inquiry-scaffolding teaching method" (as adapted in the teacher guide).

Overall, *the ways teachers integrated technology in their instructional scenarios do not show any significant departure from established science education practices in Greece*. Considering teachers' backgrounds this was not expected as the conditions [AU9] for transformation were very favorable. Zhao, Pugh, Sheldon, and Byers (2002) reported that one of the factors that might affect classroom technology innovations is the distance from existing practice. In our case this distance was relatively short given the teachers' starting point. Consequently, the teachers did not have much ground to cover in order to integrate technology in a transformative manner, i.e., along the lines proposed by Osborne and Hennessy (2003).

Interestingly enough, not only was technology merely assimilated into existing practices, but *the teachers also refused to question their teaching practices and were not open to suggestions along this direction, that is, despite* the persistent efforts from the authors to explicitly point out the limitations in the ways they had integrated technology in their teaching in the practicum section. In retrospect, there are several possible explanations for this type of resistance. *First*, as the participants in our study were already accomplished teachers and researchers, *they probably did not come to the PDT thinking that they would need to radically transform their teaching practices*, much less of course in science education which was their domain of expertise. In all likelihood, they considered that such radical transformations of their teaching conceptions and practices had already taken place in the course of their professional histories. *Second*, resistance might be due to the fact that the teachers felt that the level of ICT integration they had already achieved was part of the roadmap that other teachers (that they soon would be mentoring) would have to pass through in order to achieve more highbrow goals. In this sense, they were probably excusing themselves from putting cognitive resources in the direction of further pedagogical experimentation. *Third*, it could well be that we have experienced a ceiling effect as *the teachers were already accomplished and there was no room for progress*. Unlike other PDT [AU10] studies (e.g., Dwyer, Ringstaff, & Sandholtz, 1990; Levin & Wadmany, 2005: Prestridge, 2012) in which the entry level of teachers who participated was that of an "average," "traditional" teacher, in our study the three teacher participants had could [AU11] not be considered "average" or "traditional" by any measure. *Finally*, it could be that the constructivist practices teachers had adopted might have been producing better results in validated tests than the practices of the average Greek teacher who still strives to meet the guidelines of current teacher guides. This means that they did not have many reasons to feel "pedagogical discontentment" (Southerland, Sowell, Blanchard, & Granger, 2011) with the teaching model they were following. It is likely that neither their former practices nor the PDT program succeeded in generating the "pedagogical discontent" needed for energizing the teachers' search for ICT integration of higher quality.

In terms of the sustain-transform technology integration continuum, we argue that *the responses of the teachers to the in-service PDT marks the upper limit of the possible range of technology integration*, at least in the context of Greece. Our findings suggest that *the teachers in our study who were very advanced theory-wise and already using fully compatible teaching practices could not go past a certain degree of technology use, that of sustaining existing practices*. Although there were no first- or second-order barriers, the *highest level of integration reached was to use technology as a gateway to information and supplying visual representations*. When comparing this with the dominant science educational paradigm in Greek education we see that neither of these uses suggests a transformation of teaching practices. Interestingly enough, the teachers did not significantly modify their initial designs, even after (a) trying them out in their classroom and (b) receiving feedback from the authors which highlighted several limitations and missed opportunities for adopting new technology-based practices. This suggests that their vision of technology integration did not go past the ways they were integrating technology in their practices before attending the PDT. As our findings indicate, a more substantial level of technology integration, namely one that would go past information accessibility and visualization and move towards new teaching practices, is probably not very likely even in the most favorable conditions, i.e., with teachers who have constructivist teaching philosophies and very high qualifications.

Implications

The findings of the present study have important implications for in-service PDT on ICT pedagogy. If accomplished teachers can only go so far after attending an extensive in-service PDT program such as the one described in this study, then one can only wonder how far average teachers might go in terms of technology integration so as to achieve the much desired transformation. Not only did the participants not move past a given level of integration, but they also refused to consider other types of technology use. If this is the upper limit obtainable by teachers who hold constructivist philosophies and are highly qualified, how realistic is it to expect any further transformation of teaching practices through technology? That is, *if technology integration does not lead to teaching practice transformation in the most favorable conditions, as the ones described in this study, then perhaps the time has come to rethink PDT programs in ICT integration.*

PDT has come to the spotlight because of the importance of second-order barriers for technology integration. As second-order barriers are considered to be intrinsic to teachers, the focus that much of PDT literature puts on teachers is understandable. In the end, the teacher is broadly acknowledged as the most critical mediating factor for classroom technology use (Ertmer, 2005). The present study clearly indicates potential limitations of current PDT programs if our objective is the transformation of educational practices through ICT. We argue that to address these limitations we will need to reconceptualize the way we approach in-service PDT programs on ICT pedagogy. As we see it, there are three issues pertinent to this reconceptualization.

