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Introduction of TPACK-XL A Transformative View of ICT-TPCK for Building Pre-Service Teacher Knowledge Base

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Abstract

What is the nature of preservice teachers knowledge base that would enable them teach with technology? How preservice teacher education programs should be structured to build this knowledge base? In an effort to respond to these questions, this study examines the mostly recognized relevant theoretical grounding of the nature of the teacher knowledge base. As a result, it introduces TPACK-XL as a transformative view of a strand of Mishra and Koehler (2005) TPACK (Technological Pedagogical And Content Knowledge) theoretical framework, named ICT-TPCK as proposed by Angeli and Valanides (2009). ICT-TPCK integrates the context (X) and the learner's (L) knowledge to contribute to TPACK with more specificity on ICTs in the field of educational technology. Mishra and Koehler proposed the TPACK model that describes teachers' integration of ICTs in their classroom practices. TPACK has become known as a useful overarching conceptual framework that builds on Shulman (1986) formulation of pedagogical content knowledge (PCK). In this paper, the author analysis of ICT-TPCK model aims to contribute to the discussions on how to educate preservice teachers within the ICT-TPCK framework principles. The detailed examination and refinement of the interrelated contributing knowledge bases of ICT-TPCK: ICTs (T), pedagogy (P), content (C), learners (L), and context (X) has led to pointing thirty-one constituent knowledge constructs. TPACK-XL is identified as the elaborated form of ICT-TPCK that highlights the interdisciplinary knowledge constructs that synthesize to lead to its core knowledge and, consequently, serve as an advanced lens of ICT-TPCK for preservice teachers' educators.

Key Words: Educational technology, ICTs in teacher education, preservice teacher education, student teacher knowledge base, technological pedagogical and content knowledge TPACK

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Introduction

A knowledge base for teaching is not fixed and final.
...We may be able to offer a compelling argument for the broad outlines and categories of the knowledge base for teaching. It will, however, become abundantly clear that much, if not most, of the proposed knowledge base remains to be discovered, invented, and refined.
Lee Shulman, 1987

The proliferation of Information and Communication Technologies (ICTs) in schools in Lebanon has increasingly highlighted the importance of preparing preservice teachers to teach with technology. In parallel, the integration of ICTs in preservice teacher education in Lebanon is gaining more attention after the movement towards the "professionalization" of teaching (El Amine, 2009; Kaddoura, 2010; Ministry of Education and Higher Education (MEHE), 2010; Salameh, 2009). The review of literature related to the present use of ICTs in preservice teacher education in Lebanon is scant and insufficient to give a good indication of the status quo (Baroud & Abou Chedid, 2010; Baroud, 2011; El Hage & Abou Jaoude, 2009). The available literature points to the existence of few initiatives taken towards supplementing the traditional programmes in teacher education with new information and communication technologies in many preparation institutions. But researchers emphasize that research studies are needed to inform about the effectiveness of such initiatives in empowering prospective teachers with the knowledge required to integrate ICTs in pedagogically sound ways in their teaching practices (Baroud & Abou Chedid, 2010). As we lag behind in the research, at this level in Lebanon, a broader look to universal perspective is a deemed necessity.

This paper aims to examine the evolving nature of the mostly recognized theoretical frameworks which relate to building teachers' knowledge base and transform that to a theoretical perspective to support building preservice teachers knowledge base embedding ICT knowledge for teaching. The study aims to add to the theoretical grounding in the area of building preservice teachers' educational technology knowledge through proposing a transformative view of Angeli and Valanedis (2009) ICT-TPCK theoretical framework. The intention is to run an in-depth analysis of ICT-TPCK model to contribute to a profound theoretical conceptualization of preservice teachers' knowledge base that embeds ICT knowledge and serves to guide structuring teacher education programs courses.

Interdisciplinarity of teachers' pedagogical ICT knowledge

In essence, student teachers' ICT knowledge does not grow in isolation from other knowledge constructs. The specificity of technological knowledge might hold only true for experts in ICTs, computer scientists and other specialists in digital technologies (Mishra & Koehler, 2005, 2006). With the case of student teachers' knowledge base, the technological (ICTs and/or Digital Educational Technologies) knowledge construct is combined with other knowledge constituents, such as, the pedagogical knowledge, content (subject matter) knowledge, learners' knowledge, and learning context knowledge (Angeli & Valanides, 2009; Chai, Koh, & Tsai, 2010; Mishra & Koehler, 2005, 2009; Nordin, Morrow, & Davis, 2011; Shulman, 1986; So & Kim, 2009; Veal & MaKinster, 1999). This indicates that preservice teachers' knowledge base is broad, multifaceted, and is informed by many different disciplines. Therefore, and in its broadest terms, preservice teachers' knowledge base is interdisciplinary and combines the knowledge of several disciplines, namely, that of educational technology, pedagogy and didactics, academic subject-matter discipline, educational psychology, and educational sociology. The interdisciplinarity of preservice teachers' professional knowledge base is essential for them to become capable of analyzing, evaluating, and synthesizing information from multiple disciplines in order to make meaningful connections and to integrate the various disciplines to render them into reasoned decisions, while utilizing ICTs in their teaching. In relation, Kathryn S. LaFever (2008) suggests that "preservice teachers need interdisciplinary teacher education experiences they can utilize as students and, in turn, extend through their future practice to K-12 students and colleagues" (p.101).

Theoretical Models Reviewed and Issues of Concern

"Interdisciplinarity" of knowledge is a synthesis of two or more disciplines; theoretical frameworks that describe interdisciplinary knowledge are graphically portrayed analogous to two (or more) partially overlapping circles (Choi & Pak, 2006). From this point of view, a review is presented of three theoretical frameworks that interrelate: two, three, and five knowledge disciplines.

The first is the notable pedagogical content knowledge (PCK) framework of Lee Shulman (1986) that interrelate the pedagogy knowledge (PK) and content knowledge (CK). The partial overlap of the two circles representing the framework knowledge constructs resulted in producing three constituents: PK, CK, and PCK (PCK is the intersection of PK and CK).

The second is the TPACK (Technological Pedagogical And Content Knowledge) theoretical framework of Mishra and Koehler (2005), that interrelates the technology knowledge (TK), pedagogy knowledge (PK) and content knowledge (CK). Analogous to the graphical display of Shulman's PCK model, the graphical portray of TPACK has led to defining seven constructs: the pedagogy knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK), technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical and content knowledge (TPACK).

