OPEN ACCESS
EURASIA Journal of Mathematics Science and Technology Education
ISSN 1305-8223 (online) 1305-8215 (print)
2017 13(3):601-620
DOI 10.12973/eurasia.2017.00635a

Behavioural Intention and Pre-Service Mathematics Teachers' Technological Pedagogical Content Knowledge

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Received 19 November 2015 ▪ Revised 8 January 2016 ▪ Accepted 10 February 2016

ABSTRACT

Teachers' beliefs, together with sound technological pedagogical content knowledge (TPACK), are directly related to the effective integration of technology in mathematics teaching. This study explored the relationship between pre-service teachers' behavioural intention to use technology to teach mathematics and their TPACK. A case-study analysis was conducted to determine whether six pre-service teachers' behavioural intention to use technology in their classroom delivery was associated with a predominance of TPACK (the TPACK model component) in their choice of technology-supported mathematical tasks. The findings showed a considerable disconnect between pre-service teachers' behavioural intention and their technological pedagogical content knowledge. Even where they expressed favourable intentions, the type of knowledge they called into play when selecting technology-supported tasks was unrelated to TPACK and did not suffice to identify the educational potential of technology. An emphasis on TPACK, in conjunction with the development of favourable attitudes toward the use of technology, is therefore believed to be indispensable in pre-service teacher education programmes.

Keywords: behavioural intention; pre-service mathematics teacher; technological pedagogical content knowledge (TPACK); technology integration; Theory of Planned Behaviour (TPB).

INTRODUCTION

Although technology was first introduced in classrooms three decades ago, many obstacles still prevent it from having a significant impact on teaching practice (Hoyles & Lagrange, 2010; Ranguelov, Horvath, Dalferth & Noorani, 2011; Isac, da Costa, Araújo, Calvo & Albergaria-Almeida, 2015). Several are the causes for this scant use of technology. Focusing on teachers'

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State of the literature

- Teachers' beliefs generate resistance to the use of technology in mathematics teaching Technological pedagogical content knowledge (TPACK) is essential to determining the cognitive potential of technology-supported tasks, although future teachers find it difficult to develop this knowledge component.
- Teachers' beliefs, together with sound TPACK (technological pedagogical content knowledge), are directly related to the effective integration of technology in teaching Further studies are needed to understand the inter-relationships between the affective and the cognitive approaches.

Contribution of this paper to the literature

- This study explores the relationship between pre-service teachers' knowledge of technology and their behavioural intention to use technology to teach mathematics.
- A case-study analysis was conducted to determine whether the six pre-service teachers' behavioural intention to use technology in their classroom delivery was associated with a predominance of TPACK in their choice of technology-supported mathematical tasks.
- The findings showed a sizeable disconnect between pre-service teachers' behavioural intention and their technological pedagogical content knowledge. Even where they expressed favourable intentions, the type of knowledge they called into play when selecting technology-supported tasks was unrelated to TPACK and did not suffice to identify the potential of technology.

concerns, these causes can be analysed from two complementary standpoints: affect and cognition.

From the affective perspective, teachers are conditioned by a number of factors. Their attitudes, beliefs and perception of their cultural context generate strong resistance to the effective integration of technology in teaching practice (Pierce & Ball, 2009; Kim, Kim, Lee, Spector & DeMeester, 2013; Hsu, 2016). In specific reference to mathematics classrooms, these studies showed that although the barriers perceived by teachers, globally speaking, are outweighed by the enablers that drive the use of technology, when perceived individually some of the former (such as the economic cost of technology or the lack of time to complete the syllabus) prevail in teachers' behavioural intentions. Morelock (2015) examined the connection between perceptions of teacher self-efficacy, professional development, leadership practices and attitudes in K-12 schools and the successful implementation of technology. He found that factors such as teachers' age and sex affected their perception of the implementation of technology and of opportunities for professional development. That pattern is visible on all educational levels and seems to be subject-specific. Isiksal-Bostan, Sahin & Ertepinar (2015) showed that Turkish elementary school science and mathematics teachers' professional experience induced negative beliefs about technology-enhanced teaching. Baydasa & Goktasb (2016) found that pre-service mathematics and Turkish language teachers were least and pre-service English language and science teachers most predisposed to use technology in future lessons.

From the cognitive perspective, teachers' knowledge also plays an essential role in their decisions about technology. Although the technology presently available is accessible and easy to use, its application to teaching and learning may be complex. The Technological Pedagogical Content Knowledge model (TPACK: Mishra & Koehler, 2006) has been profusely applied as a theoretical framework in educational research on teachers and as a model to organise curricula for training teachers to use technology (Chai, Koh & Tsai, 2013; 2014). In the specific case of pre-service education, future teachers have been observed to encounter difficulties in establishing consistent relationships between technological and pedagogical factors. Ideas have consequently been put forward to help them integrate the two types of knowledge (Koh, Chai & Tsai, 2010; Karaka, 2015).

