Knowledge Base for Information and Communication Technology in Education

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Charoula Angeli and Nicos Valanides

Contents

Abstract

This chapter systematically explores the knowledge base required by teachers for the effective application of ICT in education. The Technological Pedagogical Content Knowledge (TPCK) framework and developments in associated research are reviewed. The authors suggest an alternate approach for better understanding the knowledge base required for application of ICT in education by providing a theorization about technological knowledge in relation to how a teacher realizes and actualizes the pedagogical affordances of technological tools in teaching and learning. The authors conclude that this body of knowledge cannot exist outside the frame of reference of the teacher, can be developed through systematic learning activities targeting or facilitating its development, and grows with ongoing participation or involvement in valuable professional experiences. Implications for the nature of TPCK and its development are discussed.

C. Angeli (✉)
University of Cyprus, Nicosia, Cyprus
e-mail: cangeli@ucy.ac.cy

N. Valanides
Educational Robotics and Science Organization, Nicosia, Cyprus
e-mail: robotandscience@cytanet.com.cy

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Introduction

Technological Pedagogical Content Knowledge (TPCK or TPACK) was introduced in 2005 to describe the knowledge that teachers need to have to be able to teach competently with digital technologies (Angeli and Valanides 2005; Koehler and Mishra 2005; Mishra and Koehler 2006; Niess 2005). TPCK has been conceptualized as an advancement of Shulman's (1986, 1987) Pedagogical Content Knowledge (PCK) by adding to the existing PCK framework a new body of knowledge, namely, Technological Knowledge (TK). Consequently, the addition of TK expanded PCK to TPCK.

The purpose of this chapter is twofold. In the first part, the authors report on what we currently know about TPCK as a body of knowledge that teachers need to develop to be able to integrate ICT in their teaching. In the second part of the chapter, the authors argue that the existing body of research on TPCK has failed to explain TK theoretically, and propose a framework for directly addressing this gap in the literature. The chapter concludes with implications regarding the development of this new body of knowledge as well as the construct of TPCK in pre-service and in-service education.

The Theoretical Development of TPCK

PCK is the theoretical basis of TPCK (Angeli and Valanides 2015). Succinctly, PCK emphasizes the significance of transforming subject matter into forms that are pedagogically powerful and at the same time comprehensible to students (Grossman 1989, 1990; Shulman 1986, 1987; Cochran et al. 1993). Essentially, the transformation of subject matter requires a dramatic change in how teachers perceive their role "*from being able to comprehend subject matter for themselves, to become able to elucidate subject matter in new ways, recognize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students*" (Shulman 1987, p. 13). While researchers have proposed different PCK frameworks in terms of the constituent subdomains of teacher knowledge comprising the frameworks, four subdomains have consistently appeared in all proposed frameworks, namely, knowledge of subject matter (content), knowledge of pedagogy, knowledge of learners and their characteristics, and knowledge of context. A predominant model of PCK in the literature is the one proposed by Cochran et al. (1993), as depicted in Fig. 1. Cochran et al. (1993) preferred to use the term *Pedagogical Content Knowing* instead of *Pedagogical Content Knowledge* to emphasize that PCK is a knowledge base that is not static but dynamic and develops progressively as teachers are involved in useful teaching

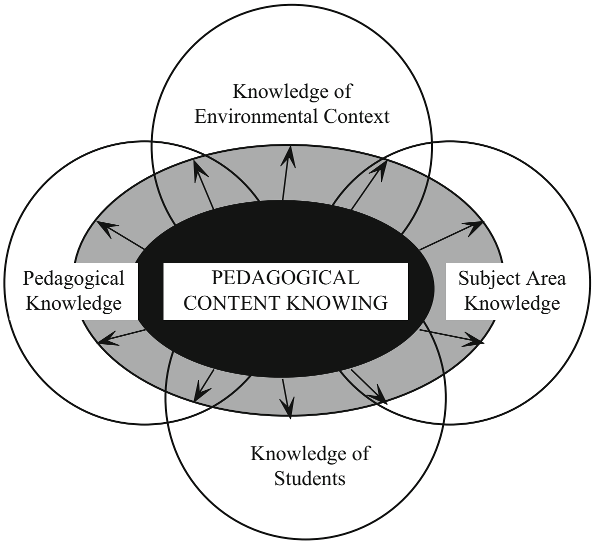

Fig. 1 Cochran et al.'s (1993) conceptualization of PCK

experiences. This is also the meaning expressed by the arrows in Fig. 1 signifying that PCK is a body of knowledge that changes due to teachers' new experiences and ongoing development.

