Many claims have been made about the benefits of using educational technology. However, as many studies have demonstrated, the impact of educational technology in schools has not transformed learning and teaching substantially so far. Consequently, a majority of teachers does not yet exploit the creative potential of technology and do not engage students more actively in the production of knowledge. Thus, there is agreement that teacher training should not just encompass technological skills but rather a full understanding and complete mastery of technologies as pedagogical tools. The paper is structured around four sections. The first section presents an analysis of how affordances, in other words, pedagogic advantages of computer-enriched environments may support students in learning physics. The second section considers teacher education as the crucial component in the pedagogical use of technology in learning and teaching. As a result, research findings from teacher training courses, which were carried out within the European Project ICTforIST (ICT for Innovative Science Teachers), are reported in the third section. Finally, the concluding section examines the continuing value of the TPACK (Technological Pedagogical and Content Knowledge) construct for the physics education community.

Introduction

The recent implementation of technology in the classroom is probably one of the most challenging innovations that many teachers have to confront today. Researchers claim that appropriate educational technologies have the potential to make physics’ concepts more accessible through visualization, modeling and multiple representations. As a result, students are engaged in more powerful scientific activities as they are able to perform investigations that would not be possible without the use of technology. Although technological innovations have the capability to significantly change how scientific investigations are done and greatly enhance the teaching and learning of science, its use is no more effective than any other resource or innovation when researched-based effective teaching practices are not followed (Bryan, 2006). A growing number of studies are discovering that both new and experienced teachers feel inadequately prepared to use computers and other forms of technology in their classrooms (Villegas-Reimers, 2003). Recent review of the effect of technology-enriched teaching activities in science lessons has shown that teachers will need training and continuing professional development in the use of technology to carefully integrate it into the teaching and learning process and to be able to provide appropriate guidance (Hogarth et al., 2006).

The mere availability or use of computers doesn't have an influence on pupils' learning, but technology can contribute to changes in teaching practices and school innovation; specific applications of computers can positively impact student knowledge, skills and attitudes (Kozma, 1994). Indeed, the application of computers as useful tools depends crucially on the software functioning within them, and also on the design of activity sequences that can scaffold students to develop scientific thinking and conceptual understanding. There is evidence that students of all ages learn science better by active participation in the investigation and interpretation of physical phenomena, and that listening to someone talk about scientific facts and results is not an effective means of developing concepts. In fact, learning environments can positively influence the learning process and learning environments can be determined by the teacher (Niedderer, 2001). According to the Bransford model, effective learning environments must be simultaneously "learner-centred", "knowledge-centred", "assessment-centred" and "community-centred" (Bryan, 2006). Consequently, well-designed pedagogical tools
(generally computer based) that allow students to gather, analyze, visualize, model and communicate data, can aid students, who are actively working to understand physics (Thornton, 1987). According to this constructivist view of learning, the potential learning benefits associated with four main software tools, which serve constructional activities in science, are addressed in the study: Data-logging, modelling, simulation and video measurement.

Research literature on computer-supported learning suggests that there are two aspects which should be considered. Firstly, due to the diversity of disciplines and unique features of technology, the ways in which technology might best be used for each discipline strongly depend on the content to be taught (Bull et al., 2007). Researchers claim that, for example, microcomputer-based laboratory (MBL) activities are effective in improving students' understanding of graphs of physical events (Thornton & Sokoloff, 1990). Furthermore, research findings suggest that online interactive simulations can generate a high level of engagement, exploration and understanding among students with very diverse ages and backgrounds (Wieman & Perkins, 2006). Besides this, appropriate educational technologies have the potential to make physics' concepts more accessible through visualization, modelling and multiple representations (Bryan, 2006). Students are engaged in more powerful scientific activities and they are able to perform investigations that would not be possible without the use of technology. As a follow-up to hands-on activities, interactive tools can empower students to pursue their own research questions without being hindered by the limitations of “real” experiments and to construct their understanding through semi-guided exploration (Urban-Woldron, 2009).

