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TPDK, A NEW DEFINITION OF THE TPACK MODEL FOR A UNIVERSITY SETTING

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Abstract

In this paper we propose a new Technopedagogical Disciplinary Knowledge model. This model integrates four separate dimensions, which we use to measure a teacher's effectiveness. These are the individual teacher's discipline (D), personal epistemology (E), pedagogical knowledge (P), and knowledge of technology (T). We also acknowledge the existence of relationships between these components. These can be more or less correlated depending on the teacher's individual profile. They are always present, but they do not necessarily have the same weighting. In order to test the potential differences between teachers' profiles, we designed a questionnaire, which tested our model's components, and the relationships between them. This questionnaire was initially submitted to a group of teachers with whom we were familiar, to ensure the questions were understandable and that, based on what we already knew of the teachers' characteristics, the profiles that emerged were reliable. A second test was then carried out, which we used to compare the answers of university and non-university level teachers, based in the two institutions in which we work. This second questionnaire was used to test the consistency of responses, and the correlations between the model's different dimensions. Having analysed the outcome of these questionnaires, it appears that "pedagogical knowledge" is significantly correlated with the other three dimensions. This consolidated framework has helped us to build a system of education development coaching for teaching practices that use technology widely.

Introduction

This study aims to present a theoretical model which can be used to understand the various influences on teaching practices. On the basis of several existing models, we propose a model-tool which can be used to analyse teachers' profiles. This model integrates several different aspects to reveal the overall profile of individual teachers. These include the influence of the culture involved in a teacher's chosen discipline, their personal epistemology, their pedagogical knowledge, and their knowledge of technology. This new component association can be used to guide the work of educational trainers (academic advisors, teachers, teachers of practical training etc.), in order to better understand why teachers use some tasks more than others. Our aim is to answer this question: why, and under what influences, does a teacher make a particular choice in their teaching practices? Using this information, a counsellor or teacher can better target their activity, basing it on different aspects of a teacher's profile and the effect this has on their teaching practice.

In addressing this issue, our epistemological position covers both educational and didactic research. This paper will be limited to defining a model-tool to guide the teaching work of teacher educators at universities. Applications and examples of this model will be presented at a future date. We present first the foundations and perspectives of the theoretical study.

This project is based on a simple observation: until recently, little research in the science of education has been focused on how content is to be taught (Shulman, 1986; 1987; 1998; 2004; 2007), or the influence of teachers' beliefs about the action of teaching (Vause, 2009). Given the technological developments which are currently evident in teaching practice, it seemed prudent to analyze how teachers' technological knowledge affects their teaching style. These questions formed the basis of our model.

We will first explore previous models which also integrate technology. The Technological pedagogical content knowledge model (Mishra & Koehler, 2006) provides a complementary look at the Shulman (1986) and Berthiaume (2007a) models.

Based on these models, our goal is to propose a new tool-model: **Techno-Pedagogical Disciplinary Knowledge**. For validation, this required two tests: a comparison study of cases and a statistical study. We want to offer school counsellors or teacher educators an analytical framework that would better guide the pedagogical and technological projects of university - professors.

Pedagogy and content

Pedagogical content knowledge – PCK

Shulman (1986) highlighted how the method of teaching can be changed to relate better to the content. He introduced the concept of Pedagogical content knowledge (PCK). This resulted in the idea of content knowledge (Shulman, 2007) or didactic knowledge, which "can be defined as the knowledge that one has from knowledge with the purpose of teaching" (Sensevy, 2009, p.53).

Content knowledge includes knowledge that relates to the material which is to be learned or taught (Schwab, 1964). Teachers must have a certain amount of knowledge of the subjects that they teach. This includes key facts, concepts, theories and procedures in their field. There are already many ways to represent content knowledge, for example, the taxonomy of Won (1985), which proposes the structuring of the different content to be taught into facts, concepts, procedures, and strategies.

Pedagogical knowledge includes knowledge about teaching and learning, i.e. – how to manage the classroom, evaluations, etc. A teacher who has good pedagogical knowledge understands how students create knowledge, acquire skills and develop good habits in their learning (Mishra & Koehler, 2006).

The work of Shulman (1986) aimed to create an intersection between these two knowledge types. According to Shulman (1987), having knowledge of the subject matter and general pedagogical strategies is not sufficient to be a good teacher. Pedagogical content knowledge (PCK) better reflects the way that certain content should be taught. "Pedagogical content knowledge also includes an understanding of what makes it easy or difficult to learn specific subjects: conceptions or preconceptions that students of different ages and different cultures deal with them in the fields and lessons most frequently taught" (Shulman, 2007, p.105).

According to Mishra and Koehler (2006), the heart of PCK is the way in which subject matter must be transformed to teach it better.

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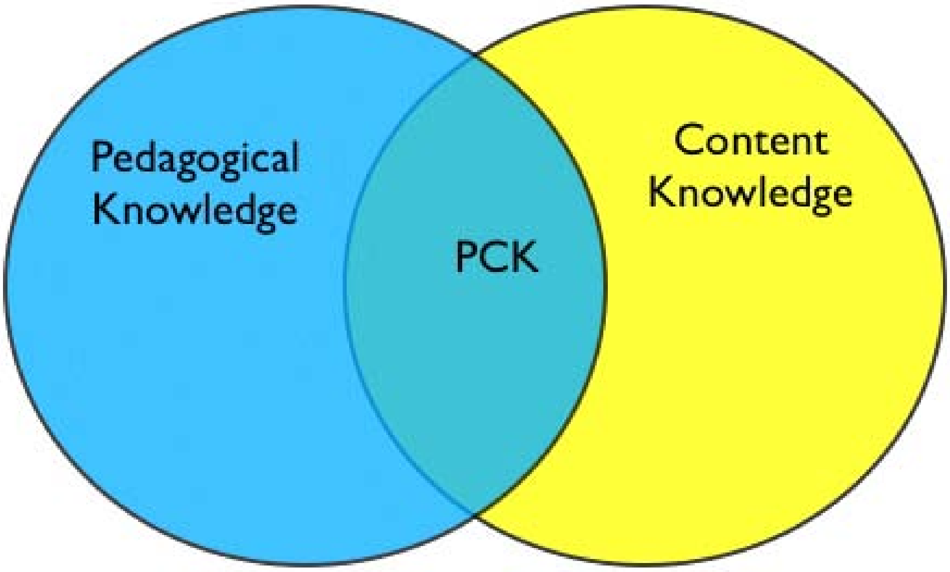

Figure 1. PCK (Shulman, 1986)

It is important to note that PCK, as proposed by Shulman (1986; 1987), is particularly interesting because for the first time it provides an explanation of the practices of teachers. It combines content and pedagogy to understand how certain themes are represented and adapted to enable them to be more easily learned. This expands our understanding of how teachers create new knowledge.

Shulman's research still has a great deal of influence in Western Europe and the U.S. today. Several studies (Amade-Escot, 2001; Gess-Newsome & Lederman, 1999; Segall, 2004) are still based on his model. For Sensevy (2009), the Western European advances can help us through their pragmatism. They study the practices as they are and allow cooperation with teachers in order to define specific devices. They "fit like without thinking, within the same research, consideration was expected rather in Francophone studies, see sometimes scattered in research science education sometimes in educational research" (p.53).

The notion of PCK has been extended and subsequently criticized by many studies. For example the work of Cochran, King and De Ruiter (1993), van Driel, Verloop and Devos (1998), Segall (2004) and even Shulman himself (2007), added the following characteristics to both content and pedagogical knowledge:

- knowledge of the curriculum (from the program),
- knowledge about learners,
- knowledge related to educational contexts,
- knowledge on educational purposes and
- knowledge of the teachers' own profession.

This means recognizing that knowledge to teach is a complex knowledge. It consists of sociological knowledge, discipline, educational, epistemological and didactic knowledge.