In the early 2000s, different researchers proposed an enhancement to PCK in order to address the issue of teaching with technology (e.g., Angeli and Valanides 2005; Koehler and Mishra 2005; Mishra and Koehler 2006; Niess 2005). Niess (2005) and Angeli and Valanides (2005) used the four-component model of PCK shown in Fig. 1 as their theoretical basis and added a fifth component (i.e., a fifth domain of teacher knowledge), namely, knowledge of ICT, in order to specify TPCK as the knowledge that teachers need to have to be able to effectively teach subject matter with technology. Angeli and Valanides' (2005) conceptualization is depicted in Fig. 2 and shows TPCK as a unique body of knowledge defined in terms of five contributing knowledge bases, namely, content knowledge, pedagogical knowledge, knowledge of learners, ICT knowledge, and knowledge of context. In order to better define TPCK, Angeli and Valanides (2005) described the construct in terms of five competencies. Essentially, a teacher who has TPCK is able to:

1. Identify topics to be taught with ICT in ways that signify the added value of ICT tools, such as, topics that students cannot easily comprehend, or that teachers face difficulties teaching or presenting effectively in class. These topics may include abstract concepts (i.e., cells, molecules) that need to be visualized; phenomena from the physical and social sciences that need to be animated (i.e., water cycle, the law of supply and demand); complex systems (i.e., ecosystems, organizations) in which certain factors function systemically and need to be simulated or modeled; and topics that require multimodal transformations (i.e., textual, iconic, and auditory), such as, phonics and language learning.

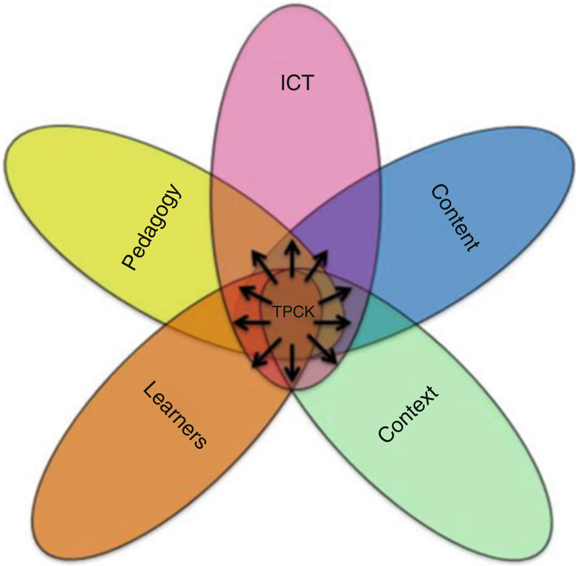

Fig. 2 TPCK (adapted from Angeli and Valanides 2005)

2. Identify appropriate representations for transforming the content to be taught into forms that are pedagogically powerful and difficult to support by traditional means. These include interactive representations, dynamic transformation of data, dynamic processing of data, multiple simultaneous representations of data, and multimodal representations of data.
3. Identify teaching tactics, which are difficult or impossible to implement by other means, such as, the application of ideas in contexts that are not experienced in real life. For example, exploration and discovery in virtual worlds, virtual visits (i.e., virtual museums), testing of hypotheses, simulations, complex decision-making, modeling, long distance communication and collaboration with experts, long distance communication and collaboration with peers, personalized learning, adaptive learning, and context-sensitive feedback.
4. Select tools with appropriate affordances to support 2 and 3 above.
5. Infuse computer activities with appropriate learner-centered strategies in the classroom. This includes any strategy that puts the learner at the center of the learning process to express a point of view, observe, explore, inquire, think, reflect, discover, and problem solve.

