Strategies to prepare pre-service teachers for Technological Pedagogical Content Knowledge (TPACK): A mixed-method study

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Abstract

The main aim of this two-step mixed-method study was to explore the effectiveness of the strategies used to prepare pre-service teachers for Technological Pedagogical Content Knowledge (TPACK). Specifically, we focused on the strategies included in the Synthesis of Qualitative Evidence (SQD) model: 1) using teacher educators as role models, 2) reflecting on the role of technology in education, 3) learning how to use technology by design, 4) collaboration with peers, 5) scaffolding authentic technology experiences, and 6) providing continuous feedback. To explore the relation between the perceived occurrences of the SQD-strategies and TPACK (controlled for pre-service teachers' general attitudes towards technology), survey data were collected from a sample of 688 final-year pre-service teachers in Belgium. In a next step, 16 telephone interviews and six in-depth interviews were conducted to gain a more in-depth insight into the nature of the six strategies and their influences on TPACK. The quantitative analyses indicated positive correlations between the SQD-strategies and TPACK, controlled for general attitudes towards technology. The findings from the qualitative analyses showed that teachers acknowledged the importance of the six strategies. However, the respondents emphasized that some of the six strategies are often underutilized. Based on the quantitative and qualitative results, the discussion provides recommendations to improve the potential of pre-service training to enhance future teachers' TPACK.

Introduction

Teacher candidates' preparation for technology use in schools has been considered as one of the priorities of teacher-training institutions (TTI) in many countries (Robinson & Aronica, 2015; Spector, 2010). Recent calls indicate that to develop pre-service teachers' effective technology integration knowledge, TTIs need to help them connect their knowledge of technology, pedagogy, and content (TPACK) (Mouza, Nandakumar, Yilmaz Ozden, & Karchmer-Klein, 2017; Sun, Strobel, & Newby, 2017). Koehler and Mishra (2009) argue that for technology integration to occur, teachers must be competent in these three forms of knowledge, but more importantly, they must be able to integrate technological, pedagogical, and content knowledge (Schmidt et al., 2009). In the TPACK framework, the importance of making sensible choices in the uses of technology when teaching particular content to a specific target group is emphasized (Voogt, Fisser, Roblin, Tondeur, & van Braak, 2013).

The requirement to better connect pre-service teachers' preparation in the use of technology with pedagogical issues into the curriculum has been noted by several researchers (e.g., Tondeur, Scherer, Baran, Siddiq, Valtonen, & Sointu, 2019; Kaufman, 2015; McKenney & Voogt, 2017). This requirement has resulted in the adoption of various strategies (e.g., e-portfolios, podcasts, field experiences) to develop teachers' TPACK (Tondeur, Scherer, Siddiq, & Baran, (2017); Polly, Mims, Shepherd, & Inan, 2010). However, promoting pre-service teachers' TPACK in an integrated manner contextualized in the curriculum is a complex process that demands various strategies (Reyes, Reading, Doyle, & Gregory, 2017). The strategies TTIs can use to support pre-service teachers' TPACK were identified and reviewed by Tondeur, Van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich (2012), and an overarching Synthesis of Qualitative Evidence (SQD) model was developed to present how these strategies relate to each other (Fig. 1). In a next step, a reliable self-report instrument was developed based on the six key SQD-strategies (Tondeur, van Braak, Siddiq, & Scherer, 2016). This makes it possible to assess to what extent these strategies are actually related to pre-service teachers' TPACK. Finally, interviews were conducted to gain a more in-depth insight into the nature of the six strategies, and their influences on TPACK. The main aim of the current study is to explore the relation between the SQD-strategies to prepare pre-service teachers in their TTIs and TPACK, controlled for their attitudes towards technology.

Background

Pre-service teachers' TPACK

TPACK outlines pre-service teachers' competencies to use Information and Communication Technology (ICT) in classrooms. Specifically, TPACK distinguishes between three main components of teacher knowledge: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). The other components, Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPACK), represent knowledge that is developed through the interactions between and among these bodies of knowledge (Koehler & Mishra, 2009).

In many studies teachers' TPACK is measured through instruments such as self-assessment surveys (e.g., Schmidt et al., 2009), classroom observations (Jin, Wang, Tai, & Schmidt-Crawford, 2016), assessment of products or artifacts (e.g., Koh, 2013), and a combination of several instruments, such as video-clips of instructional practices, follow-up interviews and surveys (Yeh, Hsu, Wu, & Chien, 2017). Generally, two main categories of instruments can be distinguished: self-assessment surveys and performance-based assessments with a focus on lesson planning and/or task/classroom performance (Chai, Koh, & Tsai, 2016).

A well-known instrument to measure teachers' self-perception of their TPACK is the TPACK Survey, developed by Schmidt et al. (2009), in which (pre-service) teachers report their perceptions of confidence in TPACK on a 5-point Likert scale with items that reflect all seven domains of the TPACK framework. This survey has been widely adopted in different teacher training contexts and validated with different pre-service and in-service teacher groups to examine their self-assessed TPACK (e.g., Kaya & Dag, 2013). In the current study, the measurement of TPACK was based on the adapted Dutch version of Schmidt et al.'s (2009) TPACK self-report scale (Authors, 2013). This instrument revealed a general TPACK factor (TPCK, TPK, and TCK) and a specific TK factor (Scherer, Tondeur, & Siddiq, 2017; see Method section).

