A METHODOLOGICAL FRAMEWORK FOR INVESTIGATING TPACK INTEGRATION IN EDUCATIONAL ACTIVITIES USING ICT BY PROSPECTIVE EARLY CHILDHOOD TEACHERS

UN FRAMEWORK METODOLOGICO PER LO STUDIO DELL'INTEGRAZIONE DI TPACK NELLE ATTIVITÀ EDUCATIVE CHE UTILIZZANO LE TIC AD USO DEI FUTURI INSEGNANTI DELLA PRIMA INFANZIA

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Abstract This paper proposes a methodological framework for the study of how the Technological Pedagogical Content Knowledge (TPACK) model is integrated into educational activity design and implementation. The proposed framework was elaborated and applied in the context of a course in which student teachers from an early childhood education undergraduate program integrate TPACK into activity design and implementation using information and communications technologies (ICT). The specific methodological framework was designed to take into account the building blocks of

TPACK for each part of the course (teaching, designing, and implementing) and to investigate and recombine these using appropriate methods and tools, such as thematic analysis for qualitative data processing and multidimensional data analysis. Findings show that after applying our initial methodological framework, several elements, for example the particular features and specificities of each subject matter in preschool education, needed to be revisited.

KEYWORDS ICT; TPACK; Teacher training; Early childhood education; Educational activities.

Sommario Questo articolo propone un framework metodologico per studiare come il modello della conoscenza tecnologico-pedagogico-disciplinare (TPACK) viene integrato nella progettazione e implementazione di attività educative. Il framework proposto è stato elaborato e applicato nel contesto di un corso nell'ambito del quale gli studenti di un programma universitario per la formazione iniziale di insegnanti della prima infanzia integrano il TPACK nella progettazione e implementazione di attività che usano le tecnologie della comunicazione e dell'informazione (TIC) e il grado in cui lo fanno. Lo specifico framework metodologico è stato progettato tenendo in considerazione, per ciascuna parte del corso (insegnamento, progettazione, implementazione), le componenti costitutive su cui si fonda TPACK e per analizzare e ricombinare queste componenti attraverso l'uso di metodi e strumenti appropriati, come l'analisi tematica per l'elaborazione qualitativa e l'analisi dei dati multidimensionale. I risultati mostrano che, applicando il nostro approccio metodologico iniziale, diversi elementi, per esempio le caratteristiche e le specificità particolari di ogni materia dell'educazione prescolare, devono essere rivisitati.

PAROLE CHIAVE TIC; TPACK; Formazione insegnanti; Educazione della prima infanzia; Attività educative.

1. INTRODUCTION

Today there are a number of programs that aim to prepare or further educate teachers in new constructive and powerful teaching and learning strategies through the use of information and communications technologies (ICT). Although most teachers tend to have a positive attitude towards ICT use, many lack the knowledge and skills necessary to implement such innovations in their classrooms; at the same time, they continue to use ICT mainly for administrative or personal purposes (Jimoyiannis & Komis, 2006; Mwalongo, 2011; Russel, Bebel, O' Dwyer, & O' Connor, 2003; Zhao & Bryant, 2006). Moreover, the programs that aim to further educate teachers in basic ICT skills do not provide a clear specific framework for ICT integration in the educational process, for example using ICT based on a specific pedagogical theory for the purpose of specific subject matter (Jimoyiannis, 2010). This finding is also supported by global research (Angeli & Valanides, 2005; Mishra & Koehler, 2006; Niess, 2005; Valanides & Angeli, 2002), which reports that among the chief reasons for this is that no specific theoretical framework for exploiting ICT in education has been established and that such a framework must be constructed carefully. Attempts to construct a new theoretical grounding seem to have intensified in order to address this lack of framework.

Mishra and Koehler (2006) propose a theoretical model (Figure 1) called Technological Pedagogical Content Knowledge (TPACK), which suggests that the basis of good teaching using ICT is to be found at the intersection of three knowledge domains, namely Content (Content Knowledge), Pedagogy (Pedagogy Knowledge), and Technology (Technology Knowledge). At the same time, under the TPACK model the relationships between these domains appear to be of equal significance. TPACK describes a new dimension of ICT integration in the educational process — a dimension that, on the one hand, factors in the complexity of teaching and learning and, on the other, marks the significance of technology in our times.

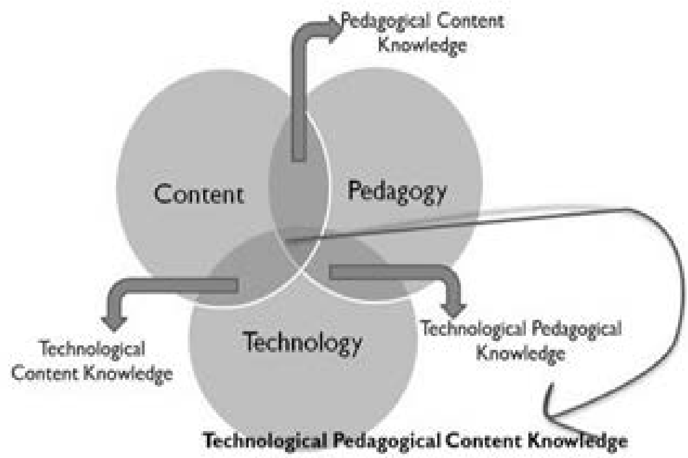

Figure 1. Technological Pedagogical Content Knowledge (Koehler & Mishra, 2008; Mishra & Koehler, 2006).

At the same time, in an attempt to study more thoroughly the knowledge domains of the TPACK theoretical framework, as well as their inter-relations and integration into the educational process, several researchers around the world have built enhanced and/or modified models (Angeli & Valanides, 2005, 2009; Hammond & Manfra, 2009; Jang & Chen, 2010; Jimoyiannis, 2010; Lee & Tsai, 2010;). As a result, TPACK has been used as a powerful theoretical tool in several research studies that investigate the complexity of the educational process in combination with ICT integration.