Several authors have attempted to inter-relate the two perspectives, cognition and affect. In the specific case of pre-service teachers, relationships have been established between TPACK model components and some types of beliefs (see Crompton (2015) for a review of the literature on pre-service teachers' TPACK and beliefs on the use of technology in secondary mathematics classrooms). Individual beliefs held by pre-service teachers with a sound understanding of TPACK (the component of the TPACK model, hereafter TPACK) are known, for instance, to condition the manner in which that knowledge is expressed in the classroom (An & Shin, 2010). In practice, pre-service teachers' beliefs on the nature of knowledge and on the most effective approaches to teaching are related to their deployment of technology, although the causality of such relationships is unknown (Abbitt, 2011; Keser, Yılmaz & Yılmaz, 2015; Kramarski & Michalski, 2015). Moreover, even when pre-service teachers profess a favourable attitude toward the classroom use of technology, they must develop suitable knowledge components to be able to benefit from this resource (Waspe, 2014). These findings can be supplemented with analyses of the ways in which pre-service teachers' knowledge of the cognitive benefit of technology relate to their intention to actually use technology in the classroom. Information is needed, for instance, on whether pre-service teachers' lack of a given type of knowledge co-exists with an adverse attitude toward technology or whether behavioural intention entails pre-service teachers' valid application of knowledge when making educational decisions around the use of technology.

This study focuses on pre-service mathematics teachers' intention to use technology, analysed using the psychological-social Theory of Planned Behaviour (TPB: Ajzen, 1991). TPB and its subsequent development have proven to be useful for identifying teachers' predisposition to use technology in the classroom (Pierce & Ball, 2009; Lee, Cerreto & Lee, 2010; Waspe, 2014; Teo & Milutinovic, 2015). Besides, we relate teachers' behavioural intention to more cognitive information. Teachers' design or choice of mathematical tasks constitutes one of the pre-service educational contexts that furnishes relevant information on the knowledge from which they draw when determining the cognitive potential of technology-supported tasks (Mistretta, 2005; Schultz, 2009). This professional context was consequently used here to explore the TPACK knowledge components mobilised by pre-service teachers.

The two types of data are analysed qualitatively to determine the existence or otherwise of relationships between the TPACK knowledge components underlying pre-service teachers' choice of technology-supported mathematical tasks and their intention to apply technology to teach mathematics. The aim is to identify the attitudes and knowledge components that would ensure an optimal choice of tasks from the standpoint of the cognitive benefit provided by technological resources. Case studies involving six pre-service mathematics teachers have been conducted to that end. The findings may prove useful for planning formal pre-service teacher training.

The paragraphs that follow set down the theoretical references that guided the research and describe the focal points of the study. The specific technology deployed is subsequently discussed, with a detailed explanation of the methodology, data collection tools and data analysis. A qualitative interpretation of the findings is then used to draw by the respective conclusions.

THEORETICAL FRAMEWORK

In the psychological-social Theory of Planned Behaviour (TPB: Ajzen & Fishbein, 1980; Ajzen, 1991), behavioural intention is described as persons' motivation to adopt a given behaviour and as the key factor for predicting whether they will in fact do so. Behavioural intention is determined through three dimensions: attitude to behaviour, subjective norm and perceived control of behaviour. Pierce & Ball (2009) adapted these three TPB dimensions to the field of technology-supported mathematics teaching. Mathematics teachers' attitude toward applying technology in the classroom reveals their favourable or unfavourable opinion of that type of teaching. The belief that this form of teaching enhances students' understanding would constitute a favourable attitude, for instance. Subjective norm refers to environmental pressure for or against a given type of classroom resources: pressure may be exerted, for instance, by peers or parental expectations around the use of such resources. Perceived control of behaviour is shorthand for teachers' perception of the factors that facilitate or obstruct the use of technology in mathematics teaching, as in their perception of their own command of technology or the cost of this type of resources. All three dimensions may be assessed favourably or unfavourably. Pierce & Ball (2009) observed that the more positive the attitude, the greater teachers' perception of pressure in favour of use and the more facilitating factors perceived, all of which led to the more consistent use of technology in the classroom.

From the standpoint of teachers' knowledge, the TPACK[1] model defines seven knowledge components that are involved in the effective classroom use of technology (Mishra & Koehler, 2006). These components derive from content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK) taken separately and from the forms of knowledge generated where they overlap: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK). While all the model components are important, the seventh, TPACK, is regarded as essential to the effective application of technology in teaching. It highlights the integration of the content to be conveyed, the respective teaching processes and the use of technology in this context.

RESEARCH QUESTIONS

Under the assumption that the affective and cognitive dimensions are related, the following questions were posed:

- Is pre-service teachers' intention to deploy technology in the classroom related to a prevalence of TPACK in their thought processes when choosing technology-supported mathematical tasks?
- Which dimensions of behavioural intention and which knowledge components are associated with an optimal choice of tasks from the standpoint of the use of technological resources in teaching?

In the study conducted to find the answers, TPB was used to determine the intention expressed by six pre-service secondary school mathematics teachers to integrate technology in mathematics teaching. The TPACK model was then applied to ascertain whether these pre-service teachers were able to assess the suitability of technology in certain exercises. Specifically, the study revealed which knowledge components they expressed when choosing between two similar mathematics tasks, only one of which entailed the use of technology, and whether those components led them to choose the most suitable tasks.

WHAT TECHNOLOGY?

The questions analysed in this study called on the one hand for reviewing technology from a general perspective and on the other for defining exactly and in detail what technology was considered.

The general perspective was necessary to assess pre-service teachers' behavioural intentions. These were gleaned from teachers' general perception of technological resources. Teachers develop these ideas based on their personal experience with technology, which may

[1] The initials TPACK are often used to mean two separate but related notions: the *TPACK model* is a seven-component knowledge model, while one of those component is denominated the *TPACK component*. This paper adheres to that terminology, referring to the former as the TPACK model and, for reasons of simplicity, to the latter as TPACK.

vary widely from one person to another. In this study behavioural intention was assessed in terms of each teacher's general perception of technology.