The Shulman model, which integrates content and pedagogy, has been primarily studied in the primary and secondary levels of education (Magnusson, Krajcik and Borko, 1999). In a university setting, Lenze (1995) altered the PCK, to create the discipline-specific pedagogical knowledge (DPK) in order to better reflect the characteristics of this educational level.

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The characteristics of the university teaching

In a multi-case study, Lenze (1995) examined PCK among both non-language and Spanish language teachers. She altered the Shulman model, providing more specific profiles of university teachers by using discipline-specific pedagogical knowledge. She justified this by showing that the content taught by university professors is actually the academic discipline as such. Therefore, content and discipline are really equivalent terms at this level.

This upgrade of the Shulman model (1986) for an academic audience reinforces our belief that there are characteristics which influence the teaching skills at this level. These cannot be ignored if we wish to understand the practices of higher online education. However, in an academic context, other studies have added to this, reflecting the diversity of teacher profiles.

There is a great deal of heterogeneity in both teaching practice and faculty profiles in a university setting. This is generally explained by the impact of many factors, more personal and contextual than organizational. Bourgeois (1990) notes that heterogeneity is a very specific characteristic of the university setting. The difficulty involved in characterizing these differences is so great that Guyot and Bonami (2000) prefer to refer to university teachers as a federation, rather than a profession. This takes into account the different occupational profiles involved in such a wide range of disciplines, departments, and units "each developing its own system of representation, method of work and task management, its paradigms, its specific culture, customer, its symbolism, its technologies and logics of action" (p.7).

This heterogeneity lead Guyot and Bonami to consider that university faculty work has a pronounced foundation in the specific discipline being taught.

Recent work, led by Vause (2009), also added the assumption that teachers' knowledge is built in their classroom, based on a process of assimilation and accommodation of the surrounding educational practice. The author assumes that teaching style is influenced by the personal school experience of the specific teacher. Therefore, in addition to the epistemological references specific to the discipline, it is also necessary to consider the personal epistemology of teachers. Hofer (2004) defines personal epistemology as a field of research that focuses on beliefs and experiences, through which individuals develop theories about knowledge and its acquisition. Understanding how these epistemic beliefs influence cognitive processes of thinking and reasoning is also at the heart of Berthiaume's work (2007a). Here the researcher proposes that as a redefinition of Lenze's DPK (1995), it is necessary to integrate the dimension of personal epistemology, disciplinary, and pedagogical dimensions. It proposes a tool-model that would take into account and interpret any heterogeneity, as discussed above.

The DPK – discipline-specific pedagogical knowledge

Berthiaume's research project (2007a) empirically examined the nature of disciplinary pedagogical knowledge (DPK), connected to the teaching of a discipline at the university. As we have seen, in the Western European tradition, DPK has its origins in two branches of research: namely those of the knowledge base for teaching and of the disciplinary specificity. However, according to Berthiaume, these two branches of research in education completely fail to understand the concept of DPK in all its complexity. He therefore added a new branch of research, related to personal epistemology.

Research on the knowledge base for teaching (Hiebert, Gallimore & Stigler, 2002; Munby, Russell & Martin, 2001; Shulman, 1986) does not lend itself easily to a discussion of the factors that are "external" to the teacher's knowledge base, such as standards, rules and practices which prevail in an academic discipline.

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Meanwhile, research on disciplinary specificity (Becher & Trowler, 2001; Donald, 2002; Hativa & Marincovich, 1995; Neumann, 2001) does not readily explain the "internal" factors such as the relationship that may exist between various types of knowledge, or the intentions of the teacher.

It therefore seemed clear to Berthiaume that previous ways of conceptualizing the DPK, taken individually, limited our ability to understand this phenomenon.

Therefore, Berthiaume brought together the two branches of research emphasised by Shulman (1986) and Lenze (1995). He added that "the junction of concepts from research on the knowledge base for teaching and research disciplinary specificity provides a way to consider simultaneously the internal and external factors contributing to the formation of DPK" (Berthiaume, 2007a, p.179). He also included concepts from a third branch of research, referring to personal epistemology, i.e. the beliefs that teachers hold regarding knowledge (Hofer & Pintrich, 1997; 2002). He suggested that "This dimension is essential to the articulation of the link between the basic pedagogical knowledge and disciplinary specificity, as beliefs that are present in the basic pedagogical knowledge interact with knowledge specific to the teacher's discipline. Personal epistemologies thus serve as a mediator between social standards of discipline and teaching practices of a lecturer teaching this discipline" (Berthiaume, 2007a, p.179).

By following the studies of all three major researchers, we therefore find a complex tool, integrating three separate dimensions (Figure 2). These are the knowledge base involved in teaching, the specific discipline, and the personal epistemology. These three dimensions are themselves divided into several components. The knowledge base for teaching includes the aim of the course being taught, the teacher's knowledge of teaching, and their beliefs about the right way of carrying it out. The disciplinary dimension is composed of the epistemological structure and socio-cultural characteristics. Finally, personal epistemology involves the teacher's beliefs about knowledge and the act of knowing, beliefs about how people learn in general and about the relative value of knowledge. Each characteristic of this tripartite model is therefore defined by a series of elements, developed from the research reviewed above.

Understanding the relationships between the components allows greater understanding and an easier definition of how it is that a teacher at a university manages to link their generic pedagogical knowledge (i.e., their knowledge of how to teach), and the specific characteristics of the subject in question (the knowledge that is to be taught), whilst also taking into account his personal epistemology and beliefs. This tool therefore enables greater understanding of why it is that a teacher chooses to use certain tasks, which another, either in the same discipline or one which is entirely removed, might not. This includes the teacher's cultural references, epistemological and pedagogical beliefs, and knowledge gathered from their own educational background.

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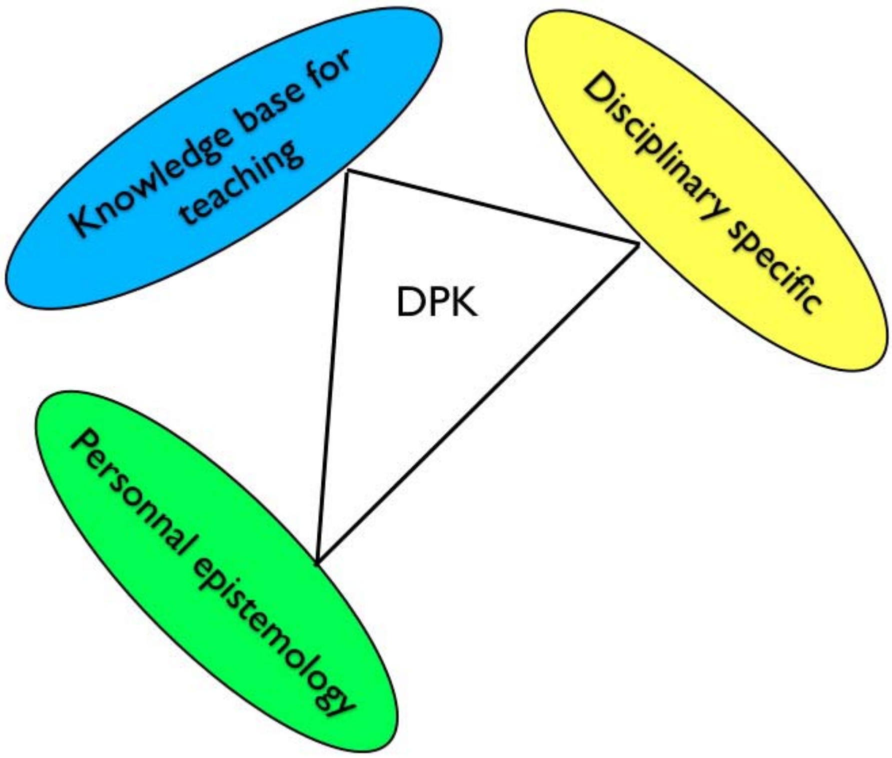

Figure 2. DPK. Adapted by Berthiaume (2007b)

Berthiaume tested the tool in a study conducted using four teachers from four different disciplines. The participants were selected in order to represent each of the four disciplinary groups identified by Biglan (1973), namely soft-pure, soft-applied, hard-pure and hard-applied. Each teacher was interviewed five times, giving access to his thought processes as regards education, discipline, and knowledge in general. According to a content analysis approach, the interviews were transcribed verbatim and analyzed using a coding process. The data analysis led to the identification of 32 empirical evidences, related to the eight components of the DPK, which were derived from the theory of the subject (Berthiaume 2007b, p.157).