Koehler and Mishra (2008) proposed a different TPCK framework in the literature depicted in Fig. 3. In Fig. 3, TPCK (a term that they changed to TPACK) is described in terms of seven knowledge domains, namely, (a) content knowledge (C), (b) pedagogical knowledge (P), (c) technological knowledge (T), (d) pedagogical content knowledge (PCK) – the interaction of P and C, (e) technological content knowledge (TCK) – the interaction of T and C, (f) technological pedagogical knowledge (TPK) – the interaction of T and P, and (g) technological pedagogical

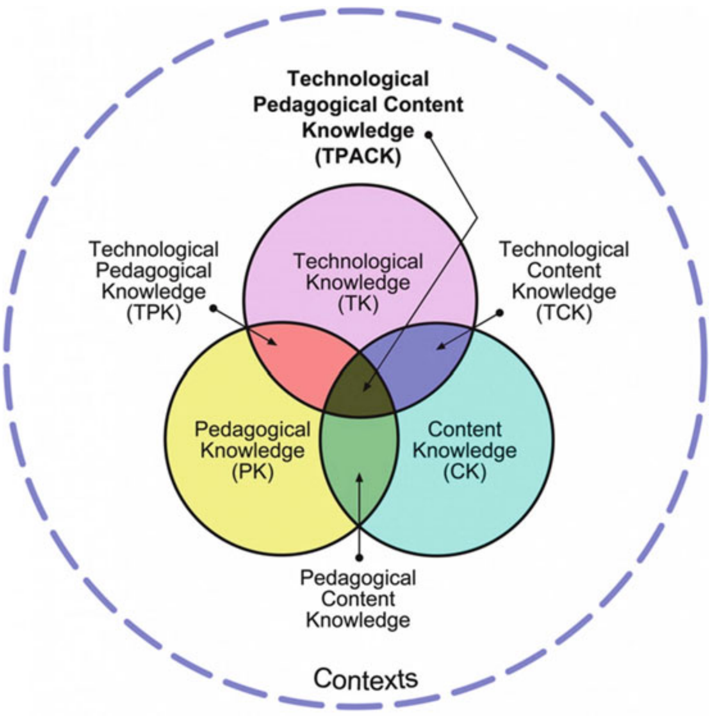

Fig. 3 TPCK framework (adopted from Koehler and Mishra 2008)

content knowledge (TPACK) – the interaction of PCK, TCK, and TPK. Angeli and Valanides (2009, 2013, 2015) discussed the differences between these two predominant conceptualizations of TPCK, as illustrated in Figs. 2 and 3, and stated that, while both models have the same theoretical basis (i.e., Shulman's work on PCK), they are epistemologically different. Succinctly, the main difference between the two frameworks is that TPACK is conceptualized and researched as an integrative body of knowledge with an emphasis on identifying and assessing TPACK's subcomponents, such as, TPK and TCK (e.g., Harris and Hofer 2011; Schmidt et al. 2009), while research based on Angeli and Valanides' (2005, 2009) framework examines TPCK as a distinctive body of knowledge (e.g., Kramarski and Michalsky 2010; Krauskopf et al. 2012). This new body of knowledge does not develop spontaneously, goes beyond mere integration or amalgamation of the constituent subdomains of teacher knowledge, and constitutes a transformative and unique body of knowledge that bolsters teachers' competency to elucidate subject matter in new ways by employing and investing on the affordances of technological tools. Furthermore, this body of knowledge can be developed only after deliberate instruction or training and grows progressively as teachers are involved in useful learning experiences.

In a recent review of the literature, Angeli et al. (2016) reported that, after 2008, a number of other TPCK models appeared in the literature that attempted to provide more elaborated perspectives on TPCK in order to exemplify the complexities of technology integration in various educational contexts (e.g., Benton-Borghi 2013; Porras-Hernández and Salinas-Amescua 2013; Yeh et al. 2014). For example, Yeh et al. (2014) proposed TPACK-Practical and conceptualized TPACK as a body of knowledge that teachers possess and apply when dealing with lesson design in their actual practice. TPACK-Practical is conceptualized as a framework with eight knowledge dimensions – namely, using ICT to understand content, using ICT to understand learners, planning ICT-infused curriculum, using ICT representations, using ICT-integrated teaching strategies, applying ICT to instructional management, infusing ICT into teaching contexts, and using ICT to assess students – in five pedagogical areas, that is subject matter, learners, curriculum design, assessments, and practical teaching.

Porras-Hernández and Salinas-Amescua (2013) enriched Angeli and Valanides' (2005) framework, by considering knowledge of context along two important dimensions, namely (a) scope (macro, meso, and micro) and (b) actor (students' and teachers' inner and external context). According to this perspective, contextual considerations, such as teachers' and students' characteristics, needs, preferences, prior knowledge, self-efficacy, pedagogical beliefs, subject or school culture, ethnicity, culture, community, and socioeconomic background, are important variables to consider in TPCK research.