Besides focusing on content, or as a second aspect, the extension of Shulman’s concept of “pedagogical content knowledge” to “technological pedagogical content knowledge” (TPACK) emphasizes the critical role of the teacher as curriculum designer (Mishra & Koehler, 2006). It follows that realizing the potential of the technology requires skills not just of technology, pedagogy, and content in isolation but rather of all three taken together. TPACK is primarily achieved when teachers know how technological tools can transform pedagogical strategies and content representations for teaching specific topics (Jang & Chen, 2010). In fact, the research literature converges on the conclusion that teachers tend to use ICT largely to support, enhance and complement existing classroom practice rather than actually re-shaping subject content, goals, activities and pedagogies and fostering active participation of students (Osborne & Hennessy, 2006; Fischer & Reinhold,2006). Otherwise, the process of professional development has a significant positive impact on teachers’ beliefs, attitudes and practices, students’ learning and on the implementation of educational reforms (Villegas-Reimers, 2003). Additionally, working in teams and engaging in reflective, collegial work, focused on developing plans for their own classrooms and doing all this in a real classroom, accelerates teachers’ professional growth (Sandholtz, 2001).

In order to make physics teachers capable of using technologies in constructive ways to teach content, particularly focusing on conceptual understanding and self-regulated learning of their students, modules from the ICTforIST project were used for teacher training. The learning activities used in the teacher training courses were inspired by publications uncovering a consistent set of student difficulties with graphs of position, velocity and acceleration versus time as well as basic concepts of electricity. Computer-based tools, virtual experiments and simulations were used to facilitate learning. In particular, the following educational technologies were used: firstly, motion detectors in combination with hand-held computer interfaces and interactive software tools, and secondarily, computer simulations. These technologies were supposed to allow students to collect relevant data, perform a series of analyses, and interactively engage them in exploration of physics concepts. The focus of the
study is on the investigation of two different types of teacher training courses: a course for pre-service secondary physics teacher students, and in contrast, a professional development course for already practicing secondary physics teachers.

In conclusion, effective technology integration has to bring together the teaching of subject matter with effective and appropriate uses of technology accompanied by the refinement of teaching practices to engage students in the use of technology as they investigate curriculum, express what they know and understand, and apply knowledge to construct new meaning. Naturally, to meet these needs, suggestive technology integration certainly requires teachers’ development of insightful sensitivity to the dynamic, transactional relationship between all three components of teacher knowledge. According to research findings from literature, the TPACK framework may provide a useful organizational structure for defining what it is that teachers need to know to integrate technology effectively. However, an essential question concerning issues about technology integration lies, firstly, in how teachers can learn to infuse technology innovatively into subject area instruction and learning, and secondly, how to help teachers to make individual meaning of new constructs and experiences with technology to determine its impact on education, including learning processes, access to content and instructional methods.

Integrating Educational Technology into Physics Topics

Results from physics education research on student understanding indicate that there is often little change in conceptual understanding before and after formal instruction (McDermott, 1993). The types of problems physics students have, for example, in the area of kinematics graphs (McDermott et al., 1987; Mokros & Tinker, 1987; Trowbridge & McDermott, 1980; Gunstone, 1987), and basic electricity (McDermott, & Shaffer, 1992; Duit & von Rhöneck, 1998; Engelhard & Beichner, 2004) have been carefully examined and categorized. Accordingly, students encounter difficulties with graphs of position, velocity, and acceleration versus time as they do not separate the shape of the graph from the path of the motion. Learning difficulties presented in the studies concerning electricity suggest a large variety of students’ misconceptions: current is consumed passing through an electric resistance; the battery is a source of constant electric current, the order of elements and the direction of the electric current in the circuit are relevant.

There are two most common errors students make when working with kinematics graphs, which have position, velocity, or acceleration as the ordinate and time as the abscissa and are used to represent kinematic phenomena and concepts: First, they think that the graph is a literal picture of the situation and do not see it to be an abstract mathematical construct. Second, there is confusion concerning the meaning of the slope of a line and the height of a point at the line (Beichner, 1994). Students often seem to read values off the axes and directly relate them to the slope, whether they apply or not.

In order to address the abovementioned issues, Metcalf and Tinker highlight the general beneficial affordances of technological learning environments: “Technology is needed…not just to give students exposure to the technology or to satisfy parents; technology greatly improves learning and supports science education standards that are difficult to teach without using technology” (Metcalf & Tinker, 2003). According to concepts of graphs in kinematics, it is generally agreed that an important component of understanding the connection between reality and the relevant graphs is the ability to translate back and forth in both directions (McDermott et al., 1987). Rosenquist and Mc Dermott (1987) suggest an approach in which actual motions in the laboratory provide the basis for developing a
qualitative understanding of the kinematical concepts. They emphasize how instruction based on the direct observation of motion can help students recognize key features of definitions and make explicit connections among concepts and their graphical representations.