The case analysis revealed that 19 of these 32 elements were present in the empirical DPK observed in four teachers (in this regard see Berthiaume, 2007b, p.155). This led to the identification of several relationships between the elements, which were also present in the four teachers' components. Based on these common elements and different relationships between these elements, Berthiaume found the core of the DPK which should be present in the majority of university professors (Berthiaume, 2007a).

For each case of his analysis, he identified the specific relationships between model components. This research project produced the Berthiaume tool-model, which captures the phenomenon of the DPK of university professors more accurately than previous conceptualizations.

The new concepts involved in this model suggest that university professors teach based on specific relationships between the three dimensions. The fundamental conclusion of this work is that there are large differences in the teaching practices at the university, and that this is related to their past experiences in their discipline.

For the academic advisor, this research aimed to clarify and identify discipline specific expectations which should be used in university teacher training. This is largely what we are attempting to do in this paper.

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However, Berthiaume's DPK (2007b) does not include the technological dimension that we are interested in. Our model will therefore include this technological dimension, creating a new model: the TPACK.

Pedagogy, content and technology

Researchers like Jacquinot-Delaunay (2008) or Rege Colet and Lenzo Marchese (2006) showed the strategic importance of providing discipline specific insight into information and communication technologies (ICT) training. These are well integrated (Jacquinot-Delaunay, 2008), and different faculties have varied and specific needs (Rege Colet & Lenzo Marchese, 2006). Comparing the use of ICT systems in the various faculties of the University of Geneva, including the use of online information retrieval, course materials, websites and forums has highlighted "differences in use of educational technologies by faculty, some of which are marked" (ibid., p.14).

In other words, pedagogical counsellors should be able to join educational concepts and disciplinary requirements, but also take into account the views of teachers on online education and distance learning practices. To manage this complexity, Kanuka (2006) proposes that the pedagogical counsellor, use a model like Shulman's Pedagogical content knowledge (PCK) to train and support university teachers. Educational guides and counsellors must therefore develop not only teaching strategies for the theories of learning, but must tailor their repertoire to reflect their knowledge of the subject taught and the culture of each discipline. Techno-pedagogical knowledge should not be applied in the same way in all disciplines.

Technological and pedagogical content knowledge – TPACK

Mishra and Koehler (2006) therefore expand Shulman's initial model, which contained content and pedagogical knowledge, to include knowledge about technology. They state that "today, knowledge of technology is often considered to be separate from knowledge of pedagogy and content. This approach can be represented as three circles, two of which (content and pedagogy) overlap as described by Shulman, and one circle (technology) stands isolated from these two" (p.1024).

The **knowledge technologies** include knowledge about the use of technological tools such as the interactive white-board, internet or podcasts, but also more simple knowledge, for instance the ability to install devices or manage a computer.

This third dimension was therefore added to give a better idea of the way in which education functions. "(...) in contrast to the simple view of technology, our framework emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy and technology. In this model, knowledge about content (C), pedagogy (P) and technology (T) is central for developing good teaching" (Mishra & Koehler, 2006, p.1025).

According to these authors, the notion of TPCK or TPACK (techno-pedagogical content knowledge) is completely new.

A more specific approach to TPACK is to analyze the relationship between content, pedagogy and technology. In addition to considering each entity separately, there must be a systematic study of the interaction between pedagogical content knowledge (association of knowledge and pedagogical content knowledge), technological content knowledge (Association of technological knowledge and content knowledge), the techno-knowledge (combination of technological knowledge and pedagogical knowledge) and the intersection of these three dimensions: techno-pedagogical content knowledge.

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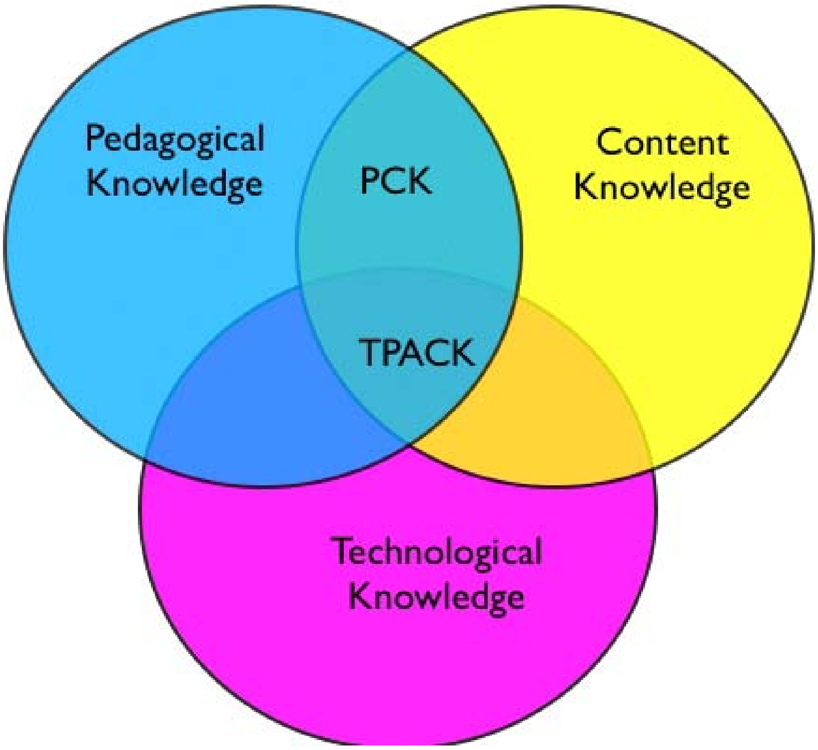

Figure 3. TPACK (Mishra & Koehler, 2006)

The intersection involved in pedagogical content knowledge is analysed above. We will therefore now analyse how technological knowledge interacts with these other two.

Technological content knowledge concerns the relationship between technology and content. This involves the influence which technology can exert on subject teaching (Mishra & Koehler, 2006). Mishra and Koehler took the example of the teaching of geometry. The use of a virtual sketchbook allows learners to easily test multiple combinations, without having to build each item to check its proportions. Therefore, technology changes the nature of learning itself (Niess, 2005).

Techno-pedagogical knowledge concerns the teacher's knowledge of the different technologies involved in teaching and learning. This enables them to associate tools with specific educational tasks.

The intersection of these three dimensions forms the TPACK. The Techno-Pedagogical Content Knowledge is a new form of knowledge. According to Mishra and Koehler (2006), it is:

- The basis of good teaching with technology and requires an understanding of how technology can be used to represent different concepts.
- Pedagogical techniques that use technologies in a constructive way to teach content.
- Knowledge of what makes concepts difficult or easy to learn, and how technology can help to solve part of the problem that learners meet.
- Knowledge of how technologies can be used to build on existing knowledge bases and develop new ones.

These authors see the TPACK as a place of essential cohesion. The three-dimensions (pedagogy, content and technology) are inseparable. A change in one of the three dimensions is offset by a change in the other two. For instance, a course in political science might offer case studies based on illustrated maps that use an overhead projector. Dynamic effects show geostrategic issues. By

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using these technological tools (animated PowerPoints, projectors, screens, etc.) the teacher is pedagogically using case studies to build the students' knowledge of geopolitics. If his goal was only to convey the historical facts without pointing out or analyzing issues, it could just as easily be given orally without visual media or animation. Changes in pedagogy and content will lead to changes in technological use.