The detailed perspective was necessary to determine the knowledge deployed by teachers when reaching specific decisions on the application of technological tools in the mathematics classroom. Here the focus was on the use of interactive applets integrated in the descriptions of mathematical tasks. For reasons of linguistic simplicity, the term ICT-task is used hereafter to mean a mathematical task involving the use of an interactive display with graphic or symbolic representation systems or both. From a cognitive standpoint, ICT-tasks encourage students' active role in their own learning, pose questions that involve students in mathematical reasoning and help materialise abstract mathematical objects, thereby providing valuable support for students' reasoning. From the teachers' perspective, the effective use of technology in teaching mathematics needs to explicitly focus on the use of multiple representations (Ozmantar, Akkoc, Bingolbali, Demir & Ergene, 2010). **Figure 1** illustrates an ICT-task. In it, questions are posed on the interpretation of the graphic representation of functions in the context of objects in motion. To reply, students would interact with the MathWorlds applet (http://www.kaputcenter.umassd.edu/products/software/smwcomp/download) that graphically and dynamically represents the motion of two fish and features an option for symbolic and tabular representation.

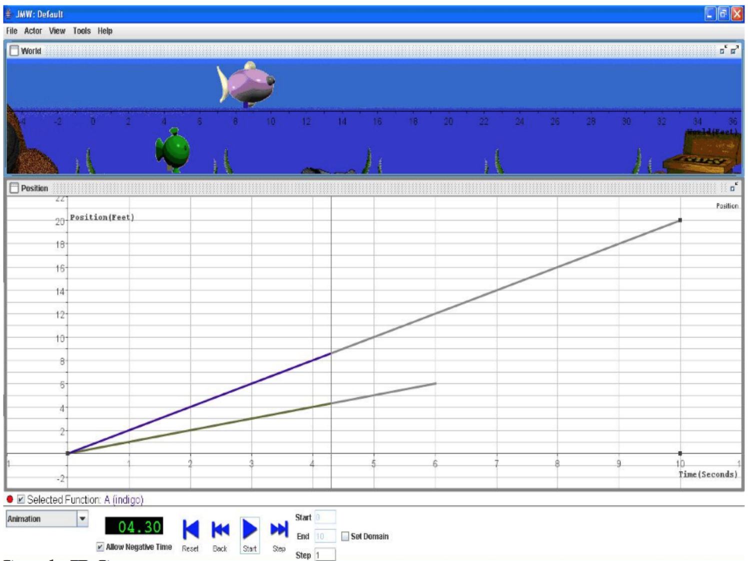
MathWorlds task

This MathWorlds display contains graphs showing the position of two fish that live in the sea depicted at the top.

a) Do the two fish reach the same end point? Does it take them the same amount of time? Do they travel the same distance?

b) What do the different slopes on the graphs mean?

c) In what way(s) does the motion of the two fish differ?



http://wikis.lib.ncsu.edu/images/0/0d/2nd_Graph.JPG

Figure 1. Example of ICT-task

METHODOLOGY

The methodology applied, based on systematic exploration with multi-data, was designed to interpret persons' assessments in a singular context, i.e., case studies. This type of methodology is suitable for exploring teachers' knowledge as defined in the TPACK model (Koehler, Shin & Mishra, 2011). While TPB is initially a theory adapted to quantitative analysis, it has also been widely applied for qualitative studies such as here (Renzi & Klobas, 2008). **Figure 2** summarizes the methodology used, which is described in greater detail in the sections below.