Several studies have used TPACK instruments to examine predictors of pre-service teachers' readiness to use ICT (Chai, Koh, Tsai, & Tan, 2011). However, only few empirical studies investigated the impact of pre-service teachers' attitudes towards ICT in combination with the support they receive from their teacher training institution on their TPACK (Authors, 2019). Moreover, research focusing on preparing future teachers for TPACK is generally limited to the impact of single strategies (e.g. Banas & York, 2014; Chai, Koh, Tsai, & Tan, 2011). In this study, we consequently focus on multiple strategies pre-service teachers experience in their TTIs.

Teacher training strategies for enhancing pre-service teachers' TPACK

There are different strategies to prepare pre-service teachers for TPACK (e.g., Mouza et al., 2014). Tondeur, Van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich (2012) reviewed the literature aiming to synthesize key themes on how to best prepare pre-service teachers to integrate technology into pedagogy, and content areas (TPACK). According to the findings of this review, twelve key themes need to be in place in the TTIs (Fig. 1). The two outward circles in the SQD-model include the conditions necessary at the institutional level, such as technology planning and leadership, training staff, access to resources, and cooperation within and between the institutions. The inner circle includes six micro level strategies: 1) Role models, 2) reflection, 3) Instructional design, 4) collaboration, 5) Authentic experiences and 6) Feedback. These strategies at the micro-level were examined in the current study.

< Figure 1 >

The existence of role models, the first strategy at the inner circle of the SQD-model, stresses the need of teacher educators to provide good practices in view of TPACK. It seems that observing a teacher (educator) using technology in relation to a specific content area in relation to a specific pedagogical approach can be an important motivator for pre-service teacher to integrate technology in their own practices (Tondeur, Scherer, Baran, Siddiq, Valtonen, & Sointu, 2019). Although this is a central motivator for the development of TPACK (Kaufman, 2015), simply having pre-service teachers watch examples of technological applications is helpful but not sufficient. In this respect, Lavonen, Lattu, Juuti and Meisalo (2006) suggested a mixture of demonstrations and practical work.

Pre-service teachers also need to reflect on the role of technology in education (Strategy 2). This strategy involves discussing and reflecting upon TPACK and the uses of technological applications in education, the opportunities and the risks of ICT uses in education (Ching, Yang, Baek, & Baldwin, 2016; Kimmons, Miller, Amador, Desjardins, & Hall, 2015). Consequently, one of the challenges for a TTI is the engagement of pre-service teachers and teacher educators in conversations about their attitudes regarding the role technology should play in teaching and learning. This might help them see the value of using a particular technology in relation to a specific teaching strategy in a concrete content area and with a specific didactical approach (Baran, Canbazoglu Bilici, Albayrak Sari, & Tondeur, 2019; Mouza et al., 2014).

Several studies also suggest that providing pre-service teachers with the opportunity to learn about technology integration by designing TPACK curriculum materials (Strategy 3) is a promising approach (Authors, 2016b; Lee & Kim, 2014). Similarly, Koehler and Mishra (2009) recommend that learning to design technology-enhanced materials is a key strategy for pre-service teachers' development of TPACK. In this respect, Koehler and Mishra (2009) advocated the use of collaborative design of curriculum materials to foster the development of TPACK. They emphasize the importance of preparing pre-service teachers to make rational decisions when selecting how to use technology when teaching specific content to a specific target group (Koehler & Mishra, 2009).

Research also demonstrated that collaboration (Strategy 4) might mitigate feelings of insecurity when teachers need to design TPACK-related curriculum materials (Tondeur, Pareja Roblin, van Braak, Voogt, & Prestridge, 2016; Koh & Chai, 2016). In this respect, an online environment can be useful in giving pre-service teachers a forum to discuss and exchange points of view with others. An online forum, for instance, has no limitation in class time, and each person has the chance and enough time to explain their opinions (Prestridge, 2010). Collaboration with peers seems to provide a time effective, high-challenge, low threat learning environment for pre-service teachers, contrary to many technology learning experiences that can induce anxiety and failure avoidance (Angeli & Valanides, 2009; Lee & Lee, 2014).

As a fifth strategy, pre-service teachers should also apply their TPACK in authentic settings (e.g., Valtonen et al., 2015). According to Authors (2013), pre-service teachers acknowledged the importance of applying their knowledge about educational technology in real technology experiences. To illustrate, Tearle and Golder (2008) stressed that watching technology being used could not substitute for doing. In this respect, Goktas et al. (2008) pointed out the importance of cooperation between teacher education programs and the K-12 schools.

Finally, the sixth strategy involves ongoing feedback, which is beneficial for developing pre-service teachers' abilities to realize TPACK. At the same time, very few TTIs provide TPACK-related feedback (see e.g., Banas & York, 2014). Lavonen et al. (2006) argue that evaluation data should be continually collected through discussions, questionnaires, interviews, and observations in order to follow how ICT competence develops, and what kind of problems and visions pre-service teachers face and have faced in using ICT. One of the recommendations in the Tondeur et al. (2012) review study was to use an e-portfolio to integrate TPACK assessment and feedback throughout the training process.

From that review study, it became clear that the effective preparation of pre-service teachers requires considering not only the separate strategies in the SQD model, but the relationship between them (cf. Philipsen, Tondeur, Roblin, Vanslambrouck, & Zhu, 2019). For example, the use of role models (Strategy 1) was often perceived as an important condition in the design of TPACK materials (Strategy 3).