The TPACK is a model that supports this idea of strong interrelationships between content, pedagogy and technology, integrating content into a dynamic two-way system. Teachers are not required to use the three components, but the choices they make will affect how the system works. Numerous studies such as those of Archambault and Crippen (2009) and Schmidt et al. (2009) have validated the interrelations between these three core areas. The authors performed validation studies with hundreds of teachers.

According to Mishra and Koehler (2006), the recent emergence of online technologies obligate academics to strike a balance between the three dimensions, often leading them to question their teaching styles. The authors add "The addition of a new technology is not the same as adding another module to a course. It often raises fundamental questions about content and pedagogy that can overwhelm even experienced instructors" (p.1030).

Studies led by the Milken family Foundation and the International Society for Technology (Moursund & Bielefeldt, 1999) show that current teacher training programs do not provide the necessary experience to enable teachers to properly use technology. These articles suggest "The most significant finding of the survey is that formal stand-alone IT coursework does not correlate well with scores on items dealing with technology skills and the Ability to integrate IT into teaching (...). Yet the current data supporting the idea do no additional technology specific coursework that will greatly improve aspects of IT use in education" (Moursund & Bielefeldt, 1999, p.3).

The surveys show that theoretical studies of technology have almost no impact on their use in teaching practices. To follow one of the recommendations of their work, Mishra and Koehler (2006) advocate learning by design. They are responsible for a variety of applications we propose to analyze below.

Application in teacher training

In order to better support the impact of training in e-learning teaching practices, Mishra and Koehler (2006) analyzed the scope of their TPACK model. They defend the idea that we learn by doing. There must therefore be a link between theory and practice. Teachers are faced with situations in which they must make strategic choices, as in real life. The authors suggest that the theory of TPACK not only helps to understand what it is to teach with technology. It is also able to make predictions as to what would make a good education, based on the subject specific context. The TPACK can be a useful organizational structure to define what teachers need to know to integrate technology into their teaching (Archambault & Crippen, 2009).

Therefore, a great deal of research (Hofer & Harris, 2010; Niess, 2005) has been focused on possible applications of the TPACK in teacher training. Niess (2005) developed a techno-pedagogical training protocol for teachers in science and mathematics. In his study, the author analyzes the different profiles of teachers based on the TPACK. Hofer and Harris (2010) have suggested that this theory may be too general in nature. They suggest that most training applications of TPACK focus primarily on tools and technology resources. Rightly, they state that this kind of training cannot take into account the heterogeneity of teacher profiles.

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They therefore developed "Learning Activity type", to support teachers in linking their curriculum learning objectives, instructional activities and technology. By doing so, they join Shulman (1986) and Mishra and Koehler (2006) in considering that teaching practices (and therefore the choice of technology) vary depending on the course content. As we shall see, this approach is consistent with that adopted in our research to guide teachers in their work. It also reflects the work of Moursund and Bielefeldt (1999) and Puentedura (2006), who analyzed the various uses of technology in the various areas mentioned above.

Hofer and Harris (2010) proposed to develop a script that takes into account:

- learning objectives,
- learning styles (variation principle of the proposed activities),
- consistency in the training sequences,
- a formative evaluation,
- a selection of resources and tools that can help students.

For these authors this practice allows the decentralization of the taught content (which is a classical trend among new teachers), in order to focus on student learning. In addition, with this strategy, teachers become more aware of the strategies that they put in place, and the activities therefore become more focused on learning (Graham, Borup & Smith, 2012).

Validating potential changes in teaching practices is only one function of the TPACK. Schmidt, Baran, Thompson, Koehler, Mishra and Shin (2009) developed a self-spotting tool with many items relating to different aspects of TPACK: Technological (T), pedagogical (P), content (C), technological pedagogical (TP), technological content (TC), pedagogical content (PC) and technological pedagogical content knowledge (TPACK).

Schmidt et al. (2009) examine how future teachers establish relationships between these seven dimensions during their basic training. Archambault and Crippen (2009) have also developed a test of this type, for use on teachers already in service. Harris, Grandgenett and Hofer (2010) recognize that these two tests provide considerable assistance in assessing the TPACK profile of teachers, who position themselves on a proficiency scale with five levels. However, according to these researchers, this information should be cross-referenced with external evaluations of their teaching.

These researchers therefore offer an observation grid with criteria very similar to the Moursund and Bielefeldt scales (1999). Harris et al. (2010) additionally add the criterion of consistency between the curriculum based objectives, teaching strategies and technology choices. For each criterion, they propose indicators that demonstrate a beginner level (e.g., learning objectives and technological choices which are not aligned) or conversely an advanced level (technological choices which are aligned with the learning objectives).

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The techno-pedagogical disciplinary knowledge model (TPDK)

Using analysis of the teaching-learning sequences online, and attempts to better understand how teachers develop their educational choices, we have incorporated the ideas of PCK, DPK, DPK + epistemology and the TPACK models.

We combined these models to better capture the complexity of profiles of university teachers. We believe that all aspects (educational, epistemological, technological and disciplinary) alter the teaching practices of the staff in different ways. The strength of our proposal lies in integrating these four variables to guide the work of teacher educators. With this tool, the counsellor can get a quick picture of the profile of a professor on what influences the most. Therefore, it can improve its board and adjust its propositions about references the teacher.

In combining these factors, we are able to ask teachers about the links they make between their pedagogical knowledge (P), technological knowledge (T), personal epistemology (E) and discipline (D).

We have replaced PCK with DPK in accordance with Lenze's work (1995), where he justifies the replacement of "content" (PCK) with "discipline-specific" (DPK), because at the university, the content is by its nature an academic discipline.

In the PCK and TPACK models, the 'disciplines', and in the DPK model 'discipline', refers to the epistemological structure and cultural characteristics used to teach content.

The TPDK model helps to understand the relationships that teachers make between these four dimensions (T, P, E and D), in order to teach content from the disciplinary field of teaching.

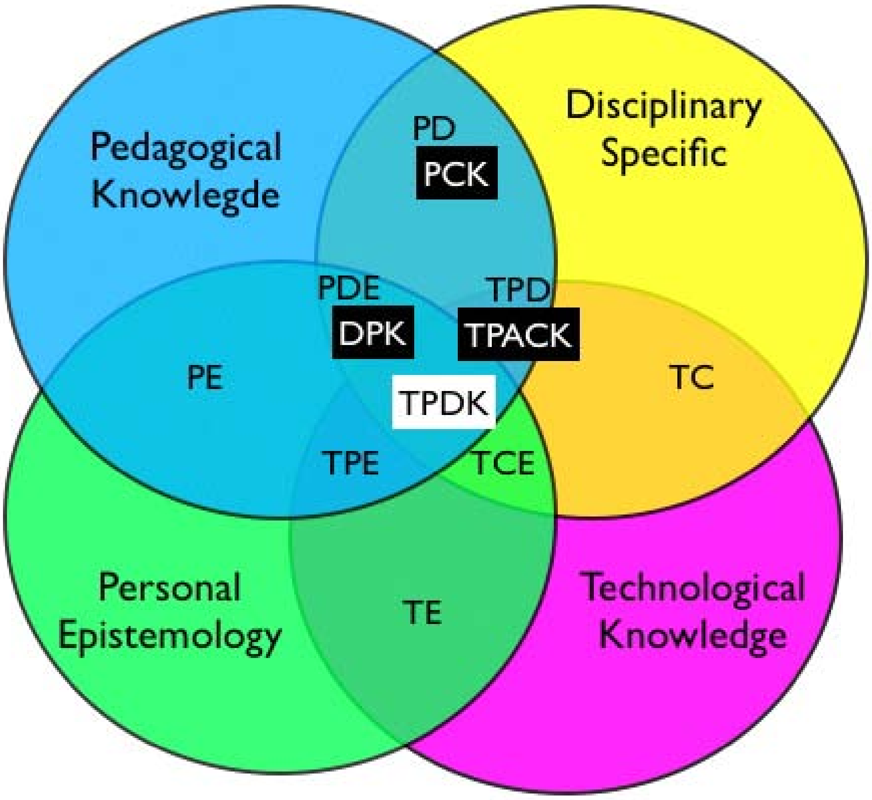

Figure 4. TPDK

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There are six relationships between the four dimensions of TPDK, as shown below (Figure 5). There is:

- PE: the relationship between pedagogical knowledge and personal epistemology;
- PD: the relationship between pedagogical knowledge and discipline (which corresponds to the Shulman PCK or Lenze DPK);
- TP: the relationship between pedagogical knowledge and technological knowledge;
- TE: the relationship between technological knowledge and personal epistemology;
- TD: the relationship between technological knowledge and discipline;
- DE: the relationship between discipline and personal epistemology.