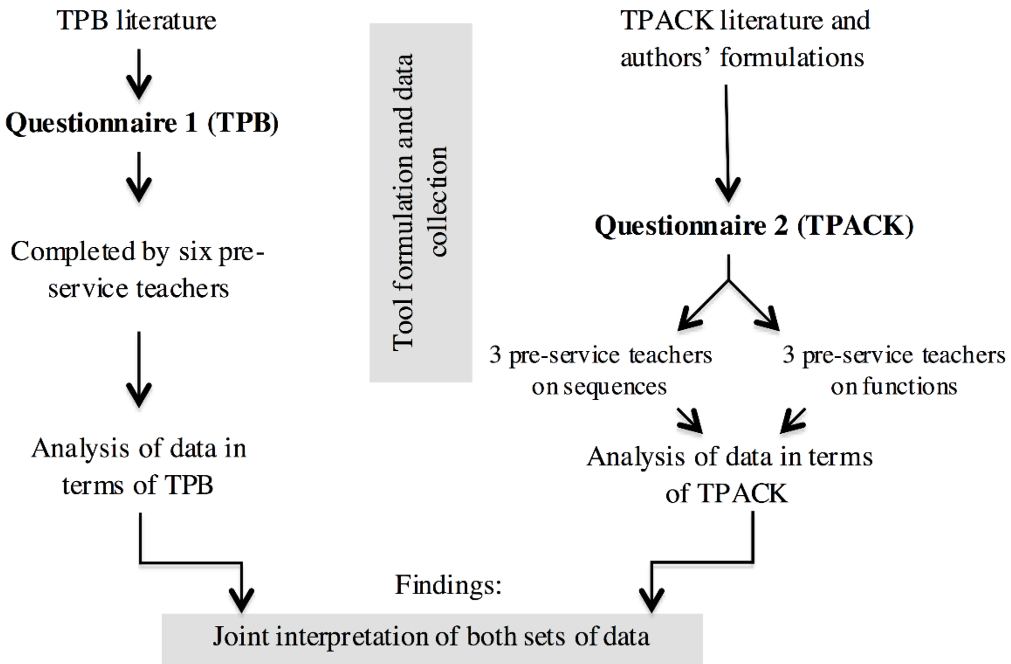


Figure 2. Outline of methodology deployed

Participants

The participants in these case studies were six pre-service mathematics teachers pursuing a master's degree in secondary school teaching in a Spanish public university. This degree is mandatory for anyone aspiring to teach secondary school in Spain. Participants had acquired their mathematical background during their undergraduate university education. Their teacher training was confined to what they were taught in the aforementioned master's course. They participated in this research approximately midway through the course. At that time, they had not yet trained specifically on how to apply technology to mathematics teaching. They all made routine personal use of technology and some had also acquired professional experience, but not in education.

Data collection instruments

The two questionnaires used in this study are described below.

Questionnaire 1 to collect data on pre-service teachers' behavioural intention

A review of the literature on TPB questionnaires led to the selection and adaptation of the six items listed in **Table 1**, which constituted questionnaire 1. These items, drawn from the questionnaire used by Pierce & Ball (2009), were adapted to the present purpose. All six were open-answer items in which the pre-service teacher could list his perceived advantages and drawbacks of technology-supported teaching. A priori, these items were associated with the three TPB dimensions, as shown in the second column in **Table 1**. However, the wealth of detail furnished by pre-service teachers in their responses translated into information on the three TPB dimensions in all the items, as discussed in the results section.

Table 1. Items on questionnaire 1 and related TPB dimensions

Item	Related TPB dimension
1. What is your general opinion about the use of technology to teach mathematics?	Attitude
2. What resources would you normally use in a mathematics classroom (textbook, your own notes, other educational aids...)?	Attitude Subjective norm
3. Would you use technology routinely in the classroom?	Attitude
4. Would you be willing to use a technological resource that you yourself did not master?	Perceived control of behaviour
5. When do you feel students should use technology (calculators, computers...) in mathematics classrooms?	Attitude Subjective norm
6. What benefits and disbenefits of the classroom use of technology do you perceive for students?	Attitude Perceived control of behaviour

Questionnaire 2 to collect data on pre-service teachers' knowledge

The second data collection tool was a questionnaire formulated by the authors, designed to identify the knowledge deployed by pre-service teachers in a specific professional situation: the choice of tasks to teach a mathematics' lesson. This method of exploring decision-making among pre-service teachers in specific teaching situations has been successfully used by other authors to identify TPACK components (Niess, 2005; Burgoyne, Graham & Sudweeks, 2010).

Each item on questionnaire 2 listed two mathematical tasks that shared the same objectives, only one of which was an ICT-task. Pre-service teachers were asked to choose one of these tasks and explain their choice. Irrespective of the task selected, the choice and explanations given showed whether the pre-service teacher was able to identify the cognitive benefit provided by the technology associated with the task, a skill associated with the TPACK component. With these elements, the other knowledge components used by pre-service teachers in making their choice could also be identified.

The questionnaire consisted in three items, in each of which pre-service teachers were to choose one of two tasks. With a view to contextualizing the choice as far as possible, all three items referred to the same mathematics lesson and the questionnaire included an introduction with information on the imaginary academic scenario addressed: students' prior knowledge, task content and objectives and the manner in which tasks would be sequenced in the lesson. The structure of questionnaire 2 is shown in **Table 2**.

Table 2. Structure of questionnaire 2

Mathematics lesson		
Contextual information for the teacher		
Item 1	Choose between Task 1 and ICT-task 1	Explain choice
Item 2	Choose between Task 2 and ICT-task 2	Explain choice
Item 3	Choose between Task 3 and ICT-task 3	Explain choice

Questionnaire 2 was designed for use in two mathematical lessons, sequences and functions, for grade nine students (i.e., in their ninth year of schooling). Each lesson was the object of a separate questionnaire to determine whether the type of lesson affected pre-service teachers' explanations of their choices. The full questionnaires are available on https://dl.dropboxusercontent.com/u/26044058/ucnCUESTIONARIO_sucesiones_web.pdf https://dl.dropboxusercontent.com/u/26044058/ucnCUESTIONARIO_funciones_web.pdf

Both tasks in each set were designed to the same mathematical concepts and objectives, which were not necessarily covered more suitably by the ICT-task. In some, the applet either introduced unnecessary complexity or the alleged improvement was irrelevant to the task. On those grounds, the optimal selection was defined as follows: choosing the ICT-task was only optimal when the applet entailed a significant improvement in students' learning in the context of task performance; otherwise, the optimal choice was the non-applet task. The list of tasks in **Table 3** shows which applets improved the learning experience for the task at issue, and therefore constituted the optimal choice for each item.