Our purpose here is not to describe every single TPCK framework that has been published in the literature, but to provide a constructive appraisal of this line of work to the research community. While no one unified perspective on TPCK exists in the literature, all existing TPCK frameworks use as their basis, implicitly or explicitly, the five fundamental teacher knowledge bases – that is, knowledge of subject matter, pedagogy, learners, technology, and context. Contemporary research efforts that elaborated on this basic model considered several other variables that were regarded important for practice, such as Yeh et al.'s (2014) TPACK-Practical, or research, as suggested by Porras-Hernández and Salinas-Amescua (2013). If the aim of the TPCK research community is to suggest a new TPCK framework for encompassing the uniqueness or the newness of a context, practical or research, then this line of research will never realize its desired goal; that of developing a robust theoretical conceptualization of TPCK. Accordingly, the authors here argue that part of the effort toward developing a robust theoretical conceptualization of TPCK should be to understand or theorize more about technological knowledge (the TK component in the TPCK framework) in relation to how a teacher realizes and actualizes the affordances of technological tools for the purpose of transforming subject matter (content) into more comprehensible forms for students.

In view of that, the authors, in the second part of this chapter, suggest an alternative approach for conceptualizing the knowledge base required for application of ICT in education by providing a theorization of the relationship between teacher and technology within the framework of Gibson's (1977, 1979) tool affordances – an area of work that has remained for the most part scarce in the field of technology and teacher education. The authors suggest that the specific theorization can be pivotal for better clarifying the concept of TPCK and conclude with implications for the development of TPCK in pre-service and in-service education.

The Concept of Tool Affordances

While technology is a principal component of TPCK and the main reason for extending PCK to TPCK, so far the fields of instructional technology and TPCK research have provided inadequate accounts about how teachers learn to recognize, understand, and actualize the pedagogical affordances of ICT tools; an issue that is of critical importance for developing teachers' cognition about technology integration (Angeli and Valanides 2009, 2013; Krauskopf et al. 2012; Krauskopf et al. 2015). Consequently, as Oliver (2013) stated, "*current accounts of technology provide poor explanations of how technology use leads to – or fails to lead to – learning*" (p. 331), simply because we do not fully understand how teachers perceive and actualize tool affordances. A better understanding of affordances in teacher knowledge development can lead to better strategies in terms of training pre-service teachers in technology integration as well as supporting in-service teachers during professional development (Haines 2015).

According to Gibson (1979), "*. . .the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill*" (p. 127). An affordance has invariant properties, and exists independently of an actor's ability to perceive it; but, when it is perceived, it is always relative to the action capabilities of a particular actor (Gibson 1979). Gibson explained the notion of affordance by providing the example of a flat and rigid surface that affords support for one actor but not for another, due to his or her higher body weight. This means that the actor in the latter case is constrained by the affordances of the object, and that an affordance may exist for one actor but not for another. Thus, the "*offerings or action possibilities in the environment are directly related to the action capabilities of an actor*" (McGrenere and Ho 2000, p. 1). McGrenere and Ho (2000) stated that in Gibsonian terms, affordances are both objective and subjective.

They are objective in that their existence does not depend on value, meaning, or interpretation. Yet they are subjective in that an actor is needed as a frame of reference. By cutting across the objective/subjective barrier, Gibson's affordances introduce the idea of the actor-environment mutuality; the actor and the environment make an inseparable pair. (McGrenere and Ho 2000, p. 1).

Hammond (2010) stated that the notion of affordance has become popular in different fields in that it offers an alternative to the view that the world exists independently of the perceiver, while challenging at the same time the notion that properties are perceptual and exist only to the extent that they can be recognized. This view of affordance can be strongly criticized by radical social constructivists who would question the existence of inherent properties of objects outside of the actors' interpretations of them. Hutchby (2001) directly addresses this concern and argues that, while the uses of tools are socially determined, at the same time, tools have material properties that may not be realized by the actor. For example, if we take Microsoft Excel as a point of reference, teachers may not realize that Excel supports dynamic transformations of data from one form/representation to another and may use it for mathematical calculations only. Nonetheless, the material properties or technical features of Excel affording dynamic transformations of data exist and are readily available for use at all times. It is this interpretation of the concept of affordance that we adopt in this chapter in order to propose a theoretical model for explaining the relationship between teachers and technology in terms of how teachers perceive and develop mental models about tool affordances for appropriation in educational settings. Appropriation refers to how technology is adopted in everyday practice (Dourish 2003; Leonardi 2011), and people appropriate artifacts in ways that may differ from the designers' intentions (Folcher 2003).