Furthermore, Thornton and Sokoloff (1990) argue that the Microcomputer-based Laboratory (MBL) tools give students the opportunity to experience the excitement of the process of science. Students can creatively build and test models and explain the world around them. “Because of their ease of use and pedagogical effectiveness, they make an understanding of physical phenomena more accessible to the naïve science learner and expand the investigations that more advanced students can undertake” (Thornton & Sokoloff, 1990). However, the authors underline that the tools are far from sufficient; there is need for a combination of tools and appropriate curricular materials as well as eligible social and physical settings. Research indicates that it is the real-time nature of MBL that accounts for the improvement in student achievement (Brasell, 1987). Students are able to examine the situation while the graphs relating to the specific event are being produced (Beichner, 1990). Five features of MBL seem to contribute to its success in facilitating graphical communication: MBL pairs, in real time, events with their symbolical graphical representations; it provides immediate feedback; it eliminates the drudgery of graph production; it encourages collaboration, and it affords genuine scientific experiences. Thus, students are able to concentrate more on discovering and understanding physics concepts, and in consequence, develop critical thinking like a scientist.

Furthermore, advances in technology have introduced remote data logging, calculator-based laboratories (CBL) and hand-held devices over the past years. A Calculator-Based Ranger (CBR), a motion detecting device, enables real data from real experiments to be captured in real time. In turn, using a CBR with graphing calculators permits rapid production of visual displays, with statistical data available for analyses leading to prediction models. Furthermore, these experiences help students see the groundwork of existing interrelationships between underlying concepts. For example, by using a CBR and a graphing calculator, students are expected to collect, view, and analyze motion data without tedious measurements and manual plotting. As a person walks in front of a motion detector back or forth, the motion of the person is plotted on the screen.

A special feature of the graphing calculator software, the activity “Distance vs. Time Graphing”, supports the generation of random target distance graphs consisting of three linear parts. Students can be asked to match a graph on the screen. The graph-match-activity addresses various student competencies: First, the students previously have to study the graphs and consider how they would walk to produce the target graph shown on the screen. Then they can test their prediction, choose a starting position and finally walk in the considered way to match the target graph on the calculator screen. Finally, when they are not successful the first time, the process can be repeated until the motion closely matches the graph on the screen.

Although the experiment “Rolling a Cart down an Inclined Plane” is a classic experiment, students’ learning activities can be significantly enriched, when technology is used. The plots, which are created from the collected data, can serve students as a visual representation of the relationships between the physical and mathematical descriptions of motion. Students can be encouraged to recognize, analyze, and discuss the shape of the plot in both physical and mathematical terms. Additional dialog and discoveries are possible when functions are entered and displayed with the data plots. In this experiment students will investigate how the angle of the inclined plane affects the velocity and the acceleration of the cart and relate their results to Newton’s second law of motion. Furthermore, technology can help students discover that, in fact, the cart is not constantly accelerating. As the cart
accelerates (downwards due to gravity), the drag force (caused by air resistance) acting on the cart increases and its acceleration decreases. Technology makes this matter of fact accessible and especially visible to the learner even in various representations.

Another data-logging experiment uses a CBR in combination with a probably more sophisticated handheld device or with computer software to record and analyze the motion of a trolley rolling down a slope and rebounding due to the action of a spring buffer. Students have to assemble the apparatus, as shown on the worksheet, so that the trolley with an attached buffer can move up and down a sloping runway. A motion sensor, which is connected to the handheld device or directly to the computer, is placed at the top of the runway. The data-logging software is configured to measure the distance of the trolley from the sensor and to present the results as a graph of distance against time. After the trolley is released, it accelerates until it hits the wooden block, bounces off and moves up and down the runway several times. Thereby, the distance travelled by the trolley reduces after successive bounces. Data is collected within a few seconds. Students obtain a graph of distance against time and have to associate the features of the graph with the observed motion. They can trace the graph and identify interesting points on the graph, and relate them to the real motion of the trolley. Asking students to make predictions about the connections between the shape of the graph and the speed of the trolley may prompt their thinking about the forces acting on the trolley, and may also be useful to engage students in scientific inquiry. They can study the velocity of the trolley more directly by setting up the data-collection software to plot velocity against time. Thereby, students have to regard that a typical motion detector velocity-time plot actually represents speed, not velocity. Only the magnitude, which can be positive, negative, or zero, is given. Direction is only implied. A positive velocity value indicates movement away from the CBR; a negative value indicates movement toward the CBR.