The third theoretical framework is ICT-TPCK that was proposed by Angeli and Valanides (2009). Their framework represents teacher's interdisciplinary knowledge that is formed by the synthesis of five knowledge disciplines: knowledge about tools and their pedagogical affordances, pedagogy, content, learners, and context. Angeli and Valanides graphical representation of their model did not clearly show the resulted interrelation between the five disciplines. This raises several questions:

1- What are the distinct knowledge constituents obtained by the overlapping of the five knowledge disciplines? How many are they? What are they?
2- How does the ICT knowledge construct interconnect with other disciplines? How does this affect building preservice teachers ICT knowledge?
3- Since the intersection between two or more of the knowledge constructs represents a specific form of interdisciplinary knowledge, does this knowledge contribute to the building of the preservice teacher knowledge base?
4- What does revealing these constructs inform educators and scholars concerned in developing preservice teachers' education programs within ICT-TPCK principles?

In broader terms the previous questions can be stated as follows:

What constitutes a preservice teachers' knowledge base? How these knowledge bases merge different disciplines that are synthesized to empower future teachers to take rational decisions while using ICTs? And, based on what theoretical model this knowledge is built in the preparation programs?

Teachers' interdisciplinary knowledge models

This section is a quick review of the three theoretical frameworks: pedagogical content knowledge (PCK), Technological, Pedagogical and Content Knowledge (TPACK), and ICT-TPCK.

Pedagogical Content Knowledge (PCK)

In a review of the conceptual analysis of teachers' interdisciplinary knowledge, Shulman (1986) developed and formulated a new conceptual framework by introducing the concept of pedagogical content knowledge (PCK). Later in 1987, Shulman defined seven categories to provide a framework for teacher knowledge by adding to PCK: content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and the knowledge of educational ends purposes and values. PCK is a concept that intensively governed later research in the field of teacher education (Segall, 2004). Shulman (1986) defines PCK as the "*subject matter knowledge for teaching*" and includes:

> "…for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others….Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. (p. 9)

As shown in figure 1, the Pedagogical Content Knowledge (PCK) is the overlap of the Pedagogy Knowledge (PK) and the Content Knowledge (CK) based on the idea that pedagogy and content are interwoven.

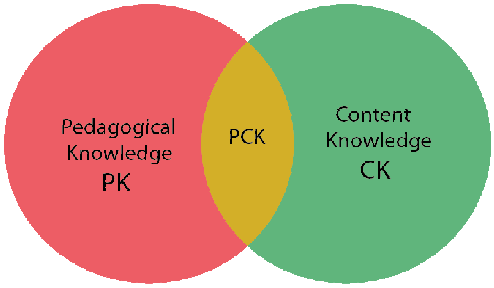

Figure 1. Pedagogical Content Knowledge (PCK)

Technological Pedagogical and Content Knowledge (TPACK)

With the increased challenge to use ICTs in education, a new theoretical framework that builds on Shulman Pedagogical Content Knowledge with the introduction of the technology knowledge construct has recently emerged by Mishra and Koehler (2005) to frame teachers' knowledge for pedagogical technology integration in specific subject matter teaching. Mishra and Koehler (2005) argued that many studies examining preservice teachers' development of ICT skills lack a clearly articulated theoretical framework, and proposed a theoretical framework for conceptualizing teachers' knowledge, which they referred to by TPCK or TPACK (Thompson & Mishra, 2008). The two acronyms stand for Technological, Pedagogical and Content Knowledge (Koehler & Mishra, 2008; Mishra & Koehler, 2006); where the Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) form the three interdependent knowledge constructs of the teachers' knowledge base. Their Theoretical framework has gained a lot of attention and is intensively used in ICTs integration in preservice teacher education research (Angeli & Valanides, 2009; Chai, Koh, & Tsai, 2010, 2011; Cox, 2008; Mishra & Koehler, 2005, 2011; Niess, 2005; So & Kim, 2009; Niess, Browning, Driskell, Johnston, & Harrington, 2009).

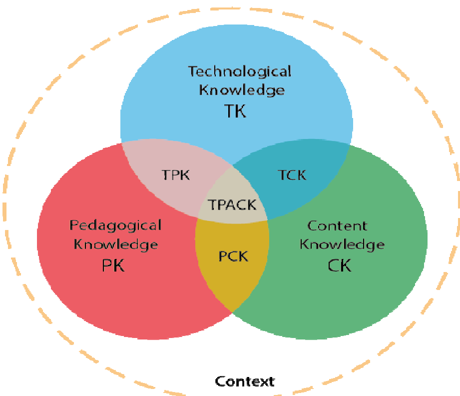

Figure 2. The TPACK framework (graphic adapted from http://tpack.org)

As illustrated in Figure 2, with the introduction of TPACK, seven knowledge constructs are formed by the overlapping of the three main knowledge constructs. Namely, the pedagogy knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK), technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical and content knowledge (TPACK).

Mishra and Koehler in http://www.tpck.org/ define:

Technological pedagogical and content knowledge (TPACK) is the type of knowledge that leads to quality teaching that "requires developing a nuanced understanding of the complex relationships between technology, content, and pedagogy, and using this understanding to develop appropriate, context-specific strategies and representations" (Mishra & Koehler, 2006, p.1029). To further explain their definition of TPACK knowledge, Koehler, Mishra, and Yahya (2007) stated that TPACK is a context-specific (represented in Figure 2 by the "context" circle that circumscribes TPACK knowledge constructs), situated form of knowledge that is necessary for the intelligent integration of technology in teaching and learning. They further explain that:

> At the heart of TPCK is the dynamic, transactional relationship between content, pedagogy, and technology. Good teaching with technology requires understanding the mutually reinforcing relationships between all three elements taken together to develop appropriate, context-specific, strategies and representations. (Ibid, p. 741)

With the intensive use of TPACK in education research several strands of the theoretical framework have been proposed.

ICT-TPCK as a strand of TPACK

In an effort to further develop TPACK, Angeli and Valanides (2009) proposed ICT-TPCK as a new strand of TPACK framework that is conceptualized as a unique body of knowledge that makes a teacher competent to design technology-enhanced learning. It is defined as the ways knowledge about tools and their pedagogical affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics that are difficult to be understood by learners, or difficult to be represented by teachers, can be transformed and taught more effectively with ICT, in ways that signify the added value of technology (Angeli & Valanides, 2009, p.159).