Table 3. Assessment of applets in questionnaire 2 and optimal tasks' choices

		The applet made a significant improvement	Optimal choice
Sequences	Item 1	No	Task 1
	Item 2	No	Task 1
	Item 3	Yes	ICT-task 2
Functions	Item 1	No	Task 1
	Item 2	Yes	ICT-task 2
	Item 3	Yes	ICT-task 2

The first item on the sequence questionnaire is reproduced in **Figure 3** by way of example. The most prominent feature of the ICT-task applet in **Figure 3** is that it shows, very visually, how to deduce the formula for the sum in an arithmetic progression. This proof is highly intuitive, for students merely need to move the sliders to see it. This, however, is something not called for in the task. The applet's other features include showing the formula for the sum and sliders that save students from having to substitute the values in the formula. In the context of this task, however, students are supposed to show that they know the formula for the sum and are able to substitute the values properly. For those reasons, the optimal choice in this case was task 1. Pre-service teachers using the above explanation for choosing task 1 in this case would reveal technological pedagogical content knowledge (TPACK).

Pre-service teachers might, of course, draw erroneously or irrelevantly from their TPACK in light of the task at issue. That possibility was identified by indicating that the TPACK invoked by the teacher was inappropriate for the situation. For instance, in the above applet, a teacher might explain that as the sliders preclude the need for substituting the values in the formula, they facilitate the operations to be performed, without realizing that such a feature would actually be detrimental to task objectives.

Item 1. Which of the following two tasks would you choose to begin to teach the lesson on sequences? Explain your answer.

Task 1

On September 1st, a ninth year student decides to review mathematics for two weeks. To do so, she determines to do two more exercises each day than she did the day before. If she does one exercise on the first day:

a) How many exercises will she have to do on September 15th?

b) How many will she have done in all?

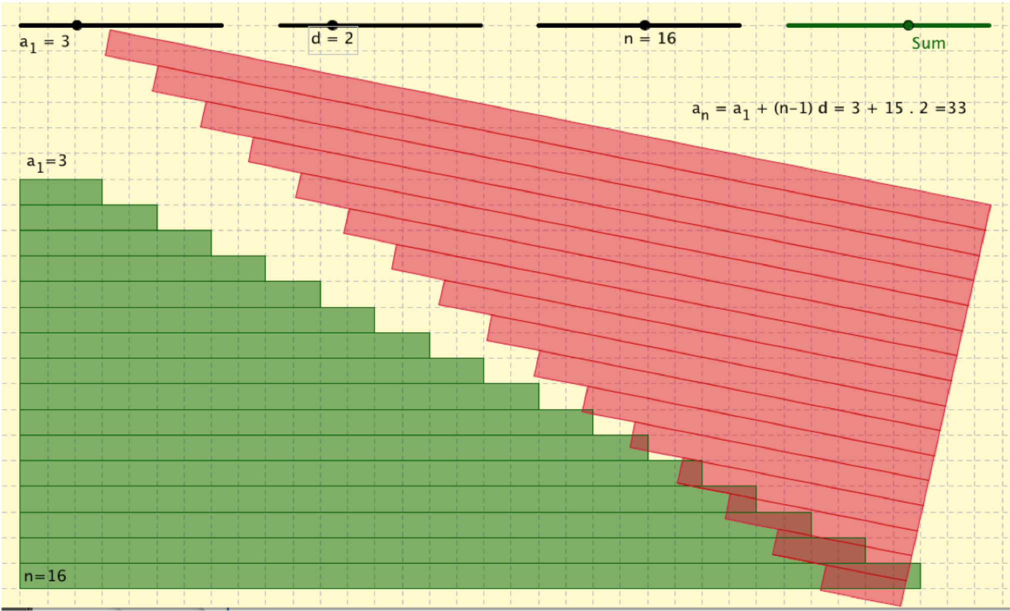
Task 2

A skier begins the pre-ski season lifting weights in a gym for one hour. He decides to increase his training by 10 minutes per day.

c) How long will he need to train after 15 days?

d) How much time will he have trained in all after 30 days?

The following applet can be used to solve this problem.



Use the sliders to set the first term, the difference and the number of terms. Then use the "Sum" slider to see how the sum was found.

Adapted from http://www.xente.mundo-r.com/ilarrosa/GeoGebra/Suma_progr_aritm.html

Figure 3. First item on the sequences questionnaire for a 9th grade

Questionnaire implementation

Pre-service teachers answered the two questionnaires consecutively. Each teacher was given an hour to complete first questionnaire 1 and then questionnaire 2. The data were collected anonymously. Three teachers chosen at random answered the sequences questionnaire and the other three the functions questionnaire. They were encouraged to explain their choices as fully as possible. The researcher responded to technical queries about the applets and teachers wishing to do so were allowed to work with them on the computer provided.

RESULTS

Pre-service teachers answered both questionnaires with detailed explanations. These replies were analysed under the criteria discussed below.

Data collected with questionnaire 1

To identify the three TPB dimensions in the pre-service teachers' replies to questionnaire 1, their answers were separated into phrases referred to some of the dimensions; interpretation was then based on the definition of the dimension itself. Since each TPB dimension has a favourable and an unfavorable interpretation (positive or negative attitude; perception of environmental pressure for or against; perception of factors that facilitate or obstruct), each phrase was also labelled as dimension-positive or negative.

Pre-service teacher 5 answered item 6, for instance, saying that technologies 'make mathematics more appealing and the problems easier to understand, but part of the meaning of the exercise may be lost'. That reply was separated into three phrases: (1) 'make mathematics more appealing'; (2) '[make] problems easier to understand'; and (3) 'part of the meaning of the exercise may be lost'. The three were interpreted to be associated with the attitudinal dimension of TPB, for the teacher referred to his belief in (1) in technology's ability to enhance student attitudes; and in (2) and (3) in its ability to improve/detract from students' understanding. Phrases (1) and (2) were classified as positive and (3) as negative.