Relations between pre-service teachers' TPACK and their attitudes

Pre-service teachers' TPACK has been explored in relation to internal (e.g., personal) factors that facilitated or limited their ICT-use in classrooms (Yeh, Hsu, Wu, & Chien, 2017). Internal factors such as their attitudes are strong determinants for teachers' integration of ICT (Scherer, Tondeur, Siddiq, & Baran, 2018), the emphasis teachers put in developing their students' digital competence (Siddiq, Scherer, & Tondeur, 2016) and their TPACK (Chai, Hong, Teo, 2009). To illustrate, Siddiq, Scherer, and Tondeur (2016) identified positive correlations between teachers' perceived usefulness of ICT and their ICT-use for instructional purposes. Perceived usefulness refers to beliefs about an external object or a method (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012) and comprises one type of attitudes.

In the context of TPACK, the results of the Blackwell, Lauricella, and Wartella (2016) study showed that attitudes toward technology are the most influential factors of TPACK. Different studies even found that among the factors that affect TPACK, teachers' attitudes towards ICT play a key role (e.g., Sang et al., 2012). Existing research supported the idea that educational ICT use and TPACK were strongly affected by specific attitudes, such as attitudes toward ICT in education and ease of use (Pynoo et al., 2011). Interestingly, Tondeur, Scherer, Siddiq, & Baran (2017) show that pre-service teachers in a profile with relatively positive attitudes and high TPACK also report higher scores on the perceived support provided by their TTI. However, little research using teachers' general attitudes towards ICT as a control variable has been conducted. Hence, we believe that, because there is a link between teachers' attitudes towards ICT and their TPACK, it may be useful to use attitudes as a control variable. The current study consequently examined the relations between pre-service teachers' TPACK and the perceived support from TTIs, controlling for their general ICT attitudes.

Purpose of the study

Since the introduction of TPACK, teacher training programs worldwide implemented interventions to examine their impact on pre-service teachers' TPACK, including tracking pre-service teachers' TPACK development in ICT-courses, content-specific teaching methods courses and practicum experiences (Authors, 2016; Jang & Chen, 2010; Mouza et al., 2014). To design deliberate and systematic TPACK-based interventions, research is needed to explore pre-service teachers' perceptions of how well teacher education programs prepare them for effective technology integration in their future classrooms in connection, specifically explaining how organizational factors (the six strategies of the inner circle of the SQD-model) and individual factors (ICT attitudes) work together to influence their TPACK. This research contributes to this desideratum. Specifically, a mixed-method research design is developed to examine the following research questions (RQ):

RQ 1) What are the levels of pre-service teachers' perceived TPACK, focusing on the technology dimensions (T-dimensions)?

RQ 2) To what degree do pre-service teachers perceive the TPACK-related support provided by their TTIs (SQD strategies)?

RQ 3) To what extent are the SQD-strategies related to pre-service teachers' TPACK (T-dimensions), after controlling for their attitudes towards ICT?

RQ 4) How do beginning teachers with less than three years of teaching experience perceive the connections between TPACK and the strategies to prepare pre-service teachers (SQD-strategies)?

Method

A complementarity mixed-method study was adopted in this study, which consisted of collecting, analyzing, and integrating quantitative and qualitative data during the research process (Teddlie & Tashakkori, 2009). In such a complementarity mixed-method design, both qualitative and quantitative methods are used to measure overlapping but also different facets of a phenomenon, yielding an enriched, elaborated understanding (Greene, Caracelli, & Graham, 1989). The quantitative data were first collected from final-year, pre-service teachers to provide a general picture about TPACK (RQ1), the SQD-strategies (RQ2) and the association between SQD-strategies and TPACK, controlled for ICT attitudes (RQ3). Two years later, a selection of the same participants, now beginning teachers, were contacted again to participate in a qualitative follow-up study to refine and explain the statistical results (see RQ 4). By exploring the beginning teachers' individual perceptions, these qualitative interviews provided more in-depth information about the nature of the six strategies. Moreover, these interviews also provided insights into the reasons why the strategies succeed or fail as well as influences on pre-service teachers' TPACK. By doing so, this two-step complementarity mixed-method study seeks elaboration, enhancement, illustration, and clarification of the results from one method with the results from the other method (Greene, Caracelli, & Graham, 1989).

Quantitative study

Sample

A survey was conducted with 688 final-year pre-service teachers from 20 TTIs in Belgium. On average, pre-service teachers were 25.0 years old (SD = 7.7 years); 74.0 % were female.

In total, 57.7 % had obtained a Bachelor degree for higher education institutions, whereas 42.3 % had obtained a teacher training degree from universities or centers for adult learning. Pre-service teachers' specializations covered a broad range of subject domains, including STEM, Arts, and Physical Education.

Instruments

In view of the first research question, the measurement of the TPACK technology-dimensions (i.e., TCK, TPK, TPCK, and TK) was based on the adapted Dutch version of Schmidt et al.'s (2009) TPACK self-report scale (Scherer, Tondeur, & Siddiq, 2017) —a scale that has formed the basis for most of the self-report-based TPACK assessments and that has shown sufficient reliability and some forms of validity (Willermark, 2018). TPACK surveys are still in the process of construct validation, and a reliable and validated instrument for measuring pre-service teachers' TPACK was still lacking (Sang et al., 2016). Therefore, the Scherer, Tondeur, and Siddiq (2017) study examined a measure that assesses pre-service teachers' technology-related TPACK dimensions. In pursuit of crafting a validity argument, they investigated its factor structure and tested it for measurement invariance across gender and educational tracks, two subgroups that may indicate considerable differences. The findings on the factor structure revealed a general factor (TPCK, TPK, and TCK; e.g., "I can choose ICT applications that enhance what and how I teach") and a specific TK factor (e.g., "I can choose ICT applications that support lessons a subject domain"). Given the high correlations among the pedagogical dimensions (i.e., TCK, TPCK, and TPK), the measure could not disentangle four separate factors. Nevertheless, TK represents a unique dimension among the T-dimensions. The general TPACK factor was measured by 14 items that tapped TPCK, TPK, and TCK (Cronbach's α = .94), whereas the TK scale was measured by seven items (Cronbach's α = .89). The pre-service teachers were asked to indicate the extent to which they agreed with statements that referred to the four technology-dimensions on a five-point Likert scale (ranging from *0 = I completely disagree* to *4 = I completely agree*).