ICT–TPCK's constituent knowledge bases, as shown in Fig. 3, include TPCK's three contributing knowledge bases, namely, subject matter knowledge, pedagogical knowledge, and technology (restricted to ICT in their case), and two additional elements, knowledge of students and knowledge of the context within which learning takes place (Angeli & Valanides, 2009, p.158).

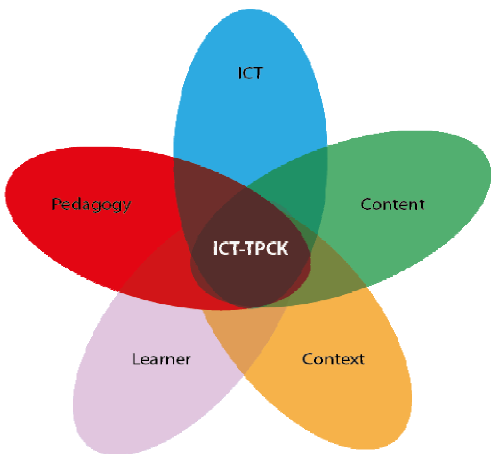

Figure 3. ICT-TPCK (adapted from Angeli & Valanedis, 2009, p.159)

Elaboration of ICT-TPCK

This section will explain the reasons behind elaborating the ICT-TPCK theoretical model, and shows the process of representing the transformative view of the model.

Why elaborating ICT-TPCK

The intention of this paper is to analyze the structure of ICT-TPCK model aiming to find leading ways to develop preservice teachers' ICT–TPCK through detecting the overlap of the five knowledge constructs: ICTs (T), pedagogy (P), content ©, learners (L), and context (X). The approach is analogues to the identification of TPACK seven constituting knowledge constructs formed by the overlap of its principal knowledge elements: Technology, Pedagogy, and Content.

The drive of this intention is determining the combinations of knowledge constructs that might be clustered to constitute a set of courses of ICT-TPCK based preservice teacher education program that converges to build its core knowledge. The pre-mentioned theoretical frameworks serve as perfect overarching frameworks to inspire teacher preparation educators, but leave a wide margin of scenarios for building the required knowledge base. Scholars in the field of teacher education, including the authors of these theoretical models, acknowledge the complexity and diversity of teachers' knowledge which might require a complex theoretical framework that clarifies and reflects that complexity. Shulman (1987) notes that:

> A knowledge base for teaching is not fixed and final…We may be able to offer a compelling argument for the broad outlines and categories of the knowledge base for teaching. It will, however, become abundantly clear that much, if not most, of the proposed knowledge base remains to be discovered, invented, and refined. (p.12)

Mishra and Koehler (2006) admit that their TPACK theoretical framework does not provide all answers relating to the teachers' knowledge base needed to teach with technology:

> We are sensitive to the fact that in a complex, multifaceted, and ill-structured domain such as integration of technology in education, no single framework tells the ''complete story''; no single framework can provide all the answers. The TPCK framework is no exception. (p. 1047)

In her doctoral dissertation study of TPACK, Cox (2008) believes that there remain areas that are as yet unexplored or not fully understood, and "… there is still much work to do to fully understand the framework's complexity" (pp.101, 102). She concludes that "… Future research involving case studies and analysis of the development of TPACK … will have a major impact on how preservice teachers are trained to use technology in the classroom" (p.103).

Angeli and Valanides (2009) suggested that:

> The development of ICT–TPCK is not an easy task. Consequently, intensive, coordinated and dedicated systematic efforts need to be planned and implemented in pre-service education programs in order to develop teachers' ICT–TPCK … and any future research efforts that will be undertaken to validate, modify, or improve the framework proposed for the conceptualization of ICT–TPCK will be important for both research and practice. (p.167)

If this is the case with the theoretical frameworks presented in this paper that deal with the domains and categories of knowledge base that empowers teachers pedagogical use ICTs in their subject matter teaching and classroom practices, then the question that arises is: Would any effort to further analyze ICT-TPCK basic knowledge elements inter-relation, if possible, helps to contribute to a better portraying the preservice teachers knowledge base constructs that build on ICT-TPCK knowledge which is basically drawn from several source knowledge disciplines? To start this process ICT-TPCK will be decomposed into its building knowledge constructs in a way similar to TPACK portray of its seven constructs formed by its three knowledge sets: TK, PK, and CK.

Mathematical analysis of ICT-TPCK model

The structure of ICT-TPCK model contains five contributing knowledge bases: ICTs (T), pedagogy (P), content I, learners (L), and context (X) – indicated by X not to confuse with C of Content. The K that stands for knowledge, as an example in TPACK, TPK, or TK, will not be used in identifying the knowledge constructs to avoid lengthy acronyms. So, T, for example, will stand for TK to represent the Technology Knowledge base. The use of the combination (order is not significant, i.e. TP is the same as PT) formula:

$$C(n,r) = \frac{n!}{r!(n-r)!}$$

Leads to 26 different combinations resulted from the overlap of the five knowledge constructs T, P, C, L, and X. The 26 different combinations added to the 5 main knowledge constructs sums up to 31 knowledge constituents of ICT-TPCK, listed in the following table.

The overlapping of the five knowledge constructs (Total 31 different constructs)				
Independent constructs (No overlap)	Overlap of two constructs	Overlap of three constructs	Overlap of four constructs	Overlap of five constructs
T	TP	TPC	TPCL	TPCLX
P	TC	TPL	TPCX	
C	TL	TPX	TPLX	
L	TX	TCL	TCLX	
X	PC	TCX	PCLX	
	PL	TLX		
	PX	PCL		
	CL	PCX		
	CX	PLX		
	LX	CLX		

Table 1. Combinations formed by the five sets T, P, C, L, and X.

The preliminary naming of the obtained constructs is shown in the following list (table 2).