This process yielded a list of phrases for each pre-service teacher associated positively or negatively with each TPB dimension. The findings are shown in **Figure 4**, where the grey bars represent the number of teachers' positive phrases and the black bars their negative phrases in each TPB dimension. For example, pre-service teacher 1's answers were separated into 10 phrases; six were associated with attitude, five positively and one negatively; two were associated with subjective norms, both positively; and two were associated with perceived control of behaviour, both negatively. These results are interpreted in section 6.3.

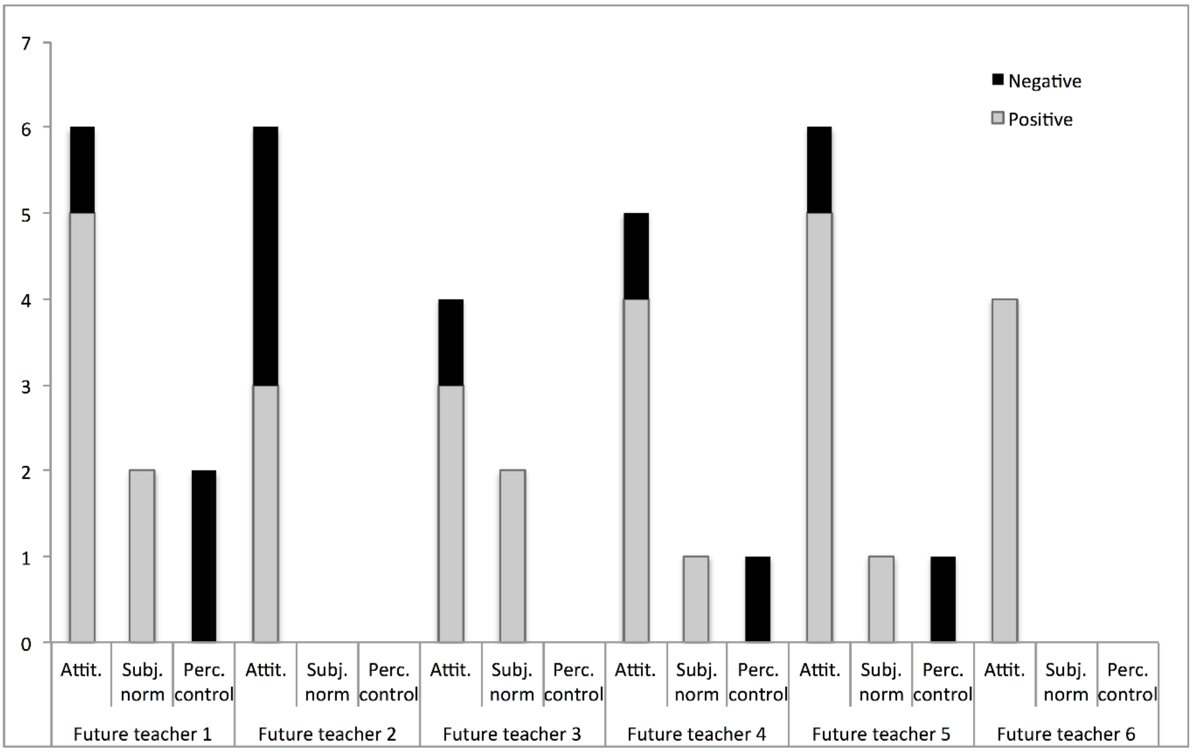


Figure 4. Results for questionnaire 1

Data collected with questionnaire 2

The data for questionnaire 2 were obtained by recording the following particulars for each pre-service teacher: the type of knowledge revealed in the explanation; where TPACK was identified, an assessment of whether the knowledge was appropriate for the situation; whether or not ICT-tasks were chosen; and whether or not the choice was optimal. **Table 4** lists the data for each teacher and questionnaire item.

To identify the type of knowledge invoked by the pre-service teachers, their answers were separated into phrases meaningful for the TPACK model and each phrase was assigned to the type of knowledge it revealed, further to the description of knowledge as adapted to the context of this study. The third and fourth columns in **Table 4** list the number of phrases into which each teacher's explanations were divided for each item and the type of knowledge identified for each phrase. For instance, the following pre-service teacher 3's explanation for item 1 was divided into four phrases[2]:

I would choose the second option, the one that uses the applet. Why? ***[Phrase 1]*** *The exercises seem similar, but in the second case I believe that the visual support provided by the graph is a useful supplement.* ***[Phrase 2]*** *In addition, being able to modify the values for a_1, d and n enables students to*

[2] Translated into English by the authors.

experiment on their own. ***[Phrase 3]*** *Use of an application helps develop digital skills and* ***[Phrase 4]*** *helps reinforce theory.*

In the first phrase, he revealed a command of pedagogical content knowledge (PCK), noting that the representation of the content ('the visual support provided by the graph') would supplement learning. The second phrase was associated with TPACK, for it contained references to content ('a1, d and n'), technology (the applet could be used to 'modify those values') and pedagogical considerations (students could 'experiment on their own'). Pedagogical knowledge (PK) was also identified in the last two phrases: in the first the teacher alluded to a curricular issue ('develop digital skills') and in the second to a general 'reinforcement' for learning.