For teachers, the process of learning about tool affordances is more than just learning about the technical features or the technical affordances of tools. Instead, it is a process of thinking creatively about how the technical affordances of tools can be thought of as pedagogical affordances to bring about educational goals and objectives in classroom teaching and learning. Webb (2005) explored the notion of affordances within the context of using Microworlds to support learning activities. Conole and Dyke (2004) also examined the concept of affordance in the context of pedagogical design and proposed a general taxonomy of ICT affordances for the modern age, including accessibility, speed of change, diversity, communication, reflection, and multimodality.

Herein, the authors assume a different perspective and seek to propose a theoretical construction of teachers' ICT knowledge by focusing on the teacher-tool relationship within the context of pedagogical and learning design. Central to this theorization are the terms *technical affordances* of tools/software and *pedagogical affordances* of tools/software. A piece of software has technical features or technical affordances. For example, the technical affordances of Kidspiration include among others, Picture View, Writing View, Audio, and Hyperlink. These technical affordances are invariant and available to all, at all times. Pedagogical affordance is a term that Angeli and Valanides (2013) used to explain how teachers perceive subjectively the functional value of software in pedagogical/learning design. Table 1 shows an example of how some technical features of a software (in this case Excel) are mapped onto pedagogical affordances. It is noted that, in this conceptualization, technical affordances are invariant and defined by the designers and developers of the software, while pedagogical affordances are perceived by teachers in various ways. The latter is emergent and directly related to pedagogical and learning design for the purpose of attaining educational objectives. In a recent study, Haines (2015) studied two teachers' conceptions of blogs and wikis as tools for language learning, and found that, while teachers learned the tools easily, they faced difficulties in utilizing them in powerful pedagogical ways. She concluded that teachers' understanding of the pedagogical affordances of tools is an emergent and demanding cognitive process directly related to instructional design tasks. These conclusions are in agreement with earlier research reported by Stoffregen (2003) who viewed affordances as being emergent properties of both the teacher and educational context.

Table 1 Technical and pedagogical affordances of Excel (adapted from Angeli and Valanides 2013)

Excel technical affordances/features	Pedagogical affordances	Explanation
Insert – Cells/rows/columns/worksheet/chart/pictures Format – Cells/row/column/sheet/style Data – Sort/text to columns/group and outline	Excel as a tool for organizing data	Meaningful and clear organization of data Attractive and intuitive organization of data Appropriate selection of visualizations for young learners Integrated presentations of pictures, text, numbers, and spoken words Appropriate symbols to promote emergent literacy
Function/IF	Excel as a tool for providing context-sensitive feedback	Feedback is provided in different modalities taking into consideration students' current level of literacy skills
Hyperlink	Excel as a tool for creating a hypertext story	The story is presented from the perspectives of multiple characters The story has multiple possible entry points The story has many internal threads The story constitutes an integrated whole Easy navigation and learner control
Formula bar Insert – Function/sum/average/count/max	Excel as a tool for performing calculations	Arithmetic calculations and mathematical formulae Mining mathematical formulae
All of the above as needed	Excel as a modeling tool	Children see clearly how their decisions/actions affect the outcomes Children add or remove objects and observe the consequences The results of an action or decision are communicated with the use of appropriate visualizations when possible

Our theoretical discussion so far has exemplified the importance of two propositions: (a) the technical affordances of tools are invariant properties, while their pedagogical affordances are emergent and subjective; (b) the pedagogical affordances of tools derive meaning only within the context of the activities that teachers consider in their pedagogical designs. As Tchounikine (2016) stated, educational software packages "*. . .are mobilized by users in the context of the activities they consider. They become instruments for users in the context of these activities, when and through the way they allow users to achieve the tasks that users consider in the way they consider them*." (p. 8). Thus, the teacher-tool relation is not to be thought of as a 1:1 relation, because one software package may be turned into multiple instruments.

All in all, the goal of the teacher is not to use the tool per se, but to solve different pedagogical problems with the tool. Thus, teachers' perceptions of software, in terms of pedagogical utilization, are related to the instructional design tasks they cogitate, and how they use the software to help them realize the tasks, given teachers' current understandings, knowledge, work practices, and context.