These modified models are usually associated with particular subject matter, such as mathematics and sciences (Chien, Chang, Yeh, & Chang, 2012; Clermont, Borko, & Krajcik, 1994; Fernández-Balboa & Stiehl, 1995; Jang, 2010; Jang & Chen, 2010; Jimoyiannis, 2010; Mor & Mogilevsky, 2013). Although in recent years there has been an emphasis on introducing ICT at early childhood and elementary school levels (Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2012), thorough research has yet to be conducted (Papanikolaou, Makri, & Roussos, 2017; Tzavara & Komis, 2015). This education level is attracting increasing research interest in terms of educational material, pedagogical approaches, and so on (Plowman, Stephen, & McPake, 2010; Yelland, 2007). Hence, the majority of studies concerning the implementation of TPACK in the field of early childhood education are mainly surveys with quantitative characteristics

(Archambault & Bamett, 2010; Blackwell, Lauricella, & Wartella, 2016; Jang, 2010; Koh, Chai, & Tsait, 2010; Lee & Tsai, 2010; So & Kim, 2009; Voogt, Fisser, Pareja Roblin, Tondeur, J., & van Braak, 2012; Yurdakul & Coclart, 2014), rather than qualitative or mixed ones, which would give us a more detailed insight (Tzavara & Komis, 2015).

This paper attempts to introduce a new methodological framework to identify and investigate the integration of TPACK's components into educational design and implementation. The proposed framework was elaborated and applied in the context of a university course in which student teachers integrate TPACK into activity design and implementation using ICT (Komis, Tzavara, Karsenti, Collin, & Simard, 2013). Specifically, this framework is derived from thorough investigation of the individual conceptual components of TPACK, which are then reused as tools to analyse the data resulting from the inquiry of the entire course. For this purpose, a qualitative approach to analysis of the gathered data was applied to investigate how, and to what extent, student teachers integrate ICT into their teaching practices. The approach presented in this paper is expected to provide better insights about the integration of ICT in teaching, when compared with those provided by the aforementioned proposals (mostly based on the use of quantitative surveys). At the same time, those research proposals highlight the need to study in real-world classroom conditions and not just analyse the data that arises at the design of courses that use ICT.

Subsequently, a detailed presentation is given of (a) how the proposed framework was elaborated and applied in the context of an educational course in which student teachers of preschool education integrate TPACK into activity design and implementation using ICT, (b) the collection of appropriate data derived throughout all steps of the course, and (c) the creation of specific conceptual tools and the use of effective methods of qualitative and quantitative analysis with characteristic examples. Finally, this paper concludes with description of the revised methodological framework which emerged after the initial proposal was applied and validated in the context of the educational course.

2. THE PROPOSED METHODOLOGICAL FRAMEWORK

This study aims to extend the methodological framework used to study TPACK to the design and implementation of an educational course in a classroom setting. For that purpose, a new methodological tool for TPACK was developed, consisting of both qualitative and quantitative characteristics. This involves designing and implementing an educational course from a TPACK perspective, developing conceptual tools to study this program, collecting suitable data, and using effective analytical methods with qualitative and quantitative characteristics. The conceptual tools were developed based on the individual components of TPACK, whereas the methods used are based on the quantitative and qualitative analysis of multivariate data. This process is described in detail in a section below.

2.1. Course design and implementation

Course design consists of the theoretical and practical portions as well as their implementation. The process unfolds in three steps (Figure 2):

1. The course is designed based on the conceptual components of TPACK and given to real student teachers;
2. The student teachers attend theoretical lectures and design educational learning activities (Theory and Laboratory);
3. The student teachers implement the activities in classroom settings.

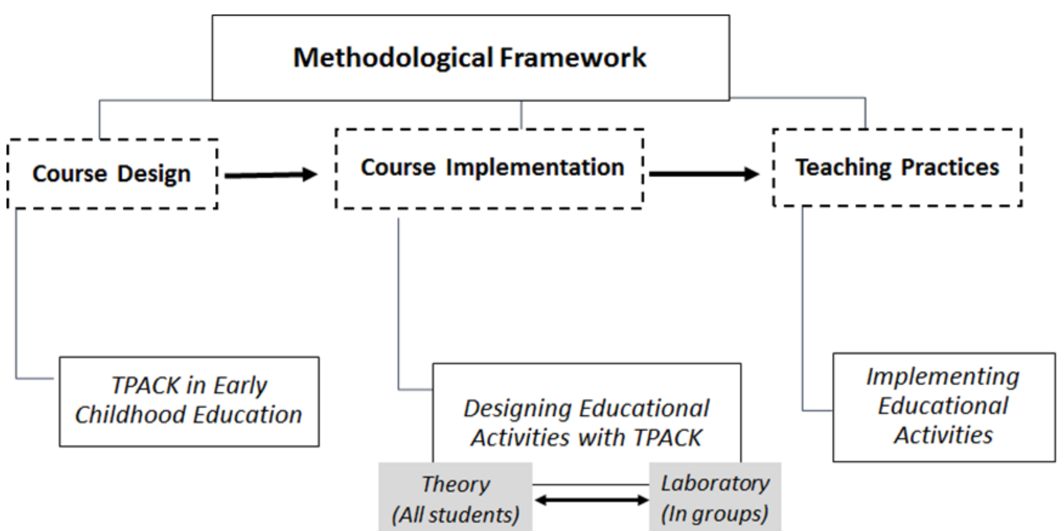

Figure 2. The methodological framework.

The theoretical and practical portions of the proposed framework were structured to reflect both the basic building blocks of TPACK and their combinations. A university course titled “Educational Activities with the Use of Computers in Preschool and Early Childhood” (third year, Department of Educational Sciences and Early Childhood Education, University of Patras) was used as a case study to validate the proposed methodological framework. We stress that this course was the most suitable for implementing and validating the new proposed methodological framework because its theoretical portion addresses in depth the basic concepts of ICT in preschool education, while the practical portion requires that these concepts be implemented in real classroom conditions. The final evaluation of this process allows us to “measure” the methods and degree of TPACK integration by the student teachers. The course was thus structured as a series of lectures on theoretical content, which are then reinforced with practical training in a computer laboratory with the appropriate educational development software.

During the course, the class supervisors randomly assigned the student teachers to groups of two to four and asked them to design activities for preschool children using an educational software series that would be used in the laboratory throughout the academic term. Note that the groups remained the same during the course as well as while implementing the activities at the kindergartens. Although activity planning had to respect requirements for the cognitive level of children at this particular age, it could concern either particular subject matter in the curriculum or cross-curricular activities. Every week, the student teachers, together with the educators, evaluated their planned activities. Once the academic term ended, the activities with the highest score were selected, one for each group. Next, activities were implemented in kindergartens, addressing children between 4.5 and 5.5 years of age, with simultaneous video recording of the entire process. The process would also be video-recorded by the laboratory supervisor (also a researcher). Children who had used a personal computer before (for drawing or games) were selected to work in pairs for the activity’s implementation. Furthermore, the laboratory supervisor did not interfere during the activity, but only recorded it.