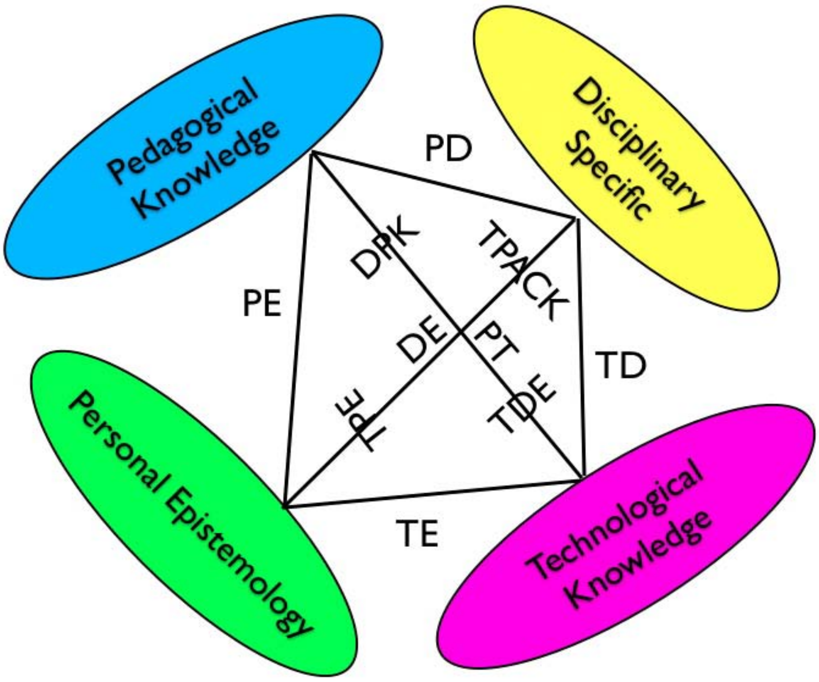

Figure 5. Relations between dimensions in TPDK

To these six relationships between the two components can be added four further relationships between three components:

- PDE: the relationship between pedagogical knowledge, discipline and personal epistemology, which uses the Berthiaume DPK;
- TDE: the relationship between technological knowledge, discipline and epistemology;
- TPD: the relationship between technological knowledge, discipline and pedagogical knowledge, which corresponds to the TPACK of Mishra and Koehler;
- TPE: the relationship between technological knowledge, pedagogical knowledge and personal epistemology.

Methodology

Based on questionnaires developed by Archambault and Crippen (2009) and Schmidt et al. (2009), our self-spotting questionnaire tested each dimension of the model, and the relationships between them. The target audience for the test (Archambault & Crippen, 2009), is already known, and in relation to student teachers covered by Schmidt et al. (2009), we have taken more items than their models. For each dimension and relationship, Archambault and Crippen proposed three or four items in the test. In total, the authors tested the techno-pedagogical skills of teachers with 24 items. They submitted their test using 576 teachers in virtual classrooms from 25 states of the USA. Teachers were asked to estimate their capacity in the different areas by five different levels: poor, satisfactory, good, very good and excellent. These authors found positive correlations between all the dimensions, some of which were highly statistically significant (Archambault & Crippen, 2009, p.80).

Our questionnaire is partially based on the items offered by previous questionnaires, although we have added the dimension of personal epistemology (E); and relationships with technology (TE), pedagogy (PE) and discipline (DE). We developed three items for 10 categories. As we will see later in the validation of the 30 original items, we had to remove two to ensure better internal consistency in the tested element, as Cronbach's alpha was too low for these categories. All items are listed below (Table 1).

The items 1, 2, 3, 4, 5, 6, 7, 9, 19, 20 and 21 come from a free translation of the items offered by Archambault and Crippen (2009). They have been in direct confrontation with other theories dealing with disciplines, pedagogical knowledge and technological knowledge. Those not translated from the original test did not include, we believe, a sufficient dimension value. For example, the TPACK provides a test item "My ability to distinguish between correct and incorrect problem solving attempts by students in order to test the relationship involved in Pedagogical Content Knowledge. As we altered the term 'content' to 'discipline', in order to integrate DPK with the TPACK model, and adapt it to university teachers, this item does not put enough emphasis, we believe, on discipline. We therefore formulated new items based on our interpretation of the components of the Berthiaume DPK". (2007b).

Thus, the six relations (PE, TE, TD, TP, PD, and TE) and the four dimensions (T, D, P and E) are each tested with two or three items. Questions on the Technology aspect were used to evaluate the teachers' technical and computer knowledge. Specifically, is the teacher able simply to use technology, can they adapt to new technologies, or are they able to assist others in using technology? Discipline specific questions assessed the influence and importance of disciplinary concepts on a teacher's style. At the university, faculty staffs are both creators and innovators. Discipline specific knowledge is therefore of great importance. We therefore chose to examine how teachers create, sequence, and organize the concepts involved in their discipline. The questions on the pedagogical dimension tested teacher's ability to vary their teaching practices, and to take account of individual learners' needs. Finally, the personal epistemological knowledge dimension assessed the influence that teacher's beliefs about how knowledge is constructed have on the subject taught. In these questions, we made reference to epistemological obstacles, and to mind maps about the content.

Teachers are asked to answer the question "How would you rate your ability to perform the tasks listed below, related to teaching?". The answers are scored using a Likert scale consisting of five levels (1 = poor, 2 = satisfactory, 3 = adequate, 4 = good, 5 = excellent). We have not carried out the validation of items that can combine three dimensions (PDE, TDE, TPD and TPE). Indeed, we found that the wording of these items was very complex and we have enough information to be able to judge the existing relationships.