According to the richness of the collected data, further and much deeper investigations can be accomplished. For example, students can be inspired to find ways to derive the velocity of the trolley from the distance versus time graph. If they do so, they possibly end up in recovering another interesting feature of the graph: the asymmetry of each loop. By this way, students can adjust appropriate functions to fit the different parts of selected scatter-plots representing the collected distance vs. time as well as velocity vs. time data. The slope of the linear functions in the graphs, showing velocity vs. time data and representing acceleration, depends on the direction of the movement. Careful examination of the graphs shows that the velocity after rebound is slightly less than the velocity before. The gradient of this graph indicates acceleration which is shown to be different for motion up the slope compared with motion down the slope. The difference may be accounted for by friction.

Furthermore, simulations from the Physics Education Technology project (PHET) at the University of Colorado were used in the teacher training courses in the field of mechanics, primarily as a follow-up to real data-logging experiments. PHET has developed and tested are large number of online simulations for teaching physics. The authors claim four pedagogically worthwhile features for their simulations: First, to be highly interactive for providing direct and immediate response to user actions; second, to literally invite students for interactivity and exploration by using an appealing environment and reasonably sophisticated graphics; third, to support exploration by simple and intuitive controls, with minimal reading required; and fourth, emphasizing connections to real-life objects. Wieman and Perkins (2006) estimate that the best animated, interactive and game-like environments “will occupy students (and, on occasion, faculty) for hours.” Particularly, the PHET simulation “The Moving Man”, which was used in the study, aims to link multiple representations, as it is a characteristic for a good
scientist. This is achieved by making the visual and conceptual models of expert scientists accessible to students through various graphs, which are created in real time. When the student drags the little man around using the mouse, graphs of his position, velocity and acceleration are created in real time. Conversely, the student can directly manipulate the man’s position, velocity or acceleration and see how the man responds. Beyond that, the student can also “play back” the man’s motion, watch the man move according to the graph, and display velocity and acceleration vectors. It is assumed that these features clearly improve the ease with which students can grasp and see these different representations.

In addition to mechanics, electricity is one of the areas of physics most studied in terms of learning difficulties. Thereby, a significant part of these studies refers to the teaching of simple electric circuits, highlighting three categories of student difficulties: inability to apply formal concepts to electric circuits; inability to use and interpret formal representations of an electric circuit; and inability to qualitatively argue about the behavior of an electric circuit (Mc Dermott & Shaffer, 1992). Duit and von Rhôneck (1998) point out the relevance of students’ pre-instructional conceptions in the learning of physics. In consequence, Engelhart and Beichner (2004) developed a multiple choice test to detect and interpret concepts about direct resistive circuits, which was used with hundreds of students and can help to evaluate curriculum or instructional materials and also various teaching approaches. To figure out certain student difficulties and link them to research based misconceptions, the author is developing a test instrument, which also could be used by teachers to informatively assess understanding of basic electricity for actuation of the teaching process (Urban-Woldron & Hopf, 2010).

For example, the PHET simulation CCK (Circuit-Construction-Kit) allows students to build arbitrary circuits involving lifelike resistors, light bulbs, wires, batteries, and switches. Students can measure voltages with realistic meters and currents whether with realistic meters or by using a non-contact-ammeter. This last mentioned feature enables students to explore the intensity of current alongside the whole circuit. Not only can they see light bulbs lighting up with various intensity, but they additionally see what cannot normally be seen: electrons that flow around the circuit with their velocity, likewise, proportional to current. Thereby, every display immediately responds to any changes in circuit parameters. Findings from studies suggest that this simulation generates a high level of engagement and exploration, and helps students understand the basic concepts of electric current and voltage (Wieman & Perkins, 2005).