To examine the second research question, the SQD-scale used in this study was constructed around the six significant domains of the inner circle (the micro-level) of the SQD-model (Tondeur, van Braak, Siddiq, & Scherer, 2016), a model based on the synthesis of qualitative evidence (Tondeur, Van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012; see Fig. 1): 1) using teacher educators as role models (ROL), 2) reflecting on the role of technology in education (REF), 3) learning how to use technology by design (DES), 4) collaboration with peers (COL), 5) scaffolding authentic technology experiences (AUT), and (6) providing continuous feedback (FEE). The overall scale comprised 22 items each of which were scored on a six-point Likert scale between 0 (*strongly disagree*) and 5 (*strongly agree*). Pre-service teachers were asked to indicate their agreement with statements that reflected on the perceived support in their teacher-training institutions with respect to the six SQD-domains (e.g., "During my pre-service training I saw good examples of ICT practice that inspired me to use ICT" or "I received sufficient help in designing lessons that integrated ICT"). The SQD-scale showed unidimensionality, acceptable item parameters, and little bias in terms of differential item functioning across gender (Tondeur, van Braak, Siddiq, & Scherer, 2016). These aspects are especially important for crafting a validity argument, as they establish the internal structure and the fairness of the assessment (AERA, APA, & NCME, 2014). On the basis of this evidence, we did not differentiate between the six SQD-dimensions as multiple, correlated factors, but represented the SQD-scale as a single factor. The resultant scale showed a high internal consistency, Cronbach's $\alpha = .97$. The items are presented in the Appendix.

Finally, an instrument employed to measure pre-service teachers' general ICT attitudes is referred to as the "General Attitudes toward ICT Scale", a five-item scale developed by Evers et al. (2009). It includes items related to "interest" (e.g., "I want to know more about computers"), "pleasure" (e.g., "I like to talk about ICT to others"), and "usefulness" (e.g., "The use of a ICT is useful to me"). Pre-service teachers were asked to rate the statements on a six-point Likert scale between 0 (*strongly disagree*) and 5 (*strongly agree*). The internal consistency of this scale was acceptable, Cronbach's $\alpha = .82$. This instrument has been used to measure to what extent do the SQD-strategies affect pre-service teachers' TPACK (T-related dimensions), controlled for ICT attitudes (RQ3).

Quantitative analyses

To explore the relations between SQD, ICT attitudes and TPACK (RQ3), we chose a structural equation modeling approach, representing both constructs as latent (unobserved) variables which are indicated by manifest (observed) items (Kline, 2012). This approach is advantageous over approaches that use only manifest scale scores (e.g., sum or mean scores) in that it corrects for measurement error (Byrne, 1998). Based on the variance-covariance matrix, the measurement model containing the representations of constructs as latent variables by manifest variables and the structural model containing the relations between latent variables are specified, and the corresponding model parameters are estimated. To evaluate the extent to which a structural equation model represents the data, the model's goodness-of-fit was evaluated (e.g., Marsh, Hau, & Grayson, 2005). For an acceptable (reasonable) model fit, the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) should have values larger than or equal to .95 (.90), the Root Mean Square Error of Approximation (RMSEA) should be smaller than or equal to .05 (.08), and the Standardized Root Mean Square Residual (SRMR) should be smaller than or equal to .08 (.10). Although these guidelines provide an indication of the goodness-of-fit, Marsh et al. (2004) warned against using them as golden rules, because they are, for instance, influenced by the number of latent variables in a structural equation model, the structure of the measurement models, the treatment of item responses (i.e., as continuous or categorical), and the estimation procedure (Rhemtulla et al., 2012).

In all analyses, robust maximum likelihood estimation (MLR) was used to estimate standard errors and $\chi 2$ statistics that were robust against deviations of the data from normality. Under this estimation, missing data were handled with the full information maximum-likelihood procedure, assuming that missing data occurred randomly (Enders, 2010). Overall, only 3.3% of the responses to the TPACK items were missing; missing values did neither occur for the items measuring the SQD-dimensions nor the general ICT attitude items.

One major concern with the use of structural equation models refers to the balance between the number of parameters estimated and the number of data points available given the sample size (Lei & Wu, 2012). The overall number of items to represent SQD (22 items), TPACK (14 items), TK (7 items), and general ICT attitudes (5 items) is high and more than four response categories for each scale were used. A structural equation model that measures SQD, TPACK, TK, and general ICT attitudes by the observed (categorical) item responses and estimates the correlations between the resultant unobserved (latent) variables comprises more than 200 model parameters, as compared to the available sample size of $N = 668$. The resultant model parameters and their standard errors would not be trustworthy. We therefore chose to perform item parceling–a strategy that creates three continuous item indicators by summarizing items within a scale in parcels. Specifically, if the factor structure of a scale is known and information on item factor loadings is available, items within a scale can be grouped together based on their factor loadings (Little, Rhemtulla, Gibson, & Schoemann, 2013). For instance, the first parcel may comprise two items, the one with the highest factor loading and the one with the lowest; the second parcel comprises the item with the second highest and the second lowest factor loading, and so forth. The result of this strategy is a set of three parcels (e.g., the means of the items that are grouped together) which can be used as manifest (continuous) indicators of latent variables. This procedure results in an exact fit of the single-factor measurement models, improved goodness-of-fit statistics of the entire structural equation model, and less biased structural parameters (Bandalos, 2002). In fact, several simulation studies could not identify substantial differences between parameters of models that used the raw item responses and parcels, when the underlying scale was unidimensional (e.g., Nasser-Abu Alhija & Wisenbaker, 2006; Sass & Smith, 2006). Yet, it is critical that the factor structure of a scale is known to create meaningful parcels and avoid bias in structural parameters (Bandalos, 2002; Little et al., 2013). We therefore analyzed the factor structure of the core constructs in this study first and performed parceling in a second step. All structural equation models presented in this study were based on item parcels. We, however, compared the results obtained from these models with models that are based on item responses to check for the robustness of our findings.