Table 4. Results for questionnaire 2

		Number of phrases	Type of Knowledge	TPACK suitable	Choice of ICT-task	Optimal choice
Pre-service teacher 1	item 1	3	PTK, PK, CK	-	yes	no
	item 2	3	PK, TPACK, PK	no	yes	no
	item 3	3	PTK, PK, PK	-	no	no
Pre-service teacher 2	item 1	4	PCK, PK, PCK, PCK	-	no	yes
	item 2	3	CK, PTK, CK	-	yes	no
	item 3	4	PK, CK, CTK, PK	-	yes	yes
Pre-service teacher 3	item 1	4	PCK, TPACK, PK, PK	no	yes	no
	item 2	4	PCK, TPACK, PK, PK	no	yes	no
	item 3	5	PTK, PK, PK, PCK, PTK	-	yes	yes
Pre-service teacher 4	item 1	2	TPACK, PK	yes	yes	no
	item 2	3	PK, PK, PK	-	yes	yes
	item 3	1	PK	-	yes	yes
Pre-service teacher 5	item 1	3	PK, PTK, PK	-	yes	no
	item 2	2	PK, PCK	-	yes	yes
	item 3	1	PCK	-	no	no
Pre-service teacher 6	item 1	2	PTK, CTK	-	yes	yes
	item 2	3	TPACK, PCK, PK	no	yes	yes
	item 3	2	TPACK, PCK	no	yes	yes

Findings: case studies

The aforementioned data are analysed qualitatively in the paragraphs below. The gender of the pronouns used for reasons of readability in these summaries has been assigned arbitrarily, in as much as the data were collected anonymously.

Pre-service teacher 1

Pre-service teacher 1 expressed a positive attitude toward the use of technology (five positive phrases of a total of six), observing for instance that technology 'enhances student motivation and interest. It makes content meaningful.' She perceived the importance of technology in today's mathematics teaching environment and mentioned only a few generic difficulties involved in the use of technology in education, referring for instance to the 'lack of resources'.

Her choices denoted mostly pedagogical knowledge (PK in five of nine phrases). She referred to the cognitive benefits of the tasks but without mentioning content: 'Being able to use different methodologies to solve a problem is a very effective way to acquire significant knowledge.' She also revealed content knowledge (CK), albeit more sporadically: '...the formula to solve it must be applied...' and technological-pedagogical knowledge not associated with content (TPK) from a negative perspective: '...how the applet works... may lead the student to a dead end.' While she exhibited TPACK, she used it inappropriately, for she invoked a feature of the applet that complicated the task unnecessarily: 'Use of the software obliges the student to understand the relationship among the variables.'

Briefly, this pre-service teacher intended to use technology, although her knowledge was found to be primarily pedagogical. Her favourable attitude led her to choose ICT-tasks on two occasions, but she failed to choose the optimal option in either. Her behavioural intention was not therefore associated with TPACK.

Pre-service teacher 2

Pre-service teacher 2 balanced his favourable against his unfavourable beliefs in the attitudinal dimension. For instance, he observed that 'If [technology] is used as a surprise factor it may catch students' attention, but if used on a routine basis students lose interest'. He made no remark that could be classified as a subjective norm or perceived control of behaviour.

The prevailing knowledge displayed in his choice was unrelated to technology. He exhibited content knowledge (CK), pedagogical knowledge (PK) of student motivation to perform one task or another and pedagogical content knowledge (PCK), alerting for instance to students' potential difficulty to interpret certain representations. These types of knowledge were evenly distributed. Of his three task choices, two (1 and 3) were optimal. Nonetheless, his remarks contained nothing that could be associated with TPACK. His references to technology were related either to content (CTK) or pedagogical (PTK) knowledge, but separately and sporadically.

In short, this pre-service teacher, who was neither in favour nor against the use of technology, expressed several types of knowledge but none associated exclusively with the technological component. He chose ICT-tasks in two of the three items, but only one was the optimal choice and his explanations showed no TPACK.

Pre-service teacher 3

Pre-service teacher 3 held a positive view of the use of technology, observing for instance that 'its use should be included in all years of schooling'. His perception of stakeholder expectations around the use of technology was also favourable although he made no remarks that could be associated with perceived control of behaviour.

His knowledge was primarily pedagogical (PK). He expressed an interest, for instance, in connecting with other disciplines: '...it's useful for developing digital skills'. He only made the optimal choice on one occasion, in connection with which he showed no TPACK. When he did express such knowledge, it was inappropriate, for he remarked on an aspect that was not pertinent to the purpose sought with the task. His other explanations revealed separate pedagogical technological (PTK) or pedagogical content (PCK) knowledge.

In brief, this pre-service teacher intended to use technology, although all his knowledge had a pedagogical component, most of the time of a general nature. The TPACK he exhibited was inappropriate. He consistently chose ICT-tasks but this was the optimal choice in only one instance and his explanations implied no TPACK.

Pre-service teacher 4

Pre-service teacher 4's attitude toward the use of technology was favourable. She said, for instance, that it 'facilitates understanding of certain notions enormously'. She also had a positive perception of stakeholder expectations around the use of technology but revealed difficulties from the standpoint of perceived control of behaviour, for she observed that 'before using it in the classroom I'll have to have mastered it myself to ensure that my own shortcomings don't interfere with students' learning pace'.