2.2. Data collection and preparation

Of course, to implement this particular methodological framework, suitable primary material had to be collected throughout all steps of the course. This material consists of the student teachers' reports (activity design), the videos recorded during activity implementation at the kindergartens, and the researchers' notes. It is noteworthy that earlier studies of TPACK use only quantitative or qualitative data derived either from questionnaires or interviews (Koh, Chai, & Tsait, 2010; Shin et al., 2009; So & Kim, 2009; Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2012). In contrast to these approaches, we believe that various types of data and alternative data analyses are necessary to properly understand TPACK integration processes. Through appropriate analysis and coding, these data will allow us to imprint, describe, and deepen the student teachers' TPACK integration process. From this perspective, the emphasis is on what they plan to do and how they actually do it. Consequently, we propose that the research material consists of at least:

1) Forms describing the activities, i.e., manuscripts for the educational activities designed by the student teachers;
2) A recording of the actual implementation in the classroom, which will provide a clear picture of what was designed and how it was actually implemented.

Additionally, to improve the processing of the primary derived material, the researchers' comments in the recording were also used. Software programs were used to process and classify these data, i.e., a qualitative data analysis program and a statistical analysis program. In this study, the NVivo8 and SPAD software programs were used for qualitative and quantitative analysis, respectively.

The primary data collected in this study are qualitative: manuscripts describing the activities, video recordings of activity implementation, and notes with the researchers' comments. Video recordings were transcribed using the NVivo8 qualitative analysis program and used as the primary material for the coding and subsequent analysis. The thematic coding method was adopted in NVivo8 to analyse the data on the methods that student teachers had chosen for TPACK components. The following section describes this analysis in detail. More specifically, the research material was entered in NVivo8, categorized, and coded into a series of categories derived from analysis and recombination of TPACK theoretical concepts. These categories are the coding scheme for all data acquired in this study. Lastly, after analysing the qualitative research material with NVivo8, we thought it was necessary to further internally validate the inferred results by hiring an independent researcher to carry out an additional control of the analysis. In this study, the kappa index was greater than 95%, versus around 70% in very few cases.

Studying the degree of TPACK integration involves statistical methods of quantitative analysis. After coding the collected research material based on the aforementioned analysis categories (coding scheme), an exploratory multivariate statistical analysis was carried out using the SPAD statistical software package. The following section describes in detail the exact method used to quantify the coding scheme. The initial qualitative categories had to be quantified in order to determine the degree associated with each category as well as its potential link to these categories. To that end, the data were classified using SPAD; multiple correspondence analysis (MCA) and cluster analysis were then applied. Specifically, we used MCA for an overall analysis of the students' activities (design and implementation phases). Accordingly, MCA was applied to the values of the categorical variables, and cluster analysis was applied to the study subjects (14 groups of third-year student teachers) involved in the research. This specific type of analysis was used to group subjects (student teacher groups) with common characteristics.

The following table shows the sequence of the analysis (Table 1).

	1. Design of educational activities	**2. implementation of educational activities**	**3. Comparison between design and implementation**	**4. Overview**
A. Third year of studies	Designing (NVivo8)	Implementation (NVivo8)	Designing/ Implementation (NVivo8)	TPACK (SPAD)

Table 1. Qualitative and quantitative analysis.

A descriptive analysis using NVivo8 was performed to examine the design (A1) and implementation (A2) step, as well as to compare these (A3). Values were subsequently attributed to the different types of analyses, in accordance with the description below, in order to determine whether the student teachers had integrated TPACK into their educational activity design and implementation in an appropriate manner. To do so, a database was created in SPAD to examine the behaviour of the student teachers in this study as a whole. The most representative examples from these databases are given in the following section.

2.3. Conceptual constructs and illustration

TPACK integration methods were studied with the development of a suitable conceptual scheme. This section presents characteristic examples drawn from analysis with the NVivo8 software. Additionally, the degree of TPACK integration is presented with examples from the applied methods, i.e., multiple correspondence analysis (MCA) and cluster analysis, using the SPAD software.

2.3.1. Coding scheme

This section describes the coding scheme used for the quantitative and qualitative study of TPACK. The type of primary data and the methodological approach in particular require that appropriate conceptual structures be developed; these are described and examined in detail below. Specifically, we present and describe the analysis categories derived from combining the structure of the course's main goals and the activities the student teachers were asked to develop using the TPACK model. Each TPACK component is a separate analysis category, which appears to create two or more subcategories (Figure 3).