A Theoretical Model of Teachers' ICT Knowledge

Based on the discussion to this point, we present in Fig. 4 a theoretical perspective of teachers' ICT knowledge developed through a process by which teachers turn software into instruments (Rabardel 2001), that is, into means for realizing their instructional designs. According to this perspective, educational software and tools have a mediating role, and the model in Fig. 4 addresses this by considering both the technical and pedagogical affordances of tools. This is illustrated as a process through which teachers transform the technical affordances of tools into pedagogical affordances within an instructional design context. The latter is a constructive, productive, iterative, emergent, and creative process that can benefit from explicit pedagogical training in pre-service teacher education programs and in-service teacher professional development. During this process, technical affordances are perceived and actualized as pedagogical affordances in instructional design lessons.

In more detail, the proposed theoretical framework, shown in Fig. 4, is represented as a five-stage process model. The first stage in the process shows that educational software packages are characterized by a number of built-in technical functions or technical affordances, as these have been determined by software designers and developers. These technical affordances exist independently of teachers' awareness of their existence. Subsequently, teachers, with certain knowledge, expertise, and educational goals, interact with the technical features of tools and come to recognize and familiarize themselves with the technical affordances of tools (Pozzi et al. 2014; Bernhard et al. 2013). Thus, the second stage related to

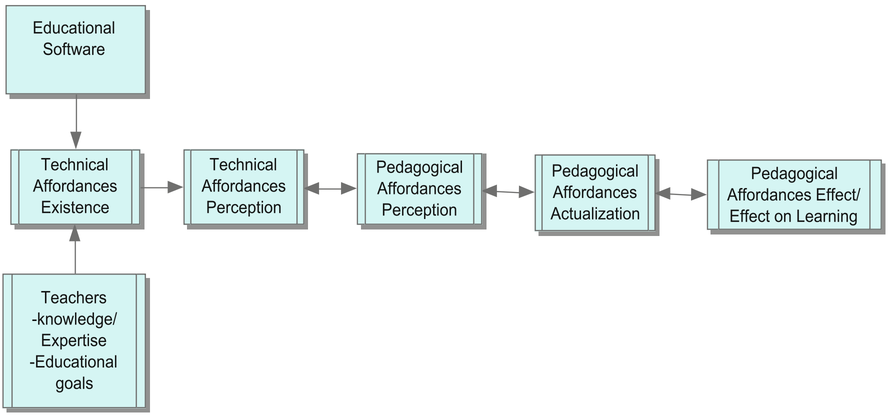

Fig. 4 Teacher ICT knowledge theoretical framework

technical affordances perception is about recognizing the existence of technical affordances and their potential for performing an action (Leonardi 2011). For example, teachers learn or find out about the SORT feature in Excel, and they ponder about how they can use it to sort a big data file in ascending order.

Subsequently, in stage 3, teachers come to realize/perceive the technical affordances as enablers of pedagogical action. This is an iterative and emergent process that involves transformation of the technical affordances into pedagogical affordances. For example, a teacher learns how to insert hyperlinks in an Inspiration diagram, but he or she gradually realizes that the use of hyperlinks in concept maps facilitates discovery and inquiry learning.

In a recent research study, Ioannou (2016) found that during a 15-h teacher professional development seminar about TPCK, teachers were not able to perceive the pedagogical affordances of tools. Interestingly, the teachers in his study were experienced computer science middle school teachers with excellent technical skills and knowledge about technology. Ioannou (2016) concluded that teachers cannot easily conceive how the technical affordances of tools can be transformed into pedagogical affordances and that the advancement of their understanding from technical to pedagogical affordances should be facilitated.

The fourth step in the model is actualization of pedagogical affordances. Actualization is a goal-oriented and iterative action during which pedagogical affordances are put into actual classroom practices (Leonardi 2011). McGrenere and Ho (2000) found that actualization is a gradual process with different degrees of difficulty. It can be an individual effort or a collaborative effort situated in real classroom practices. Haines (2015) also found that affordance actualization aids teachers to reconsider their perceptions of the pedagogical affordances of tools, in terms of action possibilities and constraints for their practice, and redefine them. Actualizing pedagogical affordances depends on several teacher-related factors, such as skills and instructional design knowledge, as well as school-related factors, such as availability of resources and a conducive curriculum. It is also, according to Bernhard et al. (2013), "*a function moderated by perceptions of the efforts that it takes to actualize the affordance*" (p. 6).