Qualitative study

Respondents

For the qualitative in-depth interviews, we selected final year pre-service teachers from three teacher training institutions who filled in the questionnaire of the current study and contributed to focus group discussions of a previous study (see Authors, 2016). These respondents were first contacted again by phone. Based on the results of telephone interviews with these 16 beginning teachers, six cases were selected for in-depth exploration of the connections between beginning teachers' instructional uses of technology and their pre-service learning experiences. Selection criteria included: 1) regular (i.e., daily or weekly) use of educational ICT use; 2) representation of the three teacher education institutions involved in the previous study; 3) diversity in teaching experience, grade level, and gender; and 4) willingness to participate in the study. These in-depth interviews provided insights into the reasons why the strategies succeed or fail as well as how the strategies influenced their TPACK. Table 1 provides an overview of the background characteristics of the six teachers who participated to the in-depth interviews in the current study.

< Table 1 >

The previous research aimed at understanding the strategies for technology integration adopted by each of the three TTIs in Flanders (Belgium). Each of the TTI included in the current study adopted a different strategy to prepare pre-service teachers for ICT integration. TTI 1 decided to move from a separate ICT course focusing on technological skills towards a more integrated approach. The ICT coordinator, previously responsible for the development of pre-service teachers' technical skills through, now teaches exemplary ICT-rich lessons across different subject areas. The goal of these lessons is to connect ICT with content (TCK). In TTI 2, a course on the educational use of ICT was introduced in the first year of the program. This course centers specifically on the development of Technological Pedagogical Knowledge across content areas (TPK). In TTI 3, the ICT team decided to move from a separate technology course to integrate technology across the curriculum; however, the results of a previous study indicate that student teachers and teacher educators perceive that there was no so much evidence of educational ICT use in the program (Authors, 2016).

Procedure and qualitative analyses

Open-ended questions were formulated for the six key strategies. In order to facilitate the interview each strategy was presented on a separate card on the table in front of the interviewee. In line with the strategies in the SQD-model, it was decided not to stress the technical aspects required for the training of pre-service teachers in the use of technology in education and to focus on the instructional and pedagogical tasks associated with the organization of technology within the learning environment. The actual interview lasted one hour to one hour and a half. All interviews were audiotaped after obtaining informed consent from the participants. The main coding categories to structure the answers of the respondents were derived from the six key strategies of the Tondeur, Van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich (2012) review (deductive approach). Sub-codes were assigned to segments of data that described a sub-theme observed in the text. Two coders individually coded one interview. Subsequently, the codes were compared in order to discuss disagreements and develop a shared coding scheme. During the data analysis of the other respondents, the coding was discussed among the researchers to safeguard the quality of the interpretative data. All disagreements were resolved through discussion. Finally, patterns and differences across the respondents were identified through constant comparisons.

Results

The main aim of this study was to explore the impact of the support pre-service teachers perceive on their TPACK. In this section, we first present the quantitative results with respect to the relation between pre-service teachers' perceptions of the extent to which they experience the six strategies of the SQD-model and the perceptions of their TPACK. Second, we focus on the qualitative analyses regarding 1) the adoption of these strategies and 2) the connections between beginning teachers' TPACK and the support provided by their pre-service teacher education programs.

Descriptive statistics, measurement models, and parceling strategy

Table 2 details the descriptive statistics of the SQD, TPACK, TK, and general ICT-attitudes scales. It is noteworthy that the sample of pre-service teachers exhibited highly positive attitudes toward ICT in general; hence, possible negative attitudes toward ICT may not necessarily bias pre-service teachers' responses to the TPACK, TK, and SQD items. The distributions of all scales showed sufficient variability around their means with slight deviations of the resultant scale mean scores from normality. The latter observation necessitates robust estimation methods in subsequent models (e.g., MLR estimation).

< Table 2 >

The factor structures of the scales used in this study were examined using confirmatory factor analysis (CFA). A CFA has been chosen because the scales were all validated in previous studies (Scherer, Tondeur, & Siddiq, 2017; Tondeur, van Braak, Siddiq, & Scherer, 2016); hence, prior knowledge and assumptions on their factor structures existed. Item responses were treated continuously, as they were based on at least five response categories (Rhemtulla, Brosseau-Liard, & Savalei, 2012).

A single-factor model of the *SQD-scale* exhibited good model fit, χ^2 (209) = 538.0, $p < .001$, CFI = .961, TLI = .957, RMSEA = .048, 90%-CI RMSEA = [.043, .053], SRMR = .027. Based on the theoretical SQD-framework and the size of factor loadings, items measuring the SQD-dimensions REF and DES were parceled to one parcel by taking their mean. Following the same procedure, items measuring the SQD-dimensions COL and AUT were parceled, and so were items on FEE and ROL. This parceling procedure resulted in a perfectly fitting measurement model of SQD with considerably high factor loadings (parcel P_{11}: $\lambda = .97$, parcel P_{21}: $\lambda = .95$, parcel P_{31}: $\lambda = .95$).