**Supporting Thoughtful Uses of Educational Technology with Teacher Training**

The physics topics of the teacher training course are to address students’ understanding of kinematics concepts and simple electric circuits. For the adaption of the ICTforIST course materials, results from physics education research about learning difficulties concerning firstly, simple electric circuits and secondly, graphing misinterpretations with emphasis on kinematics were used. The conceptual design of the teacher training course was geared to research findings that consistently reveal that, even after formal instruction, students still have difficulties and misconceptions in understanding the basic concepts of electricity, which, in consequence, seem to be very resistant to teaching efforts and change (Shipstone et al., 1988). Especially, learning difficulties in electricity may be attributed to the fact that the related concepts are highly abstract and extremely complex and thus totally depend on models, analogies, and metaphors (Mulhall et al., 2001).
Furthermore, the conceptual approach of the study builds on the TPACK framework, designed by Koehler and Mishra (2005) to illustrate the multifaceted interplay and characteristics of teacher knowledge and technology integration in education. According to Archambault and Crippen (2009), the TPACK framework may be a useful organizational structure for defining what it is that teachers need to know to integrate technology effectively. The design of the teaching materials and the working examples was driven by the publications related to TPACK. Thus, effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between the three involved components: content, pedagogy, and technology. Necessarily, appropriate structured learning environments have to bring together the teaching of subject matter with effective and appropriate uses of technology by refining teaching practices to engage students in the use of technology as they investigate curriculum, express what they know and understand, and apply knowledge to construct new meaning.

An essential question concerning thoughtful pedagogical uses of technology is related to two issues: firstly, how teachers can learn to infuse technology innovatively into subject area instruction and learning, and secondly, how to help teachers to make individual meaning of new constructs and experiences with technology to determine its impact on education, including learning processes, access to content and instructional methods (Hughes, 2005). Actually, ICT-rich environments already provide a range of pedagogic advantages to enable learning of science, but necessarily these affordances have to be integrated with other pedagogical innovations to provide an even greater potential for enhancement of students’ learning (Bryan, 2006). Beyond that, one of the most important things to understand about technologies is that particular technologies have both specific properties that allow certain actions to be performed, encouraging specific types of learner behaviour, but also constraints (Webb, 2005). Furthermore, one other important issue to understand about technologies is that particular technologies have both specific properties that allow certain actions to be performed encouraging specific types of learner behaviour and also constraints. Therefore, integration of technology into the classroom requires deep understanding of complicated interactions of multiple factors (Koehler et al., 2007). The teacher is viewed as an autonomous agent with the power to significantly influence the appropriate, or sometimes probably inappropriate, integration of technology in teaching. However, teachers mainly focus on technological issues and scarcely keep an eye on connecting subject matter content and pedagogical processes in ways that promote effective student learning in the content area by using technology (Urban-Woldron, 2008).

In order to design computer-based learning environments so that they elicit effective learning activities, it is necessary to analyze the factors that determine learners’ goals and their choices of processing strategies (Gerjets & Hesse, 2004). Van Merrienboer & Paas (2003) postulate three characteristics to be necessary making up a powerful learning environment: first of all, use of challenging problems that elicit active and constructive processes of knowledge and skill acquisition in learners; secondly, involve learners in collaborative work and give them ample opportunities for interaction, communication and collaboration; and finally, encourage learners to set their own goals and provide guidance to help them taking more responsibility for their own learning activities and processes. Concerning the promotion of students’ engagement in exploration, it was presumed that this could best be sustained by constructivist-oriented POE (Predict-Observe-Explain) tasks and the requirement that students complete written worksheets.

According to cognitive load theory (CLT), learning outcomes will mainly depend on the pattern of cognitive load imposed by learning materials onto the learner’s working memory (Sweller et al., 1998).
Therefore, in agreement with CLT, designing technology-based instructional environments should mainly aim at reducing unnecessary extraneous (or ineffective) cognitive load but, at the same time, impose a certain amount of germane (or effective) cognitive load by forcing learners to invest mental effort in activities that foster the construction of complex cognitive structures (Gerjets & Hesse, 2004). As a learner, who is confronted with a specific learning environment, has to decide which goals he or she wants to accomplish during learning and which strategies are to be deployed in order to achieve these goals, his or her selection will most likely be influenced by affordances of the learning environment and by own instructional conceptions (Gerjets & Scheiter, 2003).