Affordance actualization results in (a) reconceptualization of pedagogical affordances and (b) learning effects. In essence, when teachers integrate tools in their lessons, they gradually develop more informed understandings of the added value of the tools and consequently more complete and sophisticated mental models of the pedagogical affordances of tools. At the same time, the integration of tools in instructional lessons mediates the transformation of the content to be learned into forms that students can understand better, while at the same time it enables the implementation of new pedagogical practices promoting the active role of students in learning. Consequently, the actuation of an affordance produces measureable results such as changes in student learning. In sum, as Volkoff and Strong (2013) stated, actualized affordances provide explanations of causality at a level that is specific with respect to the technology (i.e., what is the added value of the technology in teaching?) and the organization (i.e., how does technology affect student learning?).

Implications for Theory and Practice: The Development of Teachers' ICT Knowledge

The model in Fig. 4 is aligned with current research evidence and theoretical conceptions about tool affordances and instructional/learning design. It explicates that the development of teachers' ICT knowledge requires a systematic and goal-oriented process targeting the development of teachers' understandings of the notion of pedagogical affordances within the context of rich instructional design practices. The model can be implemented in both pre-service teacher education courses and in-service teacher professional development programs. In pre-service teacher education, the five-stage model can be implemented in the context of instructional technology courses and methods courses. Teacher educators and trainers must explicitly inform teachers about, as well as exemplify, the five-stage model, the expected outcomes per stage, and what it entails in terms of their preparation. The process depicted in Fig. 4 should be enacted for each tool taught in a course or training session. Depending on the difficulty of the tool, the duration of each cycle of enactment can be about 10 h on the average, so that over the course of an academic semester, teachers can receive training on about four different ICT tools. Succinctly, teacher educators first engage teachers in activities where the focus is to learn how to use a tool. The goal during the first two stages is for teachers to become familiar with the technical features and technical affordances of tools. The third stage in the model aims at linking the technical affordances of tools with teaching. For this to happen, teacher educators need to make explicit connections between the technical affordances of tools and their pedagogical affordances. This can be done in the context of instructional design activities during which pre- or in-service teachers learn to think about technology as a pedagogical tool to solve teaching/learning problems. This third stage in the model is the most challenging to enact, because it is emergent, demanding in terms of time and effort, and does not constitute a 1:1 correspondence between the technical affordances of tools and their pedagogical affordances. The link between technical affordances and pedagogical affordances can be strengthened during the stage of actualization, which must: (a) have a focus on content (subject matter) (Desimone 2009); (b) be grounded in teachers' own classroom practices (Putnam and Borko 2000) to promote ongoing and sustainable teacher development (Darling-Hammond and McLaughlin 1995); (c) address obstacles to student learning (i.e., student misconceptions or alternative conceptions) and enablers of student learning (i.e., content transformations, approaches to destabilizing student misconceptions) (Angeli and Valanides 2009; Dopplet et al. 2009); (d) use preferred instructional practices utilized in teacher development, such as modeling and coaching (Ioannou and Angeli 2013, 2014; Angeli and Ioannou 2015; Darling-Hammond and McLaughlin 1995); (e) be grounded in inquiry, reflection, collaborative problem solving centered around pedagogical problems or problems of practice that are teacher-driven (Angeli and Valanides 2009; Darling-Hammond and McLaughlin 1995); and (f) be collaborative with a focus on communities of practice rather than on individual teacher practices alone (Darling-Hammond and McLaughlin 1995). Within this situated teacher development framework, aspects of the learning-by-design framework are incorporated for facilitating the development of complex and interrelated ideas among content, pedagogy, learners, context, and technology (McKenney et al. 2015; Angeli and Valanides 2009). Conway and Zhao (2003) stated that within the context of learning by design "*it becomes crucial to ally teachers' knowledge about not only various general pedagogical approaches, but also pedagogical content knowledge, as well as the learning affordances and constraints of various computer-based technologies allied with the current more ambitious reform-based educational goals for students*" (p. 27).

Finally, the fifth and last stage allows for reflection based on the educational outcomes observed or obtained, enabling teachers to reconsider their perceptions of the pedagogical affordances of tools and their actualization in learning design tasks.