She exhibited predominantly general pedagogical knowledge with frequent references to student motivation: '... [It] generates a more amusing, entertaining situation...' She was the only person to invoke TPACK appropriately and did so on only one occasion, in her assessment of the ICT-task in item 1: '...while the use of the applet affords nothing usable, the function involves greater variability respecting the information that students are expected to manage'. Nonetheless, as she ultimately failed to bear this reflection in mind, her choice was not optimal.

In short, this pre-service teacher exhibited an intention to use technology, although the type of knowledge she deployed to choose tasks was pedagogical (PK). She chose ICT-tasks in all cases, optimally in two.

Pre-service teacher 5

Pre-service teacher 5 had a very positive attitude toward the use of technology; his perception of stakeholder expectations in that regard was that 'it should be taught from the earliest years of schooling: this is the world we live in'. His perceived control of behaviour was cautious: 'I would try it out before using it in the classroom'.

His explanations drew most frequently from pedagogical knowledge (PK). As a rule, he did not assess applet suitability to task objectives. He exhibited pedagogical technological (PTK) and pedagogical content (PCK) knowledge separately, and his knowledge was scantly specific enough to assess the tasks proposed.

This pre-service teacher, then, expressed an enthusiastic intention to use technology. Based on his pedagogical knowledge in all cases, he chose ICT-tasks in two of the items, but his choice was optimal in only one.

Pre-service teacher 6

Pre-service teacher 6 expressed a positive attitude toward the use of technology, observing for instance that with it students 'learn more intuitively and meaningfully'. She made no mention of stakeholder expectations or of perceived control of behaviour.

Her explanations revealed a primarily pedagogical knowledge of content (PCK) related to the practical utility of mathematics, as well as technological pedagogical content knowledge (TPACK). She was one of the few teachers to exhibit TPACK, although she applied it inappropriately, for she failed to identify the potential of applets when assessing the graphics proposed in the tasks: 'What is the benefit of IT in 2.2? I think none'. Paradoxically, that opinion did not prevent her from choosing the ICT-task in that item. She also exhibited pedagogical-technological (PTK) ('...technology should be used in the classroom for purposes other than those sought with paper and pencil problem solving') and pedagogical (PK) knowledge ('...I like the second exercise better because the questions are more conducive to reflection').

In a word, this pre-service teacher intends to use technology in the classroom. She showed a wide variety of kinds of knowledge, especially TPACK, although she deployed it inappropriately. She made the optimal choice in all cases, applying different types of knowledge in each.

CONCLUSIONS AND DISCUSSION

The behavioural intentions of a group of pre-service teachers in connection with the use of technology were explored and the knowledge components they exhibited in a task selection exercise were identified. An analysis was subsequently conducted to determine whether those intentions were associated with a predominance of TPACK during their choice of technology-supported mathematical tasks.

The findings showed that behavioural intention as revealed in the explanations of the choice of technology-supported tasks given by the pre-service teachers participating in this study was unrelated to the presence of the TPACK component. On the sporadic occasions when that knowledge component appeared, it proved to be of no use for assessing the potential of technology in the tasks proposed. An in-depth analysis of the dimensions of the behavioural intentions observed and the knowledge components exhibited by the pre-service teachers showed that most of their expressions of affect fell within the dimensional attitude of TPB and on the positive end of the spectrum. Very few of their observations could be associated with subjective norms (although all were positive) or perceived control of behaviour (all negative and related to the lack of self-confidence in the use of a resource they felt they did not master). Inasmuch as all these pre-service teachers used computers in their everyday lives, that lack of self-confidence was interpreted to be directly related to their unfamiliarity with the educational utility of technology in mathematics teaching. An analysis of the knowledge components exhibited during task selection, the most prevalent of which was pedagogical knowledge (PK), confirmed that interpretation. The inference is that they ignored content, even though the setting for data collection was clearly described as involving specific content for a specific year of schooling using mathematical tasks with very specific objectives. Pedagogical technological (PTK) and pedagogical content (PCK) knowledge also appeared fairly frequently. In the former, the pre-service teachers focused their explanations on the general possibilities afforded students by applets with no reference to content; and in the latter, they alerted to the difficulty students might encounter in interpreting certain representations of content. The conclusion drawn is that they had insufficient knowledge to judge the cognitive benefits of technology in the tasks proposed. That notwithstanding, most of them, even the teachers somewhat reluctant to use technology, opted for ICT-tasks in most cases. They nonetheless failed to make the optimal choice most of the time, a finding consistent with the absence of the TPACK needed to assess ICT-tasks. Consequently, no significant conclusions could be drawn about the type of knowledge that would be associated with an optimal choice of tasks from the standpoint of the use of technological resources in teaching. Rather, the reasons underlying pre-service teachers' choices were observed to be complex and to indicate that it was their positive attitude toward the use of technology, rather than the type of knowledge from which they drew that informed their choice of ICT-tasks.

As observed in an earlier section of this paper, the pre-service teachers in the present sample had received no specific instruction on the use of technology in mathematics teaching, although they had been exposed to pedagogical training, were acquainted with technology outside its use in education and were well versed in mathematical content. This would confirm that technological pedagogical content knowledge is not developed spontaneously when the content, technological and pedagogical knowledge components are developed separately. Emphasis on the development of TPACK is therefore believed to be indispensable in pre-service teacher education programmes. The behavioural intention expressed by pre-service teachers would thus be supported by knowledge enabling them to assess the technology available for teaching mathematics based on objective criteria.

ACKNOWLEDGEMENTS

This work was partially supported by project EDU2012-33030 of the Spanish Ministry of Science and Technology.

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