T	Technology Knowledge	TPC	Technological Pedagogical Content Knowledge
P	Pedagogy Knowledge	TPL	Technological Pedagogical Learner Knowledge
C	Content Knowledge	TPX	Contextual Technological Pedagogical Knowledge
L	Learner Knowledge	TCL	Technological Content Learner Knowledge
X	Context Knowledge	TCX	Contextual Technological Content Knowledge
TP	Technological Pedagogical Knowledge	TLX	Contextual Technological Learner Knowledge
TC	Technological Content Knowledge	PCL	Pedagogical Content Learner Knowledge
TL	Technological Learner Knowledge	PCX	Contextual Pedagogical Content Knowledge
TX	Contextual Technological Knowledge	PLX	Contextual Pedagogical Learner Knowledge

PC	Pedagogical Content Knowledge	CLX	Contextual Content Learner Knowledge
PL	Pedagogical Learner Knowledge	TPCL	Technological Pedagogical Content Learner Knowledge
PX	Contextual Pedagogical Knowledge	TPCX	Contextual Technological Pedagogical Content Knowledge
CL	Content Learner Knowledge	TPLX	Contextual Technological Pedagogical Learner Knowledge
CX	Contextual Content Knowledge	TCLX	Contextual Technological Content Learner Knowledge
LX	Contextual Learner Knowledge	PCLX	Contextual Pedagogical Content Learner Knowledge
TPCLX	Contextual Technological Pedagogical Content Learner Knowledge (TPCLX stands for ICT-TPCK knowledge)		

Table 2. Key Identification of the Knowledge Constructs

Visual portray of ICT-TPCK

Is it possible to visually represent the 31 knowledge constructs of the elaborated ICT-TPCK in a simple and comprehensible model? The challenge of displaying all the possible intersections of five overlapping sets was not an easy one. The intent was to use a simple visual display of the five-set model analogous to that representing TPACK intersection of three sets. Typically in such cases, Venn diagrams are used to visualize the intersections among two or more sets. But, Venn diagrams are often drawn with circles, and it is impossible to draw a Venn diagram with circles that will represent all the possible intersections of four (or more) sets (Ruskey, Savage, & Wagon, 2006, p.1304). After several attempts to reach a simple representation of five sets with all possible intersections are shown, a Venn diagram using congruent ellipses devised by the mathematician Branko Grünbaum (1975) was found to be the simplest possible. Figure 4 shows a five-set Venn that shows all possible intersections of ICT-TPCK model, where every set represents one of its five knowledge bases.

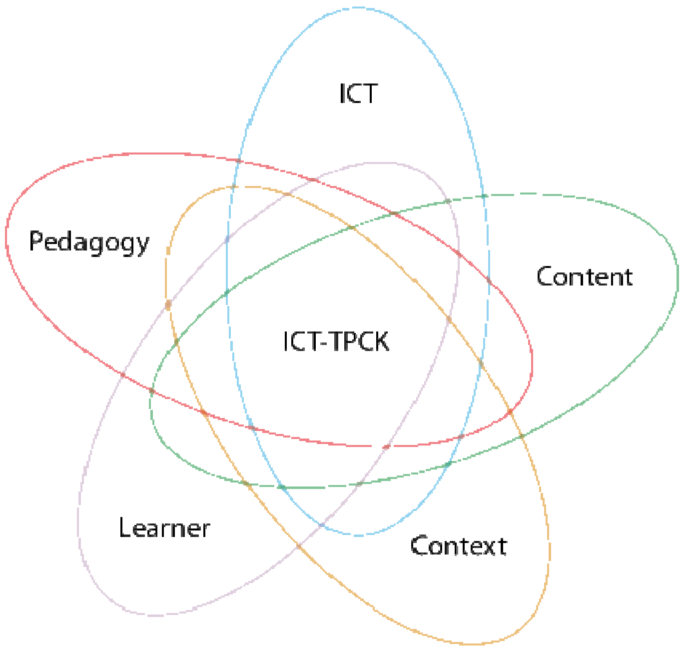

Figure 4. The Interconnectedness of TPACK-XL Knowledge Constructs

Introduction of TPACK-XL as a transformative view of ICT-TPCK

This section introduces TPACK-XL as a transformative view of TPCK with a special emphasis on the educational technology knowledge constituents.

Redefining ICT-TPCK knowledge bases

Before allocating the names of the specific constructs in Figure 4, it is useful to recall the educational disciplines that underlie the five basic knowledge constructs. According to Angeli and Valanides (2009), teachers' effective utilization of ICT relies on the ways they synthesize their knowledge about tools and their pedagogical affordances, pedagogy, content, learners, and context. In preservice teacher education, student teachers build this combined knowledge from different source disciplines.

These disciplines might, respectively, be classified as educational technology (the knowledge about tools and their pedagogical affordances), pedagogy and didactics, academic subject-matter discipline (content), educational psychology (learner), and educational sociology (context). We do not restrict to the names of the disciplines as described. Not to stick to one description of the contributing disciplines to ICT-TPCK knowledge, scholars and educators might find it more appropriate, for example, to describe the context knowledge by sociology of education rather than educational sociology or both disciplines fit to build preservice teachers' broad knowledge of educational context. From this point onward, TPACK-XL will indicate the elaborated portray of ICT-TPCK that stems from TPACK, where X and L, respectively, stand for Context and Learner knowledge.

TPACK-XL acknowledges the recognition of the Learner, and Context knowledge as basic constituents of ICT-TPCK theoretical framework in conceptualizing the nature of preservice teachers' knowledge and that is rooted in educational psychology and sociology. This does not diminish the focus of TPACK on the role of learners' knowledge and educational contexts knowledge in pursuing effective teaching practices involving technological pedagogical and content knowledge, but highlights their importance as core knowledge bases.

Graphical design of TPACK-XL

Figure 5 shows TPACK-XL knowledge constructs, where TPCLX interdisciplinary knowledge is a renaming of ICT-TPCK knowledge defined by Angeli and Valanides (2009) which constitute the ways the knowledge of T (Educational Technology), P (Pedagogy and Didactics), C (Academic/Subject-matter Discipline) , L (Educational Psychology), and X (Educational Sociology) are synthesized to promote teachers effective use of ICTs in their profession.