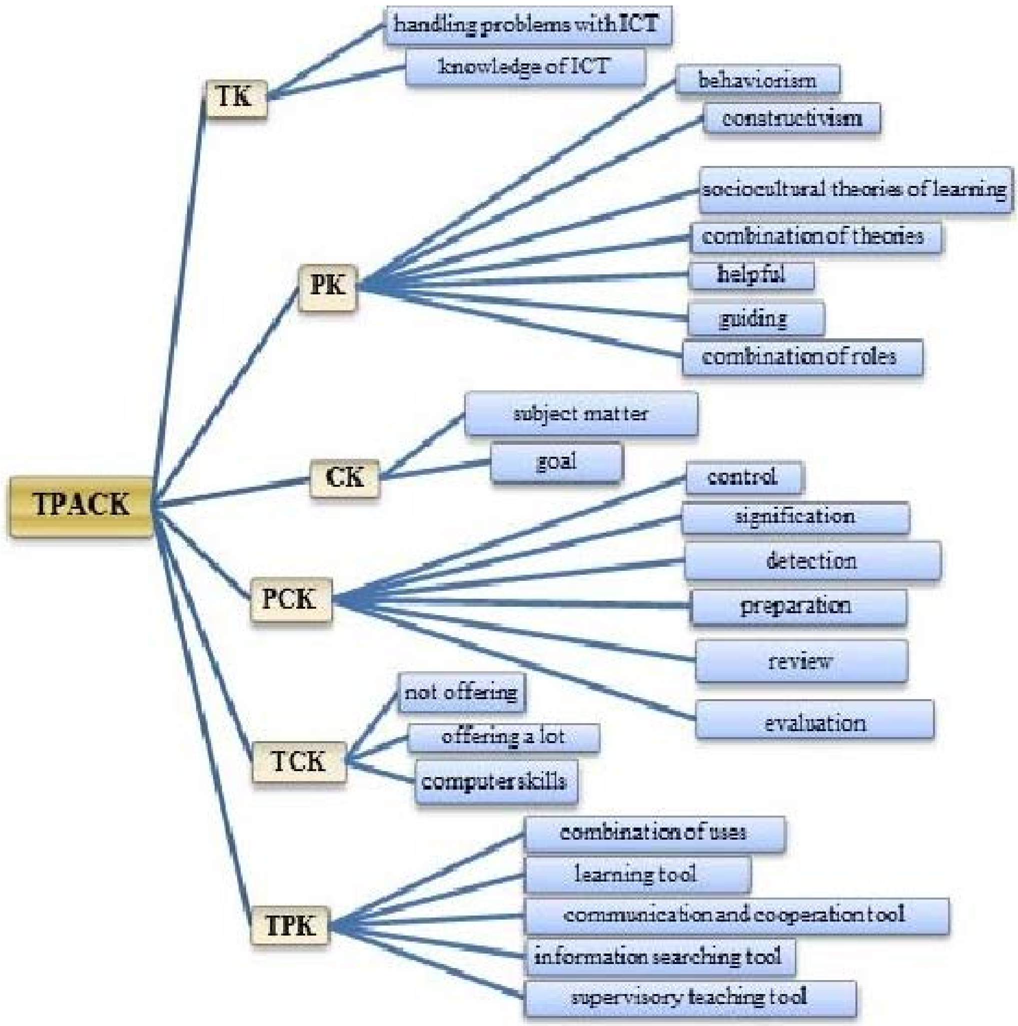

Figure 3. Analysis categories.

The definitions of these categories, as used in this paper, are described as follows:

TK: Technological Knowledge (use of computers, peripherals, software, etc.). The concept of Technological Knowledge has two subcategories: knowledge of ICT use and knowledge of how to deal with potential problems with ICT in a school classroom environment.

PK: Pedagogical Knowledge which, according to the research material, is the result of two major categories: knowing the learning theory adopted by the student teachers for designing and implementing educational activities, and self-determination of their role as prospective teachers.

CK: Content Knowledge, which in this paper is defined as knowledge of the curriculum, namely the knowledge of each and every subject matter and its relevant educational goals.

PCK: This concerns the way in which pedagogical knowledge can be applied in the teaching of specific subject matters. Specifically, it focuses on how students prepare, administer, and complete their activities. The resulting subcategories are: detection and preparation; referring to the knowledge of how to motivate children's participation; control and signification; referring to the knowledge of how to manage a classroom while implementing an activity, as well as review and evaluation; referring to the knowledge of closuring an activity.

TCK: This concerns how the teaching of each and every subject matter changes through the use of ICT. The resulting subcategories concern either the potential benefits of ICT use for the design of educational activities (i.e., whether or not they have an added value) or simply concern the acquisition of technological knowledge.

TPK: This concerns knowing how to choose the best possible way to use available technology so that educational goals can be redetermined. This concept has five subcategories in our research material, i.e., the use of the computer as a supervisory teaching tool, information searching tool, communication and cooperation tool, and learning tool, as well as a combination of the aforementioned uses.

TPACK: The concept of Technological Pedagogical Content Knowledge appears at the intersection of the individual structures described above. Under the proposed model, Pedagogy, Content Knowledge (the content as a subject included in the curriculum), and Technological Knowledge form a whole, and each region operates completely coherently with the rest. TPACK requires teachers of early childhood education to know about the smoothest and best possible integration of ICT in their daily practice. It is the way in which the teaching conditions the use of ICT in relation with the content.

For the development of the conceptual model and the definition of the subcategories helping us to study more in depth the conceptual structures of TPACK, two approaches were used (Beer, Eisenstat, & Spector, 1990; Fraser, Dougill, Mabee, Reed, & McAlpine, 2006; Sabatier, 1986): bottom up or inductive, and top down or deductive. In particular, in the present study bottom-up was applied to enrich and further clarify the initial analysis model that emerged from the top-down approach (Auerbach & Silverstein, 2003). Furthermore, both approaches had to be applied through the whole process to produce the final coding scheme (Figure 3). This process has enabled us to reconstitute the original categories and subcategories – first cycle coding method (Saldaña, 2009) – but also to add new ones to approach more complex and more meaningful concepts – second cycle coding method. Examples of these subcategories are presented in the next section.

2.3.2. TPACK integration methods (Thematic coding in NVivo8)

The NVivo8 software was used to study how TPACK had been integrated into the implemented educational courses. The bottom-up method was used to further develop the coding scheme and to add analysis subcategories for a thorough examination of TPACK conceptual components. The bottom-up or inductive method is a restriction-free method that derives directly from the research data. Nonetheless, it is not arbitrary because it is shaped by the course content and its goals in particular, as well as by the basic concepts of the TPACK theoretical framework.

In NVivo8, subcategories are called "parent nodes" (PN). For instance, the Pedagogical Knowledge category (Figure 4) consists of two main subcategories or "parent nodes" (PNs): "learning theories" (PN1) and "teacher's role" (PN2). "Learning theories" is in turn subdivided into constructivism (PN1a), sociocultural theories (NP1b), behaviorism (PN1c), and their combination (PN1d). "Teacher's role" is subdivided into helpful (PN2a), guiding (PN2b), and their combination (PN2c).