The existing empirical evidence suggests high factor correlations among the *TPACK-subscales* TPCK, TPK, and TCK for the same sample used in the current study ($\rho = .98$-.99; Authors, 2017); hence, a single-factor described the structure of these three subscales well, χ^2 (77) = 162.2, $p < .001$, CFI = .976, TLI = .971, RMSEA = .041, 90%-CI RMSEA = [.032, .050], SRMR = .028. In a subsequent step, we parceled items measuring TPCK (parcel P_{12}: $\lambda = .93$), TCK (parcel P_{22}: $\lambda = .90$), and TPK (parcel P_{32}: $\lambda = .90$).

A single-factor model describing the structure of the *TK-scale* exhibited acceptable goodness-of-fit indices, χ^2 (14) = 51.7, $p < .001$, CFI = .975, TLI = .963, RMSEA = .064, 90%-CI RMSEA = [.046, .083], SRMR = .025. Considering the factor loadings resulting from this model, we created three parcels with substantially high factor loadings (parcel P_{13}: $\lambda = .83$, parcel P_{23}: $\lambda = .89$, parcel P_{33}: $\lambda = .82$).

Finally, the *general attitudes toward ICT scale* was not represented well by a single-factor model, χ^2 (5) = 115.2, p < .001, CFI = .890, TLI = .780, RMSEA = .179, 90%-CI RMSEA = [.151, .208], SRMR = .067. Modification indices uncovered a significant residual correlation between two items (GATT3 and GATT4). These two items were parceled, and the remaining three items were divided into two parcels based on their factor loadings. The resultant single-factor model indicated sufficiently high factor loadings of the three parcels (parcel P_{14}: λ = .90, parcel P_{24}: λ = .81, parcel P_{34}: λ = .70).

Overall, the analysis of the measurement models describing the SQD, TPACK, TK, and general ICT attitudes scales led to the creation of three parcels for each scale; these parcels exhibited considerably high factor loadings. All subsequent analyses were based on the measurement models that used parcels. Table 3 summarizes the resultant parcels.

< Table 3 >

SQD–TPACK relations

To examine the impact of SQD on the two TPACK-related dimensions TPACK and TK, we specified a structural equation model with measurement models based on the previously created parcels. This model considered TPACK and TK as outcome variables and SQD as the predictor (Model 1; see Figure 2). The model fitted the data reasonably well, χ^2 (24) = 116.5, p < .001, CFI = .981, TLI = .972, RMSEA = .075, 90%-CI RMSEA = [.062, .089], SRMR = .039. SQD was significantly and positively related to TPACK (β = .57, *SE* = .04, p < .001) and TK (β = .45, *SE* = .04, p < .001), explaining about 32 % and, respectively, 21 % of variance. Testing the unstandardized path coefficients for TPACK and TK for quality with the help of the Wald test revealed that the relation between TPACK and SQD was significantly higher than the relation between TK and SQD, $\Delta\chi^2$ (1) = 18.6, p < .001.

As described earlier, pre-service teachers' general attitudes toward ICT may be significantly related to the TPACK-subscales and SQD. We therefore added this scale as a control variable to the structural equation model (Model 2; see Figure 3). The resultant model exhibited an acceptable goodness-of-fit, χ^2 (48) = 175.1, p < .001, CFI = .979, TLI = .971, RMSEA = .062, 90%-CI RMSEA = [.052, .072], SRMR = .041. The path coefficients between SQD and TPACK, and SQD and TK decreased slightly, because pre-service teachers' general ICT attitudes were significantly and positively related to SQD (β = .28, *SE* = .04, p < .001), TPACK (β = .44, *SE* = .04, p < .001), and TK (β = .61, *SE* = .04, p < .001). Once again, the Wald test of path coefficient equality indicated a significantly stronger relation between SQD and TPACK than between SQD and TK, $\Delta\chi^2$ (1) = 19.4, p < .001.

Overall, the impact of SQD on TPACK and TK was positive; it was significantly larger for TPACK than for TK, even after controlling for pre-service teachers' general ICT-attitudes.

< Fig. 2 & 3 >

Robustness checks

To test the robustness of our findings, we specified Model 1 with item responses and compared the results to the model that uses parcels as the manifest indicators of the latent variables. This model showed positive and significant relations between SQD and TPACK (β = .54, *SE* = .04, p < .001) and SQD and TK (β = .44, *SE* = .04, p < .001), which did not deviate substantially from the relations obtained from the model with parcels. The same result emerged for Model 2 (SQD-TPACK: β = .41, *SE* = .04, p < .001; SQD-TK: β = .29, *SE* = .05, p < .001). These findings lend evidence for the robustness of the SQD-TPACK relations across different types of manifest variables in the measurement models.

In-depth analysis of the SQD-TPACK relations

The telephone interviews with 16 pre-service teachers and the in-depth interviews conducted with six beginning teachers revealed teachers' perceptions about the connections between TPACK and support provided by their TTIs, including role models, reflection opportunities, instructional design, collaboration, authentic experiences, and feedback.

Role models

The analysis revealed that the ICT-applications explored in three TTIs proved to be useful when starting their teaching practice. Two teachers from TTI 1 claimed that they benefited from the lectures in different subject areas that demonstrated the teaching and learning potential of specific ICTs. To illustrate, one of the teachers designed a WebQuest about the solar system for his pupils, an application he had learned about during his pre-service education. A WebQuest is an inquiry-oriented lesson format in which most or all the information that learners work with comes from the web. The results showed that role models - embedding the pedagogical use of ICT in lectures, curriculum content and assessment - provided TPACK understanding in TTI1 and mirrored the respondents' use of technology.