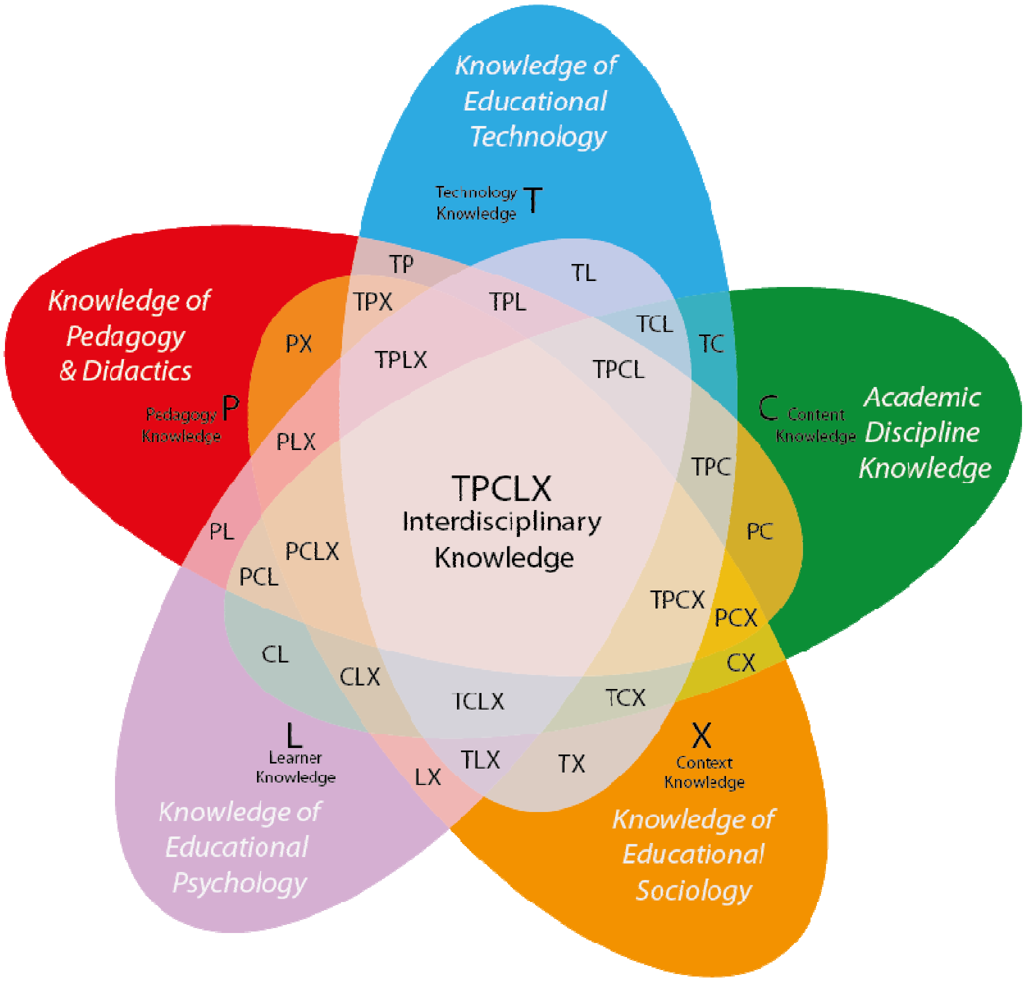

Figure 5. The Proposed TPACK-XL Theoretical Framework Model

All remaining thirty constructs represent the five major disciplines and their interdisciplinary knowledge areas, which mutually and gradually interrelate and merge to lead to the central preservice teachers' TPCLX knowledge (equivalent to ICT-TPCK knowledge).

Constituent knowledge constructs of TPACK-XL

Of the 31 knowledge constructs T, P, C, L, and X respectively represent the following academic disciplines in preservice teacher education: educational technology, pedagogy and didactics, subject-matter, educational psychology, and educational sociology. All other interdisciplinary constructs combine or involve two or more of these academic disciplines. The knowledge described in these constructs pertains to the interdisciplinary efforts that involve close and frequent collaborative exchanges among researchers from the relevant disciplines.

The Technological Learner knowledge (TL) in the framework, for example, represents the common ground, concerns, and relationship of educational psychology and educational technology and what their latest interdisciplinary research contribute to preservice teacher education. And of what it might describe, of the many common grounds, the relationships between recent educationally relevant psychological conceptions and educational usage of technologies, and the diverse ways that technological changes influence human learning and communication. In addition, preservice teachers' knowledge about TL constitutes awareness of the contemporary deliberations about the "new generation" of students characteristics influenced or generated due to ICT prevalence in their lives. Probably, TL will also raise issues that relate to the debates that support or argue against the conception that "new technologies have been such a defining feature in the lives of younger generations that they predict a fundamental change in the way young people communicate, socialize, create and learn" (Helsper & Eynon, 2010, p. 503).

If TL is to constitute this knowledge of new generations of learners that are referred to (of the many names) as "digital natives", then from this point of view, TPL (Technological Pedagogical and Learner) knowledge most likely extends TL knowledge to the studying of the implications for education affected by the characteristics of the new generations of learners, and TPLX (Contextual Technological Pedagogical and Learner Knowledge) extends TPL to the best comprehension of digital native learners group dynamics in educational contexts (Bayne & Ross, 2007; Bennet, Maton, & Kervin, 2008; Helsper & Eynon, 2010; Katz, 2005; Prensky, 2009, 2001a, 2001b; Rapetti & Cantoni, 2010). In illustrating some concerns of TL, TPL, and TPLX knowledge, emphasis is made on the interrelation between the corresponding disciplines of educational psychology, educational technology, educational sociology, and pedagogy and didactics that serve as a platform on which preservice teachers build their knowledge.

One way to promote this approach to the interdisciplinarity of knowledge understanding is multi-faceted. For example, in their essay that describes a month-long, intensive educational technology Master's program for practicing K-12 teachers, Mishra, Hershey, and Cavanaugh (in press) concluded that their "research into the psychology of learning and development has produced significant findings that have allowed us to improve teaching, construct new understanding in various academic disciplines, and develop new technologies" (p.27).

This conclusion perfectly describes the interdisciplinary trend in perceiving the role of technology in education. The analysis/fragmentation of the quoted paragraph shows below the interrelation between Educational Psychology (L), Pedagogy and Didactics (P), Academic Discipline (C), and Educational Technology (T). This view, for example, gives some meaning to the usefulness of TPCL knowledge.

"Research into the psychology of learning and development	Educational Psychology (L)
has produced significant findings that have allowed us to improve teaching,	Pedagogy and Didactics (P)
construct new understanding in various academic disciplines,	Academic Discipline (C)
and develop new technologies" (p.27)	Educational Technology (T)

Table 3. Analysis of TPCL in the work of Mishra, Hershey, and Cavanaugh

In this manner, it would be possible to perceive and conceptualize the importance of the interdisciplinary programs in teacher education, a trend that prevails in most reputed colleges of education. To truly prepare future teachers to understand the multiple ways that education shapes the lives of learners requires multiple perspectives. Consequently, the field of education is interdisciplinary by nature drawing on insights from the fields of educational psychology, sociology, technology, pedagogy and didactics, and academic (subject-matter) discipline. Recently we recognize the beginning of interdisciplinary trends in introducing educational technology in combination with other disciplines in teacher education. Lists of course offered include: Educational technology and psychology, Educational technology and sociology, learning theories and educational technology, etc.