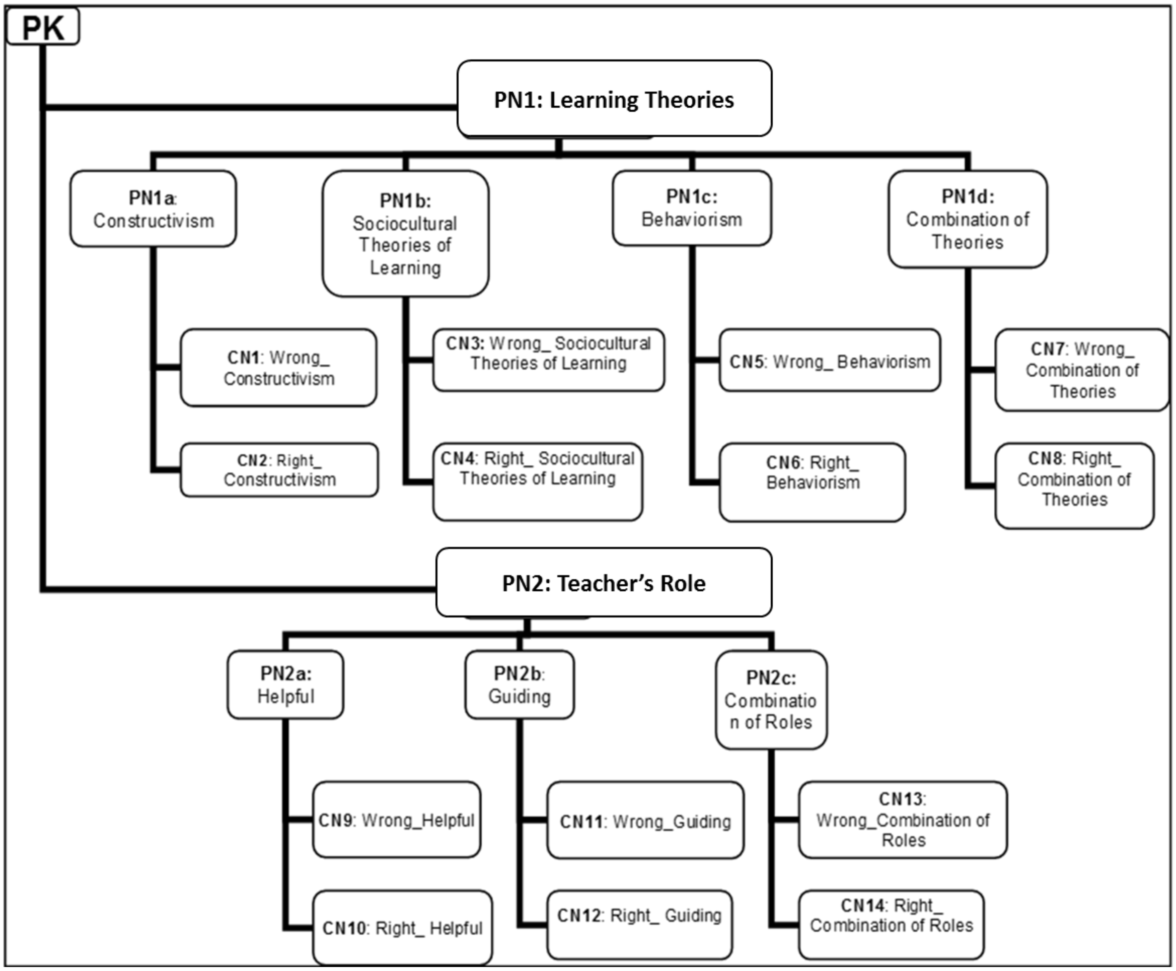

Figure 4. Parent nodes and child nodes for Pedagogical Knowledge.

The "right" or "wrong" child node (CN) for each parent node verifies and evaluates each group's work. Consequently, the part concerning the listing of the student teachers' assignments had to be coded by evaluating their answers. For example, a group may have claimed and adequately elaborated in the assignment that it had designed a constructivist activity, in this case to be coded as "right". However, during activity implementation it may actually have adopted teaching strategies that were clearly behavioural, and thus to be coded as "wrong".

For instance, for the Pedagogical Knowledge (PK) subcategory shown in Table 2, NVivo8 reports the researchers' coding, in particular showing one reference for a group that implemented an activity using the Kidspiration software and was labelled as "right" (CN6). This means that the group of student teachers successfully integrated the "constructivism" subcategory into their activity, as they claimed in their assignment. Conversely, another reference from a group that designed an Internet-based activity was labelled as “wrong” (CN5), which means the group failed to integrate the specific subcategory, in contrast to their description in the assignment.

Child Nodes	**Examples**
CN6*	*<Memos\C year memos\13.01_2 activity_Kidspiration> - § 1 reference coded [9.31% Coverage] Reference 1 - 9.31% Coverage* *They allow time for children to browse alone.* *They give children chances to figure out the problem.*
CN5**	*<Memos\C year memos\21.01_1 activity Internet> - § 1 reference coded [74.60% Coverage] Reference 1 - 74.60% Coverage* *They guide their children constantly in order to facilitate or coordinate their movements.* *They give too much information, e.g. “go there,” “do that”* *They don’t leave much time for children to browse alone - they coordinate them constantly - they immediately correct them.*

Table 2. Coding examples for Pedagogical Knowledge.

Table 3 shows a representative example of consistency in design and implementation. This particular group of student teachers claimed in the assignment to have designed an activity involving the use of WordPad and properly explained that its role would be a guiding one, thus it is coded as “right” (CN16). During implementation of this activity, the group followed the same strategy, so it is coded again as “right” (CN16).

Child Nodes	**Examples**
CN16*	*<Internals\papers\C year_papers\12.01_1 activity wordpad> - § 1 reference coded [4.34% Coverage] Reference 1 - 4.34% Coverage*

	Our role in the implementation of this activity is guiding. We guide children to properly carry out their exercises based on the available computer tools.
CN16	*<Internals\activities\C year_activities\1 activity WordPad_12.01> - § 15 references coded [42.02% Coverage] Reference 2 - 0.81% Coverage* *teacher1: say that ... when you take that down and then it goes ... now click that* *teacher2: click that* *Reference 3 - 0.42% Coverage* *teacher1: try to click that letter* *teacher2: here, here*

Table 3. Example of consistency in activity design and implementation.

In Table 4 a third example is given to illustrate potential contradiction between design and implementation. In this case, the group of student teachers successfully suggests a constructivist activity with drawing, and it is therefore coded as "right" (CN6). However, during implementation in kindergarten, the group adopts a purely behavioural role that contradicts their initial claim, and so it is coded as "wrong" (CN16).