The analysis also revealed that all the teachers from TTI2 and TTI3 are seldom confronted with inspiring examples of TPACK. They argued that teacher educators seemed to lack ICT-competencies themselves in order to provide clear examples. For example, one of the teachers stated: "*They (the teacher educators) stood in front of their PCs and worked with a beamer. But, this is not the approach they want in primary education, since they want children to know how to suitably handle these media, which they actually did not show*." Unlike TT1 that provided a range of ICT embedded examples and field work, TTI2 included only a skill based first year course (TK). In order to develop a sound understanding of TPACK, two teachers from TTI2 felt that concrete examples of how technology could be used in teaching and learning processes were missing in their pre-service training. Teachers noted that teacher educators often seemed to lack ICT-competencies themselves.

Reflection

It becomes clear from the interviews that the TTIs gave ample attention to reflection. However, reflections on the integration of ICTs in education were limited. One of the teachers stated: "*We have practiced a lot of reflection, but not about the role of ICT in education*." He refers to the focus on "reflective practice" in their TTI as a process that facilitates teaching, learning and understanding. Most of the teachers indicated that they would prefer an explicit focus on TPACK during their teacher training. One teacher, for example, commented that reflecting on educational ICT-practice could have helped her to further integrate ICT: "(…) *reflection would have been nice. Then they could have helped us from another angle: have you maybe already tried or thought about integrating ICT*?"

Instructional design

For theme 3 the teachers from TTI1 and TTI3 refer to classes in which they explored a few ICT-applications. In TTI1, for example, the ICT-coordinator taught every semester one peculiar lesson in every teacher training section to exemplify how specific technology may fit with their subject domains. Subsequently the teachers got an assignment to put this application into practice. One of the teachers explained: "*We got assignments, e.g. on interactive PowerPoint and Excel, so that we can now actively use these.*"

The pre-service teachers from TTI1 also reported about an assignment including the design of five ICT-rich lesson plans. At the same time, they mentioned that additional support was needed to design such TPACK materials. The design components in the other TTI's can be only illustrated by a couple of examples mentioned by Walter and Marie. To illustrate, the pre-service teachers in TTI3 had to design a classroom setting with a favorable arrangement for ICT. Nevertheless, the pre-service teachers from TTI1 and TTI3 indicated that this mattered for their present practice.

Collaboration

The beginning teachers felt that their pre-service education did not give them sufficient opportunities to work together, to share ideas, to discuss about the role of ICT in education, etc. During the interviews, most of the teachers made clear that everybody worked individually during their teacher training in the field of TPACK. Both teachers from TTI3 could only give just one example to illustrate that collaboration was structurally integrated for an ICT-related assignment: "*We had to design a classroom with a favorable setting for ICT*". The analysis showed that they would have preferred to do the ICT-related assignments in groups so as to learn from each other. One of the teachers commented: "*I would like to do these assignments in pairs. You get for instance that class on interactive Excel, in one session, and then: do this at home.* (...) *You could actually learn much more from each other than by messing around about it for a full Sunday*." On the other hand, one teacher indicated that informal cooperation took place during his teacher training. To illustrate, the results show that the pre-service teachers were willing to help each other with ICT-related problems, such as issues with the use of the electronic learning environment.

Authentic experiences

As stated by the teachers from TTI2 and TTI3, it became clear that the use of ICT during their internship was complementary noncommittal. They eventually only integrated ICT during their training lessons when imposed. For example, one of the teachers commented: "*During my final internship I had to work with a digital board. Out of the blue I had to work with such a board, which I obviously couldn't. (...). Otherwise I never used any ICT during my internship.*" Yet, in TTI3 the use of ICT was compulsory during the last internship. Although one of the teachers mentioned that ICT was rather superficially dealt with during that period, different teachers stated that they found it useful to try out what ICT might yield. To illustrate: "*At the end of my pre-service education I used more ICT. You feel more confident, you dare to use it, and you also score!". At the same time, the beginning teachers stressed the need for more authentic tasks wherein they could explore the possibilities of technology*".

Feedback

According to the findings, an evaluation of TPACK only rarely took place. One of the beginning teachers stated: "*Actually they seldom or never focused on our ICT integration*." As mentioned before, the pre-service teachers from TTI1 and TTI3 did get ICT-related assignments, in line with TPACK. These assignments were assessed, but during internship periods the assessment was given by the teacher trainers on a rather casual basis. In the eyes of the beginning teachers their student advisers were better placed to give them feedback on a continuous basis. For example, one of the teachers stated: "*The lecturers came occasionally, but the student advisers were always present, so they were in the best position to tell you what you did, and how* (…)".

< Table 4 >

The qualitative analysis of the interviews overall revealed that a common strategy implemented at TTI1 was providing exemplary ICT-rich lessons (role models) across different subject areas (PCK). Interestingly, the respondents from the three TTIs claimed that reflection on TPACK was missing. Although the beginning teachers felt additional support was needed to design TPACK materials, they all valued the opportunity to apply their knowledge about ICT in authentic experiences during the internship. Most of the respondents reported that the mentor encouraged them to use technology during the internship (authentic experience) and in some cases they provided feedback (for an overview see Table 4). These results clearly demonstrate the role of mentors during the internship. Encouraging collaboration was limited for connecting technology, pedagogy, and content in a specific context.