Self-regulated learners are generally characterized as active learners, who efficiently manage their own learning experiences in many different ways (Schunk & Zimmermann, 1994). That is, self-regulated learners are motivated, independent and meta-cognitively active participants in their only learning process (Zimmermann, 1990). Pintrich and de Groot (1990) propose three components constituting self-regulated learning: first, students’ meta-cognitive strategies for planning; secondly, monitoring and modifying their cognition as well as valuing students’ management and control of their effort on classroom academic tasks; and third, students’ actual cognitive strategies that they use to learn, remember, and understand the material. Findings of further research on self-regulated learning indicate that student involvement in self-regulated learning is closely tied to students’ beliefs about their ability to perform classroom tasks and to their beliefs that these classroom tasks are interesting and worth learning (Wigfield & Eccles, 2000).

**Designing and Conducting Teacher Training Courses**

What do physics teachers need to know about educational technology and how they acquire this knowledge? These questions have guided the design and evaluation of teacher training courses within the European project ICTforIST focusing on the development of TPACK, as conceptualized by Koehler and Mishra (2005). Accordingly to this aim, the courses should support both pre-service and in-service teachers in understanding how the use of particular technologies changes both teaching and learning. The paper reports on the use of selective teacher training materials of ICTforIST project in differently designed courses. Mainly focusing on pedagogical techniques to use technologies in constructive ways to teach physics content, the courses should additionally help teachers to also reflect on the effects of the particular strategies for integrating technology.

Effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between the three components technology, content and pedagogy (Koehler & Mishra, 2008). The aim is to bring together the teaching of subject matter with effective and appropriate uses of technology as well as refining teaching practices to engage students in the use of technology as they investigate curriculum, express what they know and understand, and apply knowledge to construct new meaning. According to the conceptual framework of Sandholtz, Ringstaff & Dwyer (1997) teachers have to move through an evolution of thought and practice (ETP) when learning to use technology in the learning process. They start in the so-called entry-phase and end up in the invention-phase discovering new uses for technology tools and using technology as a flexible tool in the classroom facilitating the emergence of new teaching and learning practices.

Based on the conceptual frameworks of TPACK and ETP a blended learning course for teacher training of practicing physics teachers, including a half-day session, was designed and offered to
twelve (8 female, 4 male) teachers. It started with a face-to-face session; all twelve teachers participated. Over the next ten months the teachers were supported by an electronic platform, where they were offered additional materials and where they were expected to discuss their lesson plans and collectively reflect on their teaching activities and how to become more learner centred when implementing technology in teaching kinematics. In the face-to-face teacher training session, as a starting point, according to the first two phases of EPT, the teachers were primarily introduced to the use of the CBR used along with graphing calculators by trainer demonstration. Addressing phases three to five from EPT teachers were next introduced the a special application of the graphing calculator software, which supports the activity “Distance vs. Time Graphing” by generating random target distance graphs consisting of three linear parts. The teachers were invited to consider what specific teaching and learning goals within the context of kinematics could be addressed by this particular feature and to discuss how it could be implemented. At end of the face-to-face session the teachers were motivated to continue participating in the course by using the electronic platform to pose questions, stay in touch, discuss and exchange ideas and to reflect collaboratively on lesson plans and teaching experiences. The ELearning-part of the course should enable teachers to share and discuss their ideas.

Whereas four of the twelve teachers actively used the ELearning platform by asking questions, encouraging colleagues in discussions, exchanging materials and lesson plans as well as refining and reflecting ideas, the other teachers did not scarcely took part in discussions. Only two of them occasionally contributed ideas or materials or posed questions. In contrast, all 17 participants of the course for prospective teachers (9 female, 8 male) actively participated also in the ELearning part of the course. All students were novices in the field of technology integration in physics teaching and learning. The course for future teachers was designed as blended-learning course lasting 16 weeks throughout a whole semester. For communication and collaboration as well as for the distribution of the training materials and the questionnaires an electronic platform, based on the software Moodle, was used. There were three 4-hour in-class units in the weeks 1, 6 and 10, during which the prospective teachers were offered opportunities to learn from and not about teaching with technology. By means of self-study materials, prospective teachers had to work on individual assignments, designing lesson plans for each of the three topics, and deliver them to the instructor.