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Table 1: Items TPDK

How would you rate your own knowledge in doing the following tasks associated with teaching in a distance education setting?" Likert-type scale (1 = Poor, 5 = Excellent)	
T	(1) Ma capacité à résoudre les problèmes techniques liés au matériel (par exemple, les connexions réseau). My ability to troubleshoot technical problems associated with hardware (e.g., network connections). (2) Ma capacité à traiter diverses questions liées aux logiciels informatiques (par exemple, le téléchargement plugins pertinence, l'installation de programmes). My ability to address various computer issues related to software (e.g., downloading appropriate plug-ins, installing programs). (3) Ma capacité à aider les étudiants à résoudre des problèmes techniques avec leurs ordinateurs personnels. My ability to assist students with troubleshooting technical problems on their personal computers.
D	~~(4) Ma capacité à créer des outils qui répondent aux spécificités et normes dans ma discipline~~ ~~My ability to create materials that map to specific district/state standards.~~ (5) Ma capacité à décider de la portée des concepts enseignés dans ma classe. My ability to decide on the scope of concepts taught within in my class. (6) Ma capacité à planifier la séquence des concepts enseignés dans ma classe. My ability to plan the sequence of concepts taught within my class.
P	(7) Ma capacité à varier les méthodes pédagogiques My ability to vary my teaching methods (8) Ma capacité à tenir compte de la manière dont on apprend en général pour guider mon enseignement My ability to reflect on how we learn in general, in order to guide my future teaching (9) Ma capacité à ajuster la méthodologie d'enseignement basée sur la performance/réaction des élèves. My ability to adjust teaching methodology based on student performance/feedback.
E	(10) Ma capacité à organiser différents savoirs les uns avec les autres My ability to organize different types of knowledge with each other ~~(11) Ma capacité à élaborer de nouveaux savoirs~~ ~~My ability to develop new knowledge~~ (12) Ma capacité à relever les obstacles épistémologiques dans les processus de construction d'une connaissance My ability to meet the epistemological obstacles in the process of buildingknowledge
PD	(13) Ma capacité à guider l'apprentissage des étudiants par des illustrations disciplinaires. My ability to guide student's learning by disciplinary illustrations. (14) Ma capacité à produire des plans de cours adapté au champ disciplinaire My ability to produce lesson plans adapted to the disciplinary field (15) Ma capacité à adapter mes méthodes d'enseignement aux pratiques véhiculées par la profession My ability to adapt my teaching practices to the standards promoted by the profession
TD	(16) Ma capacité à illustrer des pratiques disciplinaires au moyen des technologies. My ability to illustrate disciplinary practices through technology. (17) Ma capacité à choisir des environnements techniques les plus adaptés pour ma discipline My ability to choose the most suitable technical environments for my discipline (18) Ma capacité à me référer à la culture disciplinaire dans l'usage des outils informatiques My ability to refer to the disciplinary culture in the use of IT tools
TP	(19) Ma capacité à créer un environnement en ligne qui permet aux élèves de construire de nouvelles connaissances et des compétences My ability to create an online environment that allows students to build new knowledge and skills (20) Ma capacité à mettre en œuvre des différentes méthodes d'enseignement en ligne My ability to implement different online teaching methods (21) Ma capacité à encourager l'interactivité entre les étudiants en ligne My ability to encourage interactivity between students online
PE	(22) Ma capacité à adapter les méthodes d'enseignement en fonction de ce que je sais des obstacles et difficultés dans la construction d'un savoir My ability to adapt teaching methods based on what I know of the obstacles and difficulties in the construction of knowledge (23) Ma capacité à aider les élèves à remarquer les liens entre différents concepts dans le programme d'études. My ability to help students to notice the connections between different concepts in the curriculum. (24) Ma capacité à guider l'apprentissage des étudiants en fonction de ce que je sais sur la construction des savoirs My ability to guide student learning based on what I know about how knowledge is built
DE	(25) Ma capacité à organiser les savoirs dans ma discipline My ability to organize knowledge in my discipline (26) Ma capacité à lier mon rapport au savoir avec les conceptions disciplinaires par rapport à ce savoir My ability to link my report to the discipline specific knowledge, with designs based on different knowledgetypes (27) Ma capacité à déterminer dans ma discipline les modes de construction de connaissances My ability to determine my discipline's main modes of knowledge construction
TE	(28) Ma capacité à utiliser des technologies appropriées à la construction d'un savoir My ability to use appropriate technology to build knowledge (29) Ma capacité à mettre en œuvre des parties de mon programme dans un environnement en ligne My ability to implement parts of my program in an online environment (30) Ma capacité à choisir des outils technologiques (représentations variées) en lien avec ma perception sur la manière d'apprendre un savoir My ability to choose technological tools (of various types), which connect with my perceptions on how to gain knowledge

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We validated the test with a pilot group to verify that the items measure what they should, and with a large group of teachers, in order to check the consistency of groupings of items.

Validation

We proceeded to complete the questionnaire in two steps:

1. a validity analysis with a pilot group;
2. an analysis of the consistency of the items.

Analysis of validity with a pilot group

To ensure that the questions measure what they should, and are usable in this state; we increased the grid by four teachers at the university level. On many occasions we already understood their technological and educational profiles. We have deliberately chosen four very different profiles in relation to the use of technology. This pilot group has been selected to ensure (i) the layout of the questions (are they clear and easy to understand?) and (ii) the scope of the profiles (are they good for make an individual picture?).

This group includes:

- Professor A, a professor of Germanic languages for management engineers for 15 years. He does not use technology except when forced to through his collaborations with other teachers (he has to use the same course materials as all other teachers in his unit). He does not use online courses. He does not follow technology-related courses. He has been involved in teacher training.
- Professor B, a teacher at the school of engineering for the last 12 years. He has no online courses and he has never taken technology-related training. His school does provide teacher training. In his classes, he uses slides and numerous illustrations. He records podcasts from his course in their entirety (without editing).
- Professor C, a teacher in political science for the last 7 years. He has begun teaching online (he has one year of experience). He has already undergone training related to e-learning. He learned how to develop scenarios in his courses with an academic advisor.
- An assistant, D who has taught statistics for 8 years. His subject has several online courses. He attended educational and technological training. He recently completed a master's degree in university Pedagogy. He develops specific computer interfaces to guide student learning. He is interested in epistemological obstacles in learning.

The four teachers surveyed were able to answer almost all questions. Sometimes there was a reluctance to answer (particularly on items 16, 18, 24 and 28), but without consequence to the results. Professor B had more difficulty than others in understanding the concept of "technology" in the questions. This concept is also used in engineering, with another meaning.

The rank 1 analysis (Table 2) shows the percentage that the technological dimension takes up in the teachers' profiles, in relation to other dimensions. A and D have two contrasting profiles. Both believe both they have good disciplinary, pedagogical and epistemological qualities, but A does not have technological knowledge, whilst D has attained an excellent level of mastery in the technological aspect.

Rank 2 leads to further comment. For example, teacher B has greater links between discipline and the way in which he perceives components of knowledge to be constructed (DE). Similarly, the way in which he sees certain content to be constructed strongly influences his teaching activities (PE). A foundation in epistemology (beliefs about knowledge and ways of learning)

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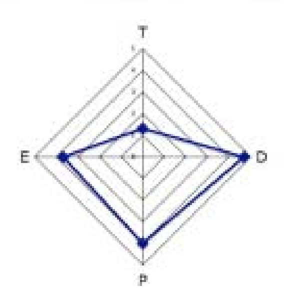
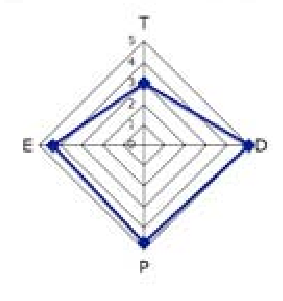
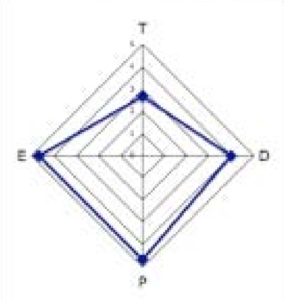
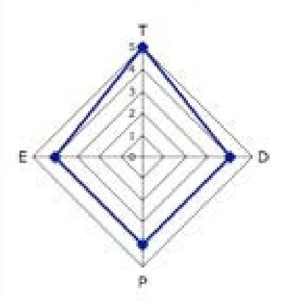
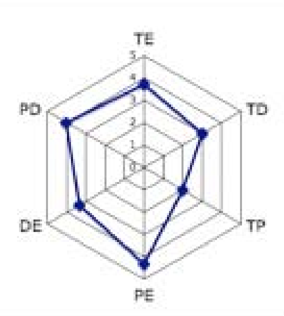
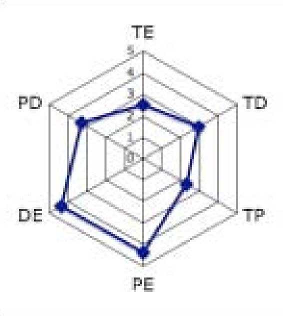
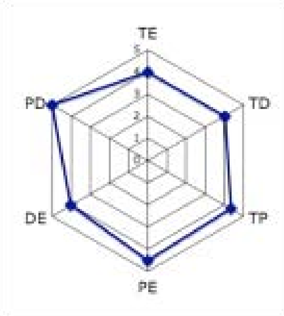
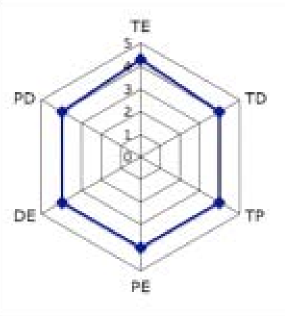
dominates in his profile. We see that he uses technology, but it does not necessarily result in a change to his teaching decisions.