Child Nodes	Examples
CN6*	*<Internals\papers\C year_papers\11.01_1 activity drawing> - § 1 reference coded [3.49% Coverage] Reference 1 - 3.49% Coverage* *The activity was designed based on the theory of constructivism. Therefore, knowledge is embedded through team work, personal expression and involvement in the learning process.*
CN16**	*<Internals\activities\C year_activities\1 activity drawing_11.01> - § 5 references coded [27.05% Coverage] Reference 1 - 5.06% Coverage* *teacher2: put your hand here…you must choose…you must click this button only once*

student2: which one? This?

teacher2: yes…that one…so you can choose your favourite car and then put it wherever you want…you are now inside the city… where can we place this car? Choose and then click the button once

Reference 2 - 5.49% Coverage

teacher1: take it there

teacher2: let me show you how…put your hand here… no, no, leave it. Do you see this arrow?

student2: yes

teacher2: the arrow goes where you want to put your car. And then you click the button of your mouse… that is what we call "click"… now leave it… did you see where it went? Try with some others. You can change objects here.

Table 4. Example of inconsistency between activity design and implementation.

Using the exact same method, the initial coding scheme derived from the top-down method was enriched in all basic analysis categories, resulting in a tree node consisting of three levels of subcategories. Based on this new enriched tree node, the primary research material derived from implementation of the proposed educational course was coded. This includes the student teachers' assignments, the video recordings of activity implementation, and the researchers' personal notes based on the videos.

2.3.3. Degree of TPACK integration (Multidimensional data analysis)

Now that we have presented the analysis categories and subcategories, as well as the NVivo8 coding of the primary research material, in this section we will attempt to quantify the above categories. This will help assess the degree to which the student teachers integrated TPACK into activity design and implementation. Each subcategory was coded with one of four possible values: Sufficient, Not Sufficient Enough, Insufficient, and Not Found. In other words, each subcategory in Figure 2 constitutes a categorical variable attributed to one of the four possible values in order to assess whether the TPACK model analysis (design and implementation) was properly applied. For this purpose, the SPAD statistical analysis software was used (multiple correspondence analysis and cluster analysis). Specifically, based on the incidence of each right/wrong subcategory for every category in each group, the resulting values were as follows:

a. If the student group activities present categories that include only subcategories coded as "right", then it is labelled as "sufficient".
b. If the student group activities present categories that include subcategories coded either as "right" or as "wrong", then it is labelled as "not sufficient enough".
c. If the group presents categories including mainly subcategories coded as "wrong", then it is labelled "insufficient".
d. If the group presents categories that do not include any subcategories, then it is labelled as "not found".

Furthermore, in the following example one group developed an activity using the WordPad software; for the subcategory CK/content, it appears to have been coded twice as "right" (for design, Table 5, and implementation, Table 6) and once as "wrong". Based on the above definitions for the values attributed in the SPAD data analysis, this group's performance is labelled as "not sufficient enough."

Internals\papers\C year_ papers\10.01_1 activity WordPad | **Document**

Node Coding	References	Coverage
Tree Nodes\CK\ Curriculum Content\Goals\Right_ Goals	2	7, 38%

Reference	1 - 2	Coverage	7, 38%	*Character Range*	554 - 987

Table 5. Coding example for design.

Internals\activities\C year_ activities\1 activity WordPad_10.01				Document
Node Coding		**References**	**Coverage**	
Tree Nodes\CK\Curriculum Content\Goals\Wrong_ Goals		1	1, 96%	
Reference 1	Coverage 1, 96%		*Character Range*	5920 - 6045
Node Coding		**References**	**Coverage**	
Tree Nodes\CK\Curriculum Content\Goals\Right_ Goals		1	3, 32%	
Reference 1	Coverage 3, 32%		*Character Range*	26 - 237

Table 6. Coding example for implementation.

Similarly, values were attributed to all groups (units of analysis) that participated in this study in order to quantify the data. The gathered data was processed in order to illustrate the degree of TPACK integration in each group's activity design and implementation, as well as to distinguish groups that share common characteristics. All the main variables derived from the qualitative data sorting were used, with the exception of those that did not show value distribution in the separate subjects of the study. Additionally, during analysis, an auxiliary variable associated with the computational tool was used. Specifically, the type of software used by each group to design and implement the educational activities was defined as a category. The values attributed were the five types of software used by the group of student teachers: WordPad, Internet tools, concept mapping, drill and practice software, and drawing programs.

Cluster analysis and multiple correspondence analysis were used to study the degree of integration. While cluster analysis creates groups of study subjects (in this case, the individual groups of student teachers), multiple correspondence analysis groups the variable modalities. The study subjects can be projected in the same chart. Figures 5 and 6 show the degree of TPACK integration, as this was imprinted from the subject teachers of year C.

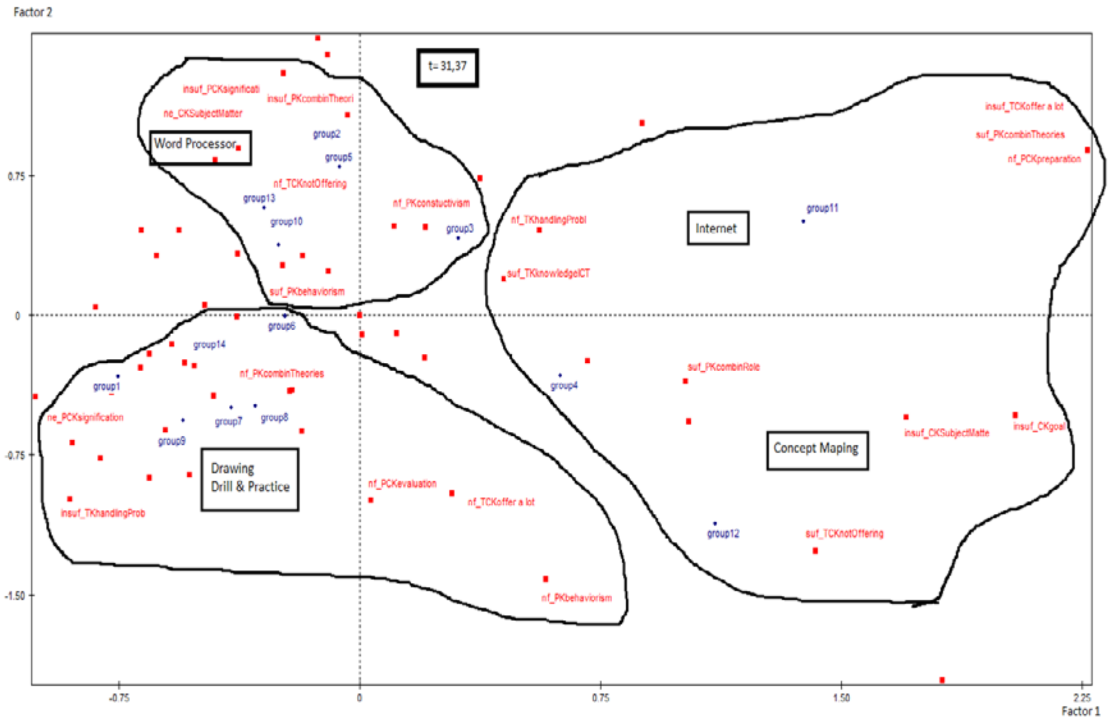

Figure 5. Example of multiple correspondence analysis.