The scales and items for assessing prospective teachers’ motivational orientations and their perceptions in TPACK domains were primarily drawn from literature (Pintrich et al., 1992; Schmidt et al., 2009) and accordingly adapted. A motivation questionnaire was administered in week 1, whereas a TPACK questionnaire was completed twice, as initial one and at the end of the semester. Additionally each of the participants of the study prepared a reflective journal on the overall process of the course at the end of the semester as well as three lesson plans at specified dates. Responses from the TPACK questionnaire were analyzed as matched-pair means for each survey question. The quality of technology integration was assessed by means of the rubric from Harris and her colleagues (2010). Also, the relationship among motivational orientations, perceived TPACK and pre-post-difference as well as the quality of TPACK inferred from the lesson plans was analyzed. As the primary method of data examination for the reflective journals and the open questions verbal inductive analysis was used. Accordingly, the data were assigned to four categories, resulting in a numerical overview of the outcomes. All items of the questionnaires were aligned on a Likert scale, ranging from 1, “I totally disagree” to 4, “I totally agree”. 
The findings of the study indicated that prospective teachers value the course materials as well as the design of the course to be helpful for developing a critical understanding of TPACK, independently from gender and motivational orientations. Prospective teachers’ goals and value beliefs for the course seem to have a positive impact on the evolution of TPACK, both inferred from self-reports and the external assessment of the associated lesson plans. There is a relationship between motivational orientations and evolution of TPACK. According to the course for practicing teachers, it can be stated that there is a significant relationship between student perception of experiencing competence and the extent of participation of the associated teacher in the teacher training course. Students, whose teacher was engaged in teacher training, valued the learning environment significantly higher than their peers in the classes with a teacher, who did not make apparent use of the ELearning part in the teacher training course.

**Implications for further research**

The studies examined how teachers used computer-based technology to enhance their lesson plans, by selecting appropriate technology tools from the course materials and creating learning opportunities for students. Questionnaires, lesson plans and reflection journals, which were analyzed by both quantitative and qualitative techniques, provide evidence that teachers’ TPACK developed individually. There is evidence that the training materials not only appear to stimulate teachers’ thinking about useful instructional technologies, but also to encourage them effectively integrate technology into practice. However, the findings of the study highlight important differences between the two different groups: the pre-service and the in-service teachers. In consequence, there is still need for future research on the development of physics teachers’ TPACK in order to arrange training for integrating TPACK into teacher training and professional development.

Although the findings of the two case studies relied on data yielded from self-report surveys of students and teachers, some important implications for both research and practice can be derived. Firstly, taking a look at students’ outcomes and teachers’ responses in the first study, it appears that it might be reasonable to teach technology in contents that honour the rich connections between subject-matter (content), technology and the means of teaching it (the pedagogy). Secondly, according to both groups of teachers, it can be assumed that long lasting blended learning teacher courses, in contrast to singular face-to-face meetings, can be an effective means fostering development from viewing technology integration through a simple skill-based lens to effectively integrate it into physics content. Third, specifically related to the first study, it seems likely that TPACK of the teacher is a significant predictor how students perceive the technology- enriched learning environment and how technology can help redress some of the misconceptions students have in a particular area.

Therefore, further research should aim at achieving three purposes: first of all, focus on different personal variables as predictors for learning motivation and learning activities. Secondarily, employ triangulated methods to examine the changes in teachers’ instructional practices and their impact on student outcomes. Finally, employ more quantitative research methods that could serve as an assessment tool to reliably access components of the TPACK framework within the context of teacher training courses and provide valuable insight into the development of teachers’ TPACK.

From the practical point of view, the findings from the studies could favour the design of suitable teacher courses helping teacher students and teachers to imagine the contingencies how to use the potential of educational technology in the physics classroom and develop an open mind for using a
variety of approaches and strategies with their students. Starting from an understanding of the manner in which technology and content influence and constrain one another, teacher must comprehend which technologies are best suited for addressing which types of subject-matter learning, and how content dictates or shapes the technological application – and vice versa. In relationship to disciplinary contents, they need to know, how to help students meet particular curriculum content standards using educational technologies appropriately and finally and they have to possess knowledge of pedagogical techniques to use technologies in constructive ways to teach content focusing on conceptual understanding and self-regulated learning of their students.

References