First, we *need to redefine what technology integration really means*. We need to be very explicit about the range of integration as well as its nature. For example, if the objective is simply to integrate technology so as to enrich the curriculum, then the ways the teachers in our study integrated technology in their lessons are exemplary. From this point of view, current implementations of PDT programs can be very effective. However, if the objective is to integrate technology so as to change current teaching practices in specific directions (such as to foster student-centered learning, meaningful learning, problem-based learning), then the ways our participants integrated technology in their teaching practices are quite limited. It is imperative to define clearly what this direction actually is. In this sense, technology integration would have to be explicitly described not only in terms of teaching practices but also in terms of student learning and the crucial mediating role technology can play in order to achieve this learning. Recently, other researchers have also called for a reconceptualization of what it means to teach with technology and stressed the importance of sketching out such a vision (e.g., Ertmer & Ottenbreit-Leftwich, 2010).

Second, *we need to address other possible background variables that could influence the effectiveness of PDTs*. For example, the presence of pedagogical discontent (Southerland et al., 2011) that was mentioned above is such a variable that might make a difference. Such variables need not be strictly personal. They may be constructs that are strongly determined by the context of teachers' practices. For example even teachers with constructivist beliefs may not have the opportunity in terms of time or available assessment instruments to test the limits of their current designs and thus to experience pedagogical discontent. Or they may not feel psychologically safe to try innovations because they do not have the administrative support to try out very innovative designs in order to conceptualize and desire new goals for their students.

Finally, while a focus on the individual teacher is indispensable, we need to *broaden this focus to take into consideration not just the teachers themselves but also the contexts in which they function*. Ultimately, the "grammar of schooling" (Tyack & Tobin, 1994) is very important as it is these contexts that shape teacher beliefs and attitudes. Take for example the ACOT report conclusion, in which Dwyer et al. (1990) argue:

> Although the direction of change in ACOT classrooms is promising, the pace of change is slow, for even when innovative teachers alter their practices and beliefs, the cultural norms continue to support lecture-based instruction, subject-centered curriculum, and measurement-driven accountability. (p. 2).

This clearly delineates the power current norms have in shaping teacher thinking and consequently to teacher responses to ICT integration—even for innovative teachers. The importance of the context of an innovation has been stressed (Penuel et al., 2007; Starkey, 2010). Therefore, regardless of technology familiarity and constructivist beliefs about learning, the material conditions of actual practice (i.e., curriculum, legislation, high stakes testing, working conditions, resources) exert significant pressures on how teachers eventually come to view innovations in general and technology in particular. As it has been demonstrated, all these influences might eventually shape an object of activity for teachers that is markedly different to the one envisaged by educators, reformers, researchers, parents, politicians, and other stakeholders (Karasavvidis, 2009). For the most part, PDT research has failed to employ theoretical frameworks that take into consideration not only the teacher—as the alleviation of second-order barriers clearly demands—but also other contextual factors that have the power to shape teacher thoughts and practices. Future studies need to draw on theoretical frameworks that help conceptualize PDT programs in systemic terms so that the individual teacher no longer remains the focal point of attention and the sole unit of analysis.

Conclusion

The current research addressed a gap in the current literature with respect to the way teacher background properties such as expertise and qualifications might influence the effectiveness of PDT programs. The first main study finding is that even after attending an extensive in-service PDT program, three teachers with constructivist teaching philosophies and high academic qualifications integrated technology in ways that sustained rather than transformed their existing practices. The second study finding is that the teacher participants found it very challenging to consider other types of technology integration that would be more on the transform end of the sustain-transform continuum. As teachers who hold constructivist beliefs and have high levels of qualification are expected to exhibit the most favorable response to PDT programs, this work raises serious concerns with respect to how far contemporary PDT programs can go in the direction of transforming teaching practices through technology. Despite its main limitation, namely the small number of teachers who participated, we think that the present study contributes to delineating the upper limit of technology integration that could be realistically expected from mainstream PDT programs. Further research in this direction should take the "grammar of schooling" into consideration and carefully examine the shaping influences of context on teacher beliefs and, consequently, on their responses to PDT.

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