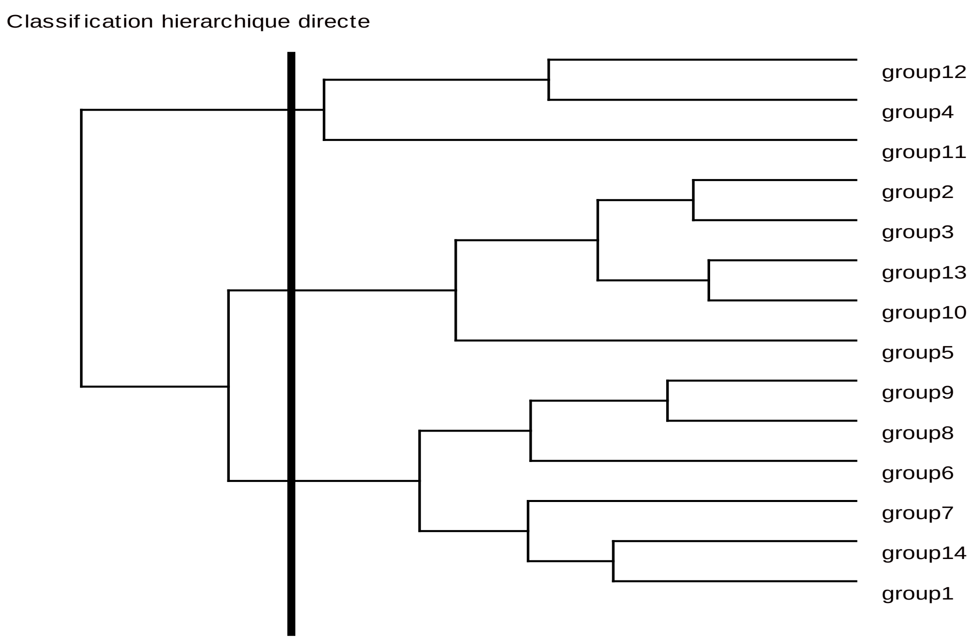

Figure 6. Example of cluster analysis.

Based on the cluster analysis example of Figure 6, three main clusters of groups derive from the study subjects. These are also profoundly formed in the multiple correspondence analysis in Figure 5, in the shape of three modality groups, each of which includes groups with common characteristics. Specifically, in Figure 5, three clusters can be observed: (group1, group14, group7, group6, group8, group9); (group5, group10, group13, group3, group2); and (group11, group4, group12). The same groups can also be distinguished in Figure 5, another topological representation of the analysis, in which both groups and modalities can be distinguished. The modalities that belong to one cluster describe its characteristics. The information presented in this plot (defined by the vertical and horizontal axes) is relatively detailed (t= 31, 37%).

Furthermore, in the first and fourth quadrants, there are fewer clusters (only three groups) but these are the most adequate with respect to the individual TPACK components. This group appears to have designed and implemented activities using mostly constructivist tools, such as the Internet and conceptual mapping software. In the first and second quadrants, there is a group that consists of five subjects and exhibits behaviorist preferences, but is characterized by adequacy, partial inadequacy or even no value for the other subcategories of the theoretical model in this study. This group seems to have used WordPad as the auxiliary variable. Lastly, in the third and fourth quadrants, in which the remaining six analysis subjects are found, there is a group characterized by the absence of most subcategories and by inadequacy in handling technology-related problems. The subjects, in this case, appear to have used drill and practice software and drawing for activity design and implementation.

This process was applied to all research material by attributing values to all tree node subcategories, as these were derived for development in NVivo8. After using and studying the reports with coding for the material exported from NVivo8, each group was attributed four values for each subcategory. We were able to use the aforementioned quantitative methods to assess the degree of TPACK integration by subsequently transferring the quantified research data and their potential combinations into the SPAD software.

Furthermore, attempting to meet the professional development needs of student teachers to integrate ICT in their teaching practice and through our analysis, we identified topics requiring further research and redesign. The design and implementation of educational activities for kindergarten with ICT is a particularly complex process which should take into account many factors, such as the specific characteristics of young children, the potential of the classes, the specificity of each subject matter, as well as many other (often unpredictable) elements - which constitute a diverse field of research. Therefore, the findings showed us that after applying our initial methodological framework, several elements needed to be modified.

3. DISCUSSION AND CONCLUSION

Research on TPACK has intensified considerably in recent years. Nevertheless, although theoretical substantiation of the field has been satisfactory and the number of experience-based applications has risen, limited progress has been made in developing methods and techniques to assess TPACK, in particular the design of educational activities based on TPACK and, more importantly, their implementation in the classroom. The goal of this study is to contribute to the development of a methodological framework for assessing TPACK in the design of preschool educational activities and their application in the classroom. That is why the study focuses on how student teachers integrate TPACK into activity design and implementation and the degree to which they do so. These activities involve the use of ICT in the context of an educational course. As such, the study emphasizes TPACK concepts and interrelations when ICT are incorporated into the design and implementation of pedagogical activities for preschool education. More specifically, we consider that a comprehensively designed and implemented educational program (i.e., university or training curriculum), which integrates the teaching and practical application of TPACK in the classroom is particularly important in developing an appropriate methodological framework for the study of TPACK.

In this paper, we present, validate, and discuss this methodological framework and its qualitative and quantitative characteristics. The methodological framework was applied and validated in the context of an educational course that includes: a) the process of preparing student teachers to use ICT in their future work, primarily through theory lectures; b) the background, state of the art, and design of activities that make extensive use of ICT (mainly through laboratory work); and c) implementation of the activities in real classrooms. The proposed methodological framework factors in the distinctive characteristics of TPACK at every step of developing the educational course (i.e., preparation of the student teachers through lectures, activity design during laboratory work, activity implementation in the classroom) and concurrently analyses and synthesizes these characteristics by using appropriate research techniques and tools.