Table 2: Validity analysis with a pilot group

A	B	C	D
			
			

Profile C showed the same sense of technological competence as B. However he makes more links between the technological dimension and pedagogy (TP). Of the four teachers interviewed, he is also the only one who has followed a process of storyboarding and e-learning.

The TPDK profiles developed through the questionnaire's 28 items seem to show what it is we already knew about these teachers.

Consistency analysis

In accordance with Czaja and Blair (2005): "The reliability of data obtained through survey research rests, in large part, on the uniform administration of questions and their uniform interpretation by respondents" (p.73), we placed the questionnaire on LimeSurvey and submitted it to 150 university and non-university teachers in our institutions of work. A Cronbach's alpha was calculated for each dimension to ensure that the grouping of items was consistent in dimensions.

Unfortunately, we only received a limited number of responses. We were expecting 150, but at final count there were only 55 respondents. Based on the responses, we have removed two items (4: "My ability to create tools that meet the specifications and standards in my field" and 11: "My ability to develop new knowledge") so that the dimension is as close as possible to limiting 0.71 reliability with the Cronbach index. For relationship DE, the index remains low (alpha = 0.639), however, it is presented here with the value of the highest reliability. The removal of an item weakens the score.

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Table 3: Alpha de Cronbach

Dimensions	Items	Responses N= max 55	Cronbach's Alpha
Technology (T)	3	52	0,923
Discipline (D)	2	35	0,760
Pedagogy (P)	3	51	0,799
Epistemology (E)	2	33	0,737
PD	3	25	0,703
TD	3	38	0,878
TP	3	42	0,872
PE	3	41	0,745
DE	3	27	0,639
TE	3	40	0,891

For other dimensions, the three items developed showed good internal consistency with close to or above 0.71 alpha.

According to the average of the results for different dimensions, we conducted a Pearson's test (Table 4). The analysis of linear correlation coefficients, Bravais-Pearson, also shows some interesting significant positive correlations. We note positive correlations with a star (*) when the correlation is at or below the 0.05 level. We note two stars (**) when the correlation is at or below the 0.01 level.

Discipline is strongly positively correlated with education (r = 0.489 **) and epistemology (r = 0.533 **). In other words, according to our test, when a teacher makes a disciplinary choice, it is in line with his belief in the construction of knowledge and what he knows about pedagogy. EDP seems generally highly significantly related. At this level, the work of Archambault and Crippen (2009) also showed strong positive correlations between content and pedagogy (r = 0.690 **). The addition of the epistemological dimension in Berthiaume's model (2007b) seems relevant when we note the positive and significant correlations between discipline and education.

The dimension of technological knowledge appears to be linked to the educational dimension (r = 0.274 *). It is not related to the discipline (r = 0.028), in contrast to Archambault and Crippen's (2009) study, and is not significantly associated with personal epistemology. Pedagogical knowledge is significantly correlated with all dimensions.

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Table 4: Correlations among subscale variables for the question: "How Would You Rate Your Own Knowledge in Doing the Following Tasks Associated with a Distance Education Setting?"

	T	D	P	E	PD	TD	TP	PE	DE	TE
T	-									
D	NS	-								
P	0.274*	0.489**	-							
E	NS	0.533**	0.491**	-						
PD	NS	NS	0.484**	0.537**	-					
TD	0.641**	NS	0.359**	0.315*	NS	-				
TP	0.559**	NS	0.482**	NS	NS	0.658**	-			
PE	NS	0.413**	0.552**	0.718**	0.462**	0.344*	NS	-		
DE	NS	0.487**	0.354*	0.704**	0.325*	NS	NS	0.638**	-	
TE	0.528**	NS	0.483**	NS	NS	0.694**	0.773**	NS	NS	-

*: correlation is at 0.05 level,
**: correlation is at 0.01 level,
NS: no significant correlation.

In other words, we may suggest that knowledge technologies are meaningful only if they are associated with pedagogical knowledge. Note also that all relationships include technological dimensions: TE, TD and TP are never correlated significantly with discipline.

Discussion

Relationships between the four dimensions are presented (Figure 6) in order to validate the Berthiaume DPK model (2007b), which showed a relationship between pedagogical knowledge, personal epistemology and discipline among teachers teaching higher level education. It also validates the basis of Shulman (1986) and Lenze's (1995) research, which associated discipline and pedagogy. Finally, it also validates the link between pedagogy and technology, present in the work of Lebrun (1999; 2002b; 2005; 2007).

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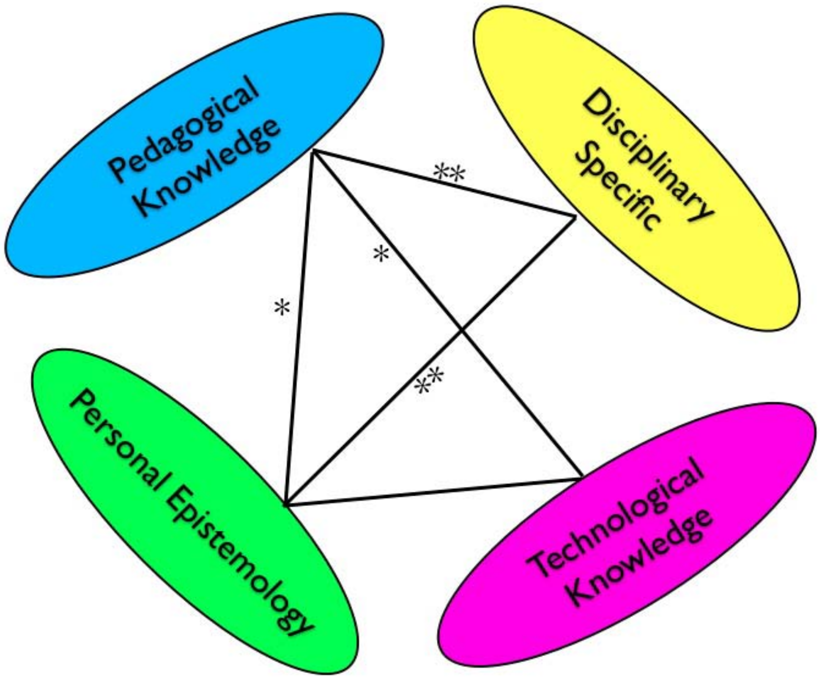

Figure 6. Correlations between the four dimensions

In contrast, we do not find direct links in our study between technological knowledge and discipline. However, analysis of the results (Figure 7) shows more complex relationships. We see that discipline is closely related to the relationship between pedagogy and epistemology (PE), but when this is associated with another dimension in the profile of teacher's technologies(TE, TD, TP), there are then significant relationships with the teaching-discipline (PD) links.