Hence, teacher education programs should directly capitalize on the strength that multiple perspectives afford. To this end, TPACK-XL portrays thirty-one constructs, listed in Table 1, that highlight the amalgamation of contributing disciplines to building preservice teacher knowledge base.

TPACK-XL Acknowledges the General and Particular knowledge

As described earlier, TPACK is a context-specific technological pedagogical and content knowledge; the specificity of context is portrayed in the theoretical model (figure 2) by a "context" circle that circumscribes TPACK teachers' knowledge. What differentiates TPACK-XL framework form TPACK is its focus on the broad, and not only context-specific, interdisciplinary knowledge that preservice teachers need to acquire, during their preparation, in educational technology, pedagogy and didactics, academic subject-matter discipline, educational psychology, and educational sociology. Their knowledge is a combined knowledge that recognizes the general and particular, the global and local, the universal and situated, the international and national knowledge of the basic five disciplines and their interrelation that enables preservice teachers to develop thoughtful context-specific, situated teaching practices. As Shulman (2002) quote:

> Seek generalizations, relish them, challenge then, and take them as far as you can. Seek particularizations, collect them, explore them, and build local neighborhoods of understanding from them. And let those generalizations and particularizations interact and engage with each other, for only in that manner will our capacities for engaging in the practical work of teaching and learning flourish. (p. ix)

Educational technology constituents in TPACK-XL

To highlight this feature of TPACK-XL, we will investigate - as an example that applies to remaining major disciplines - the constituents of the educational technology knowledge construct of TPACK-XL deprived in figure 6.

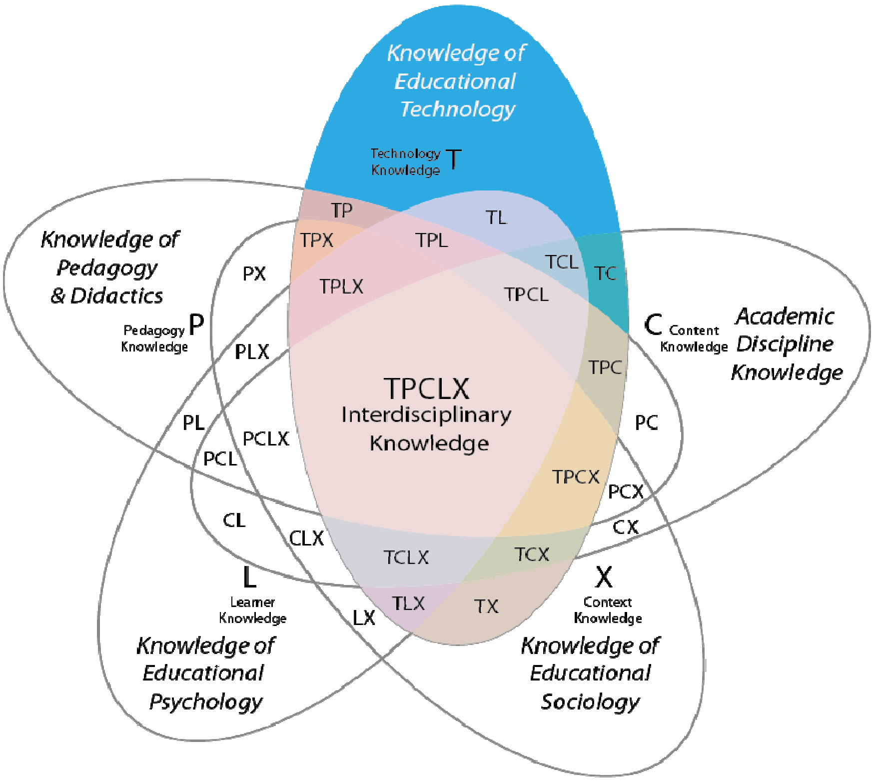

Figure 6. Educational Technology in TPACK-XL

As shown in figure 6, the educational technology knowledge for teaching with technology is comprised of 16 constructs distributed equally, according to the nature of knowledge, between the broad general knowledge type and the societal particular, context-specific (X) ones:

General Knowledge	T	TP	TC	TL	TPC	TPL	TCL	TPCL
Particular knowledge	TX	TPX	TCX	TLX	TPCX	TPLX	TCLX	TPCLX

Table 4. Educational Technology Knowledge Interdisciplinary Constructs

Thus, the elaboration of ICT-TPCK has led to a balance between the "generalizations and particularizations" of each discipline. The matching between the general and particular (referred to by Contextual (X)) knowledge constructs, of the interrelated disciplines that serve as an integrated source of knowledge of educational technology, can be observed in the rows of table 5.

	General /Universal/ International/ Global/ Broad Knowledge	Versus	Particular/ Contextual/ National/ Local/ Context-Specific Knowledge
T	Technology Knowledge	TX	Contextual Technological Knowledge
TP	Technological Pedagogical Knowledge	TPX	Contextual Technological Pedagogical Knowledge
TC	Technological Content Knowledge	TCX	Contextual Technological Content Knowledge
TL	Technological Learner Knowledge	TLX	Contextual Technological Learner Knowledge
TPC	Technological Pedagogical Content Knowledge	TPCX	Contextual Technological Pedagogical Content Knowledge
TPL	Technological Pedagogical Learner Knowledge	TPLX	Contextual Technological Pedagogical Learner Knowledge
TCL	Technological Content Learner Knowledge	TCLX	Contextual Technological Content Learner Knowledge
TPCL	Technological Pedagogical Content Learner Knowledge	TPCL X	Contextual Technological Pedagogical Content Learner Knowledge

Table 5. Educational technology: General knowledge versus particular knowledge

The sixteen knowledge constructs are listed in two columns: the first represents the general (universal/ international/ global/ broad) knowledge constructs and the second that contextualizes the elements of the first column in the light of preservice teachers understanding of educational sociology (and/or sociology of education) to turn them into a particular (contextual/ national/ local/ context-Specific) knowledge constructs. Next, table 6 lists the source disciplines of the general knowledge constructs.