Discussion

This study contributed to the literature by revealing the association between teacher education strategies and future teachers' TPACK. The findings of the quantitative data collection showed a positive and significant relationship between pre-service teachers' TPACK and their perceptions of the SQD-strategies implemented in their TTIs, even after controlling for pre-service teachers' general ICT attitudes. Interestingly, the relation between SQD and TPACK was significantly stronger than that between SQD and TK. It seems that TTIs in Flanders are moving from ICT-courses focusing primarily on technological knowledge towards a more integrated approach in developing the knowledge, skills and dispositions of their pre-service teachers' consistent with the TPACK framework (cf. Mouza et al., 2014).

Qualitative results revealed the importance of the SQD-strategies at the micro level. Specifically, it appeared that teacher educators modeling ICT-use was an important motivator for enhancing future teachers' TPACK. The respondents referred to concrete examples of how technology can be used across various subject domains (cf. Ching, Yang, Baek, & Baldwin, 2016; Authors, 2015). Modeling technology integration activities would enhance pre-service teachers' repertoire of possible strategies they could use in their future classrooms (Chai, Koh, Tsai, & Tan, 2011).

Clearly, the results demonstrated the importance of the SQD-strategies for enhancing pre-service teachers' TPACK, but at the same time that not all of them were sufficiently addressed during their pre-service learning experiences. The findings from the interviews revealed the lack of concrete examples on how content, and technology knowledge could be inter-related. Therefore, pre-service teachers' technology learning experiences should be connected with their disciplinary areas and subject-specific pedagogies. One of the reasons is that teacher educators do not feel adequately prepared to effectively integrate technology into their classrooms (Mirzajani, Mahmud, Ayub, & Wong, 2015). This suggests that teacher educators should be provided with professional development in order to infuse TPACK in their practice (see Authors, 2017). The lack of ICT-competent teacher educators can also be the reason why the respondents felt that their pre-service education did not give them sufficient support to design ICT-rich lessons and to provide continuous feedback (cf. Lee & Kim, 2014).

Implications of the study

The current study presents evidence of the potential influence of the six strategies of the SQD-model on pre-service teachers' TPACK. At the same time, the findings also reveal some challenges. The results suggest that not all of the strategies were sufficiently addressed during their pre-service learning experiences. To illustrate, the respondents felt that their pre-service education did not give them sufficient support to design, reflect, and evaluate teachers' TPACK. Therefore, the SQD strategies need to be infused as a systemic and systematic process (cf. Albion, Tondeur, Forkosh-Baruch, & Peeraer (2015), as demonstrated in the SQD model (Fig. 1). In this respect, Koehler and Mishra (2009) advocated collaborative design of curriculum materials to foster the development of TPACK (see also Becuwe, Roblin, Tondeur, Thys, Castelein, & Voogt, 2017). A design team can be described as a group of two or more pre-service teachers who (re) design TPACK curriculum materials together (Voogt, Pieters, & Handelzalts, 2016). It means that pre-service teachers reflect together on how ICT can support the content and pedagogical aspects of their practice in order to attain TPACK. In a next step, they design ICT-rich lessons and experiment with them and, finally, reflect on the results. This final step is important as the overall comments emerging from the interviews indicated that feedback with respect to TPACK was one of the main problems in TTIs. According to Boulton (2014) ePortfolios seemed to be useful in giving pre-service teachers a forum to discuss, exchange opinions and provide feedback. Moreover, ePortfolios could continue to support the professional development of teachers during their teaching career (see Prestridge, 2010). All these strategies are identified in the inner circle of the SQD model to prepare pre-service teachers for technology use.

Limitations of the study and recommendations for future research

In order to implement the strategies mentioned above, the development of pre-service teachers' TPACK needs to be infused as a systemic and systematic process, as demonstrated in the SQD model. While this was beyond the scope of the current study, future research is needed to analyze the combined impact of school-level characteristics, beginning teacher characteristics, and their pre-service experiences. Moreover, the results of the interviews have a limited generalizability. However, the added value lies in the deeper, richer account and the broader context, even though the results cannot simply be generalized to other institutions or educational levels, for instance. At the same time, the data sources used in this study were limited to self-report data in the surveys and interviews. Future research may integrate observations in pre-service teachers' teacher education courses and field-experiences to examine how specific SQD strategies impact the integration between specific types of technology use (TK), to specific subject areas (CK) and pedagogical approaches (PK) in a specific context. Stimulated recall interviews can be a promising approach where the (pre-service) teacher is asked to verbalize his/her thoughts while looking at his/her own behavior on video. By doing so, future research should also consider a wide range of ICT related characteristics of (pre-service) teachers (e.g. technological competencies, ICT self-efficacy, ICT attitudes). This can lead to a more nuanced and in-depth insight in the different TPACK dimensions. Future research can also explore how such strategies impact TPACK over time with longitudinal studies. Finally, other factors can be included in future models, such as pre-service teachers' pedagogical beliefs (cf. Sang, Valcke, van Braak, & Tondeur, 2009) and their self-efficacy, to provide a richer account on the impact of the strategies implemented by TTIs.

Conclusion

The positive and significant association between pre-service teachers' perceived TPACK and their perceptions of the strategies implemented in their TTIs showed that pre-service training plays critical roles in enhancing TPACK. Additionally, in-depth analysis of the SQD-strategies showed increasing need for a more integrated and connected pre-service teacher learning experiences for effective technology integration. More exemplary TPACK lessons and experiences are needed to help future teachers understand the connections between their content areas, content-specific pedagogies, and technologies. This study also supports the importance of providing more support to pre-service teachers to design TPACK curriculum materials they can explore during field practices. Finally, monitoring pre-service teachers' practical TPACK development both during their coursework and field experiences would help examine how they enact their TPACK in action.

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