Obviously, effective technology integration presupposes robust knowledge and understanding of the technical affordances of tools and how these can be transformed into pedagogical affordances, in order to be used in teaching and learning for the purpose of elucidating content into more understandable forms for the learner. The development of this body of knowledge is, therefore, directly related to the development of teachers' TPCK, and has implications for the existing theoretical conceptualizations of TPCK or TPACK.

To remind the reader, in the first part of this chapter the authors referred to two prevailing views of TPCK in the literature: (a) the transformative view explicating TPCK as a distinct or unique body of knowledge that needs to be taught (Angeli and Valanides 2005, 2009), and (b) the integrative view defining TPACK as a body of knowledge that is created from other forms of teacher knowledge *on the spot* during teaching (Koehler and Mishra 2008). These two views have raised important research questions during the last decade regarding the construct of TPCK and its development. For example, research questions framed from the transformative view investigated the construct of TPCK itself, while research questions framed from the integrative view inquired about the constituent components of TPACK, such as TPK and TCK.

In fact, many researchers pursued studies from the perspective of TPACK as an integrative body of knowledge and sought to identify and measure the constituent knowledge bases of TPACK, such as, CK, TK, TCK, TPK, and PCK. Recent research findings from this line of research have been reported by Shinas et al. (2013) who examined the construct validity of the Survey of Preservice Teachers' Knowledge of Teaching and Technology, a survey that according to its developers is grounded in the integrative framework of TPACK and is designed to measure seven subdomains of TPACK (Schmidt et al. 2009). Shinas et al. (2013) administered the survey to 365 pre-service teachers enrolled in an educational technology course and conducted an exploratory factor analysis on the data. Their results revealed that participants did not always make conceptual distinctions between the TPACK domains and raised issues about the validity of the TPACK framework and the research instruments that have been developed based on its theoretical foundations. Shinas et al.'s (2013) results are in agreement with the research findings of other researchers who also problematized the validity of the TPACK framework and the inherent difficulty in distinguishing the boundaries between the constituent subdomains of TPACK, such as TPK and TCK (Angeli and Valanides 2009; Archambault and Barnett 2010; Cox and Graham 2009; Graham 2011).

From the perspective presented and discussed in the present chapter and the line of argument that was developed based on the theoretical discussion about the technical and pedagogical affordances of tools, TCK, for example, cannot possibly exist without the mediating role (action capabilities) of an actor (teacher) and his (her) knowledge, expertise, and educational aims and goals. Thus, TCK should not/cannot be included as a common and identifiable body of teacher knowledge in any framework describing teacher knowledge. This inference is also supported by Shinas et al. (2013) who concluded that "*factors were congruent across only technological knowledge (TK) and content knowledge (CK) and not congruent across pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and TPACK*" (p. 339).

Concluding Remarks

In this chapter, we presented an alternate perspective on teachers' knowledge of ICT. A theoretical model has been proposed illustrating a five-stage process through which teachers perceive and actualize the pedagogical affordances of tools in the context of learning design activities. In order to better situate the new theoretical framework depicted in Fig. 4 with the existing body of research on TPCK, it is specified that the model in Fig. 4 provides a theorization about technological knowledge (TK) in relation to how a teacher realizes and actualizes the affordances of technological tools in teaching and learning. This theorization in conjunction with contemporary research evidence seems to refute the existence of at least some of the knowledge bases integrated in the TPACK framework (Mishra and Koehler 2006, such as, for example, TCK, and provides further support to the transformative perspective of TPCK (Angeli and Valanides 2005, 2009). The proposed model contributes to the bigger effort related to the theoretical conceptualization of TPCK as an extension of Shulman's PCK and the knowledge that teachers need to have to be able to teach competently and adequately with technology. It should be emphasized also that this conceptualization maintains the point of view that TPCK is a way of *knowing* that can be developed only after deliberate instruction or training and can grow progressively through involvement in useful professional experiences.

At this point, the model should be considered as an emergent theoretical model, since it has not been tested empirically yet, although ample research evidence converges with the model's theoretical conceptualization. Mixed-method research designs may be adopted for providing details about the validity of the model in terms of how the concept of pedagogical affordances emerges, and what influences positively and/or negatively teachers' conception and actualization of pedagogical affordances in their professional practice. In conclusion, the model provides further support to the transformative view of TPCK as a unique body of knowledge that requires purposeful training, and cannot possibly exist and/or be studied in terms of artificial and fabricated bodies of knowledge, such as TCK, outside the frame of reference of the teacher.

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