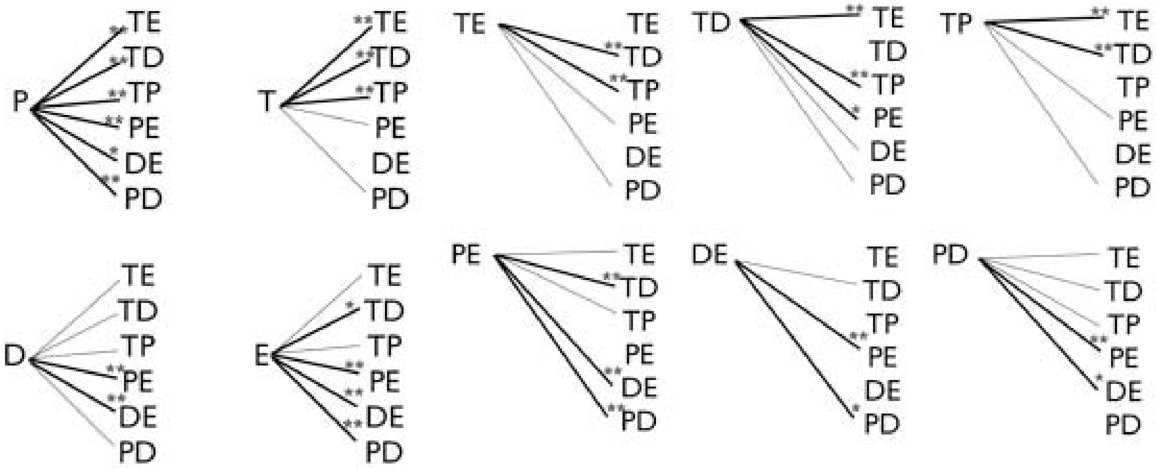

Figure 7. Correlation between dimensions
* significative correlation
** higher significative correlation

When a teacher feels competent in the technology associated with their discipline (TD dimension), it influences their educational choices (r = 0.359 **) and, to a lesser extent (we observe a lower, significant, correlation), their epistemological choices (r = 0.315 *). Moreover, if the teacher feels competent in their technological choices, according to their epistemological beliefs (TE), a fairly strong correlation is created with the educational dimension (r = 0.483 **), but also with other combinations, such as TD (r = 0.694 **) and TP (r = 0.773 **). The presence

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of the positive and significant correlation between PE and TD (or four dimensions) suggest that the dimensions are related, but the T dimension would only be linked through association with another dimension. Correlations could be explained through links with the educational dimension and other dimensions.

Like the work of Archambault and Crippen (2009), we find a strong correlation (0.658 **) between the technology-discipline (TD) and technology-pedagogy (TP) interaction. They suggest that this confirms that there are many links between these dimensions (discipline and technology), and that there are no distinct areas. The redundancy of the T dimension in this correlation can be discussed. One way to check the actual correlation between TD and TP would develop psychometric tests to check how well the associated TD can be compared to T associated with P.

Limitations

This survey is limited by its questions and scale. We are conscious that Internet surveys have disadvantages. We don't have personal contact with the teachers and we collected only 55 responses (70% of all persons concerned). This limitation restricts us in our ability to generalize the results. Accordingly, it should be noted that the statement of the results of this study reflects a sample of only 55 teachers online, and does not therefore necessarily reflect the population as a whole.

Another limitation of this study is that our survey research is composed of a self-report, instead of a measure of observable behaviour. Our plan is to later use this tool in a combined self-report and observation.

Finally, additional validation of the items used to measure the TPDK framework would be beneficial. These questions are still in need of more extensive and thorough validation measures. This validation could be achieved through the definition of items about personal epistemology.

Conclusion

The disciplinary pedagogical knowledge model (DPK) helps to explain why a teacher of the university offers some educational activities rather than others, with reference to his teaching skills, personal epistemology and discipline. Based on Berthiaume's reflections (2007b) we found the Shulman model (1986) and Lenze's work (1995). The Shulman pedagogical content knowledge (PCK) model proposes to relate disciplinary content knowledge with pedagogical knowledge. Lenze (1995) reinterpreted the term "content" to 'discipline', in order to more accurately reflect the teaching situation at a university. From these models, Berthiaume added personal epistemology and proposed a model for encoding the relationships that teachers express verbally during a semi-structured interview. This tool is a real help to the school counsellor who can better understand what references a teacher uses when he puts forward his teaching strategies. Nevertheless, the model is relatively complex to use and it does not refer to technological knowledge. Mishra and Koehler (2006) proposed a theoretical model that incorporates a technological dimension into Shulman's initial theoretical representation. Based on this new model, and technological pedagogical content knowledge (TPACK), Archambault and Crippen (2009) developed a model based on a survey to analyze the relationships (correlations) between the different dimensions of the TPACK model tool. Their research aimed to validate the theoretical model.

Building on these studies, the **Techno-Pedagogical Disciplinary Knowledge** model that we propose integrates many of the different dimensions found in the previous research. It combines four dimensions: discipline (D), personal epistemology (E), pedagogical knowledge (P), and

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technology (T) and recognizes that the relationships between these components may be more or less strong, based on individual teachers' profiles. These dimensions are present in all teachers' profiles, but they do not necessarily always have the same relevance.

To determine the different teacher profiles which we intend to represent with radar, we have developed a survey. Different items have been proposed to test each dimension, along with the relationship between these dimensions (DE, TE, PE, TP, TD, and PD). The items were constructed from Archambault and Crippens' (2009) study and based on the definitions of the dimensions in the studied theoretical models. The survey was subject to a first validation to check that the questions were understandable, and that the patterns that emerged were faithful to the characteristics that we knew of the teacher-witnesses. A second validation was performed based on the responses of 55 teachers, of both university and non-university higher educational institutions. Our objective was to analyze the consistency between groups of items and the correlations between the different dimensions of the model. It appears that the pedagogical knowledge dimension is significantly correlated with the other three dimensions (technological knowledge, personal epistemology and discipline). Correlations also confirmed three previous findings:

1. The numerous works of Lebrun (2002b, 2007, 2012), which put forward the idea of a relationship between pedagogy and technology. We can prove this link through the higher educational teachers' responses.
2. Berthiaume's research (2006, 2007b), which reintroduced the importance of personal values and references for the construction of knowledge in the dynamics of the DPK. We also show that teachers associate this dimension (E) not only with pedagogical knowledge, but also with their discipline. This validates the DPK model.
3. A long term educational assumption that there is a strong link between discipline/content and pedagogical knowledge. This echoes the work of Lenze (1995) and Shulman (1986). We find a positive and highly significant correlation between these two dimensions.

Moreover, it is clear that in this model the role of technological knowledge makes sense only where there is pedagogical knowledge. Indeed, technological knowledge is not correlated with discipline, and not significantly with personal epistemology. In contrast, as they are associated with the pedagogy (TP), they show a strong correlation with the technology-epistemology relationship (TE $r = 0.773$ **), and the latter is also strongly related to the technology-related discipline (TD $r = 694$ **). At this level, we discussed the systematic presence of the technological dimension in these three relations. A psychometric study of the items would help to show whether there is in fact any valid link.

In future research, these results will be discussed as potential avenues for the explanation of teachers' techno-pedagogical development.

The analysis involved in the TPDK profile seems to bring to light important elements, which can help to guide academic advisor's in their activities. In discussions with teachers, the pedagogical counsellor will therefore be able to better focus their presentation tools or methods, based on the teacher in question.

The tool-model that we propose (the TPDK) is a system which will benefit from further research. The validation tests are encouraging, but it is only in its practical use that we can assess its scope. The items on the relationship discipline-epistemology may well need to be revised. Cronbach's alpha was lower (0.7 in) for this relationship. We have, however, maintained this relationship, because we felt it was important to test it further with more teachers. In addition, the test has been validated in a High School that offers courses at both university and non-

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university level. It is questionable whether we would have received the same results using a faculty composed solely of members of the university.

This study also shows that there is a techno-pedagogical correlation. Pedagogical knowledge and technological knowledge showed a clear link in the correlation test.

Finally, the tests carried out encourage us to offer this tool to other school counsellors for further testing and discussion, which has not been possible up to this point. Improvements can therefore be made based on the feedback from practitioners. We believe that we now have a tool that would allow better understanding of teachers' educational strategies. Using these elements, it will now be easier for us to address teaching methods and tools involved in the e-learning platform.

This new model is the first tool to allow advisors and university teacher trainers to better understand teachers' strategies, particularly with regard to technology. It allows the references that dominate a teacher's profile to be quickly read. With the rapid development of online courses, it is important that the pedagogical and technological areas be merged. To this end, we propose this model.

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