Furthermore, the proposed framework examines all data derived from every phase of course implementation by using various qualitative and quantitative techniques. A thematic analysis was initially applied during data coding (qualitative technique with NVivo8) to identify the integration of TPACK components. Multidimensional data analysis (quantitative analysis using SPAD) was then employed to assess the degree to which these components were integrated. TPACK was also used as the basis for the coding scheme design, which was subsequently used to analyse all our data. This analysis helped us study how the student teachers learn and understand all aspects of TPACK.

More specifically, TPACK was initially used as a theoretical tool to design and teach a course on ICT implementation in preschool education. During the initial phase of course design, an Activity Form was also created. The student teachers went on to use this Activity Form in designing their educational activities with ICT in the next phase of the proposed educational course. The form was also part of the primary research material analysed with the aforementioned methods. Course implementation included two closely tied parts: theory lectures and laboratory work. Their main focus was activity design based on the conceptual components of TPACK and on the requirements of preschool education. In this phase, the student teachers' assignments were collected. In the third and final phase of the course, the student teachers were asked to implement their designed activities in real classrooms (teaching practices). Researchers video-recorded, coded, and processed these practices with the methods described above. Moreover, comments were recorded by the researchers for each video. These comments were also used as primary research material.

After collecting, coding, and processing the research material, we reviewed and revised the initial framework, particularly with regard to 'Course Design' and 'Course Implementation' (Figure 7).

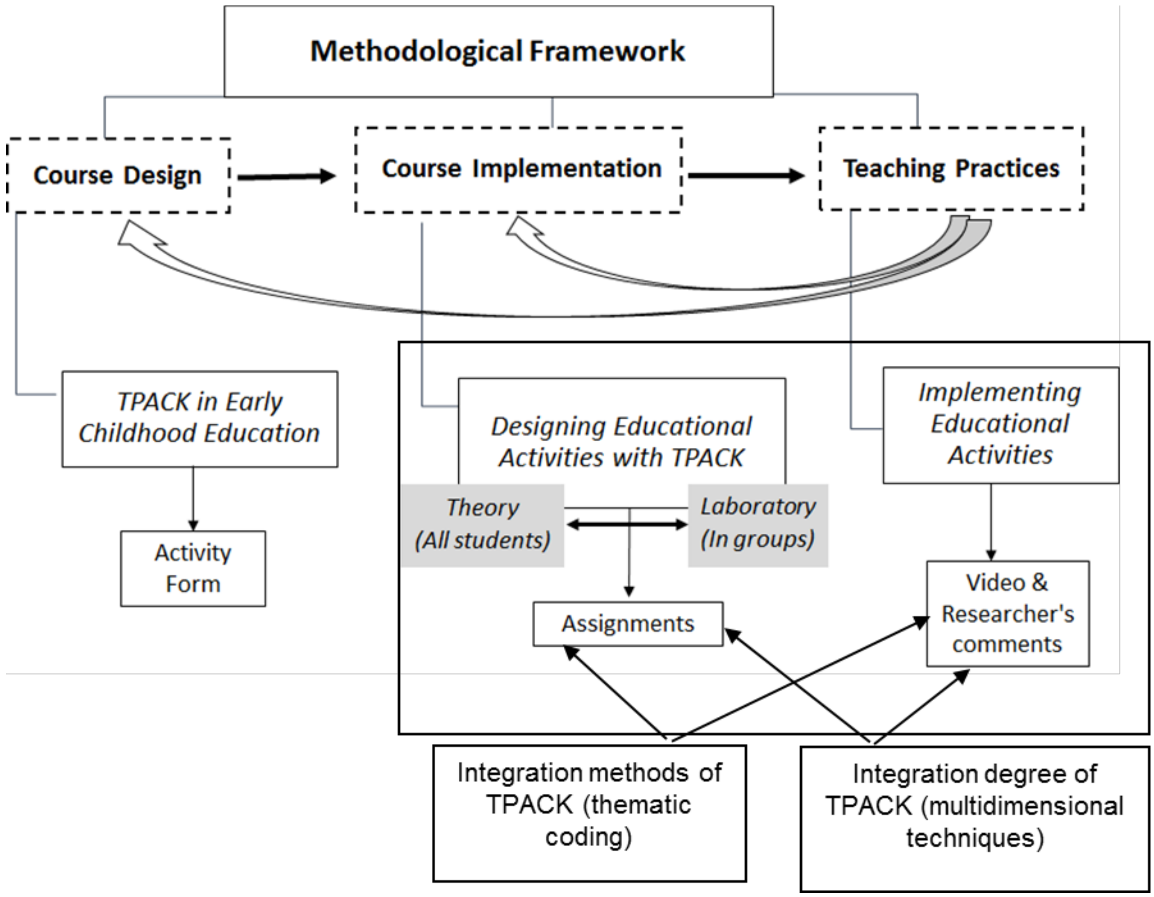

Figure 7. The revised methodological framework.

In order to give an example, the implementation of 'Teaching Practices' has shown that the organization of daily ICT educational practices should take into account the particular features and specificity of each subject matter and not just general pedagogical theories. This led us to modify the first two phases of the initial proposed framework, 'Course Design' and 'Course Implementation', taking into consideration a new important element, the subject matter. Therefore, with the parallel development of the Didactics of Science (Tzavara & Komis, 2015), a new enriched model is proposed which prioritizes the needs and the requirements of each subject matter, a parameter that must be taken into account from the beginning and can also lead us to a new in-depth analysis of educational practices. The present research proposed a methodological framework that could be applied by other researchers in other research fields and contexts, and with different student populations. In order to verify its soundness and general applicability, the proposed model needs to be applied on a larger scale (range and variety of courses) and validated by specific field studies in actual teacher training conditions. Particularly interesting is the analysis of both the design and the implementation of educational activities as well as the comparison between them. Furthermore, our methodological approach involves holistic evaluation of TPACK (both quantitative and qualitative). However, the approach has certain shortcomings: it is rather complex and time-consuming in terms of data coding and analysis, and is therefore difficult to apply to large amounts of data. Nonetheless, it has allowed us to identify a wide range of nuanced information that could not otherwise be acquired using only quantitative tools.

As such, we believe it is particularly important for other researchers and university educators to apply the proposed methodological framework in various settings and contexts.

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