	First Group of Educational technology construct	
	General /Universal/ International/ Global/ Broad Knowledge	Source Disciplines
T	Technology Knowledge	Educational Technology
TP	Technological Pedagogical Knowledge	Educational Technology and Pedagogy & Didactics
TC	Technological Content Knowledge	Educational Technology and Academic disciplines
TL	Technological Learner Knowledge	Educational Technology and Educational Psychology
TPC	Technological Pedagogical Content Knowledge	Educational Technology, Pedagogy & Didactics, and Academic disciplines
TPL	Technological Pedagogical Learner Knowledge	Educational Technology, Educational Psychology, and Pedagogy & Didactics
TCL	Technological Content Learner Knowledge	Educational Technology, Educational Psychology, and Academic disciplines
TPCL	Technological Pedagogical Content Learner Knowledge	Educational Technology, Educational Psychology Pedagogy & Didactics, and Academic discipline knowledge

Table 6. Constituents of educational technology knowledge

Why TPACK-XL?

The approach to building preservice teachers ICT knowledge has gained a lot attention in research (Enochsson & Rizza, 2009). TPACK-XL can serve as a road map to designing teacher education courses that include the interdisciplinary knowledge that leads to building the future teachers knowledge base described in ICT-TPCK of Angeli and Valanides, TPACK of Mishra and Koehler, and PCK of Shulman.

TPACK-XL is a detailed transformative view of ICT-TPCK that builds on TPACK and PCK theoretical frameworks as shown in figure 7. The significance of TPACK-XL lies in the elaboration of ICT-TPCK and the representation of the inter-relation between the disciplines that leads to its synthesized knowledge as an ultimate goal in teacher education programs in the way described by Angeli and Valanides (2009). This elaborated model describes the detailed interdisciplinary knowledge that can be useful to guide building ICT-TPCK based preservice teacher knowledge.

TPACK-XL is addressed to preservice teachers' educators and teacher education programs designers and developers aiming to prepare future teachers to use the pedagogical affordances of ICTs in their profession. We argue that a thoughtful use of the set of TPACK-XL constituent knowledge constructs will serve as an advanced lens of ICT-TPCK and a knowledge map for educators and researchers to study and develop preservice teachers' knowledge and education programs that appreciates the pedagogically wise permeation of ICTs in education.

To clarify, hypothetically, the TPACK-XL thirty-one knowledge constructs' content can be defined by educators on the basis of: the contributing disciplines knowledge, their interdisciplinary knowledge and corresponding research results, the advancement of ICTs, and their impact on the knowledge society education trends. The content of the thirty-one knowledge constructs can be carefully ordered and grouped to form a set of courses guidelines of preservice teacher education programs that leads to building TPACK-XL prospective teacher knowledge. The order of building the thirty-one knowledge constructs is of extreme importance. Pamuk (2011), for example, suggests that preservice teachers developing pedagogical content knowledge (PCK) must be acquired prior to learning about technology integration.

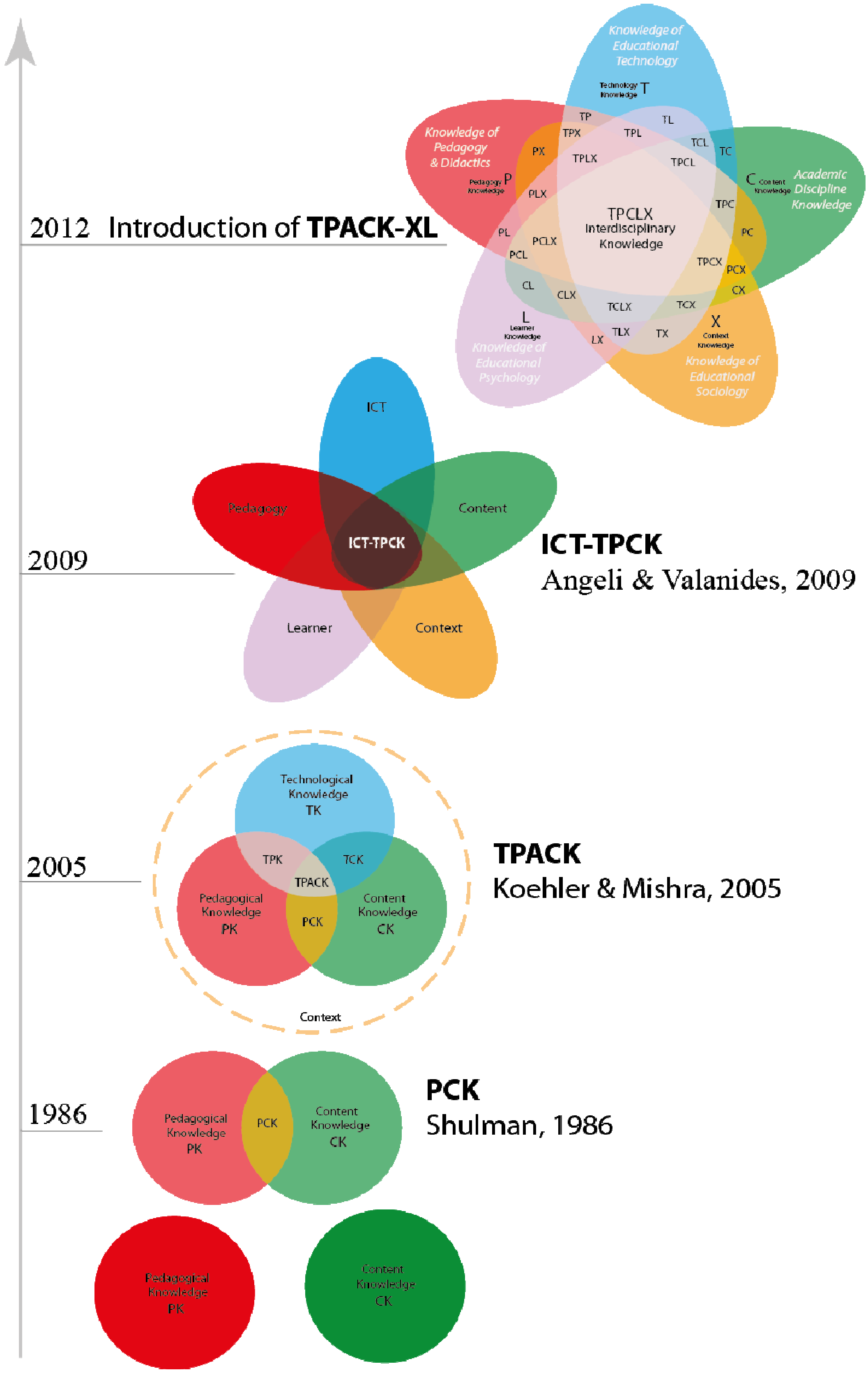

Figure 7. The Evolution of TPACK-XL

Conclusions

The detailed examination and refinement of the interrelated knowledge bases structure of ICT-TPCK: ICTs (T), pedagogy (P), content (C), learners (L), and context (X) has led to thirty-one constituent knowledge constructs, many of which are scrutinized as new to both TPACK, and ICT-TPCK.

Since intensive and coordinated systematic efforts are always needed to plan ICT–TPCK based pre-service education programs (Angeli & Valanides, 2009); this study exhibits ICT–TPCK as a powerful model that integrates the knowledge of educational technology (ICTs) with other contributing disciplines of education.

The proposed theoretical model, identified as TPACK-XL, reveals the ICT-TPCK interdisciplinary knowledge constructs interconnectedness with ICT knowledge needed to educate preservice teachers within ICT-TPCK principles. By that, it illustrates the ways preservice teachers' educational technology knowledge interconnects with other disciplines in the sciences of education namely: educational psychology, educational sociology, pedagogy and didactics, and subject-matter content knowledge.

The effort to reveal the interdisciplinary knowledge constructs of ICT-TPCK stems from the desire to organize, within the model, the increasing trend of offering interdisciplinary courses in teacher education programs; thus, turning TPACK-XL, the transformative view of ICT-TPCK, to a knowledge map that inspires preservice teachers' program and curriculum designers.

TPACK-XL portrays the knowledge base network and the webs of relations among the contributing disciplines and the knowledge of educational technology. It, also, names the interdisciplinary knowledge constructs that synthesize to build preservice teacher knowledge that leads to teaching in technology-rich environments. Consequently, TPACK-XL is suggested to serve as an advanced lens for scholars and preservice teachers educators with different educational disciplinary backgrounds in designing and developing teacher preparation programs that address ICTs in preservice teacher education.

The analysis of the structure of ICT-TPCK model and the introduction of TPACK-XL aimed to contribute to a profound theoretical framing of preservice teachers' knowledge base which embeds ICT knowledge within the new educational technologies knowledge.

In developing a curriculum for preservice teacher education, a framework can be useful in portraying, usually in visual form, the different knowledge components and the interrelationship between these components within a coordinated and coherent whole. A framework, then, is a kind of scaffold or architect's blueprint that curriculum developers take as a starting point in determining content, sequencing, and pedagogical process (Anderson & Glenn, 2004, p.28). From this perspective, TPACK-XL is a visual portray of a knowledge framework which helps educators to view the interrelation of the knowledge constructs that lead to ICT-TPCK knowledge by preservice teachers. It is, also, presented for curriculum developers to avoid designing curriculum courses as separate islands of knowledge, but rather intuitively cluster TPACK-XL interdisciplinary components to cover the whole knowledge that builds preservice teacher base.

The potential of TPACK-XL framework might seem useful to serve as an advanced lens of ICT-TPCK for educators and researchers to open the discussion about the strategies leading to building preservice teachers' knowledge and the corresponding teacher education programs content that appreciate the pedagogically wise negotiation to fit the capacities of ICTs in education. "The negotiation process referred to here is the process in which educators do not simply adopt ICT because they are available but rather they learn more and more about what is possible with ICT and then match the ICT with what they think is important to achieve in education." (Johnson, 2004, p.7)

Professor Mathew Koehler, in his email comment on TPAK-XL diagram (August 8, 2012), says:

> That's an impressive looking a diagram - I bet it was a feat just to figure out how to represent all of that! In general, I see the temptation to add more realms of knowledge (in this case, X and L). We originally had four, for example (we used to have an R). While these representations probably capture more depth - they sacrifice parsimony and the ability to communicate with

teachers and teacher educators. That is, there's a lot to be said for parsimony (M. Koehler, personal communication, August 8, 2012).

This recalls the controversial view raised since William of Ockham (1287–1347) law of parsimony known by Ockham's razor; a principle stating that among competing hypotheses, the one that makes the fewest assumptions should be selected. Where on the other side, Walter of Chatton who was a contemporary of William of Ockham, and in response he devised his own anti-razor rule: "If three things are not enough to verify an affirmative proposition about things, a fourth must be added, and so on." (http://en.wikipedia.org/wiki/Parsimony)

In some respects, it might be true that TPACK-XL sacrifices parsimony. But, since a lot can be said about parsimony, scholars and educators are to pursue the usefulness of this framework in their interdisciplinary endeavor to educate future teachers to teach in technology-rich learning environments.

After all, and in agreement with Anderson and Glenn (2004): “Frameworks, like models do not have the property of being true or false. Rather, they may be more or less useful or perhaps not useful at all, for particular purposes.” (p.28); TPACK-XL is no exception.

Implications

The ultimate goal of our present efforts is to enable preservice teachers develop awareness about the diverse considerations brought from the different sciences of education that influence the successful integration of technology in their teaching practices.

Our recent endeavor in the field of ICTs in teacher education lead to proposing TPACK-XL, as a transformative view of ICT-TPCK, to model preservice teacher education programs and address the inevitable change due to the accelerated proliferation of ICTs in education. Our research in this regard addresses the increasingly salient role of interdisciplinary knowledge in building preservice teachers ICT knowledge. In our present work, TPACK-XL is gaining more and more attention as it highlights the importance that educators with different disciplinary backgrounds to capitalize on joint, coordinated, and continuously integrated research to produce tightly interwoven joint reports, papers, and plans. Our present focus is to set TPACK-XL guidelines that defines the interdisciplinary domains that bridges the gap between ICT knowledge and other education disciplines in preservice teacher education programs.

In our work with TPACK-XL, we highly acknowledge the importance of the overarching theoretical models in the field of teacher education offered by professors Lee Shulman (1986), Mathew Koehler and Punya Mishra (2005), Charoula Angeli and Nicos Valanides (2009). TPACK-XL is introduced to highlight these efforts and to offer a closer look to ICT-TPCK model for a better understanding to the interdisciplinary efforts needed for building preservice teachers ICT knowledge.

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