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**Transforming pre-service teacher education through Virtual Exchange: a mixed methods analysis of perceived TPACK development**

**Abstract**

Across the globe teachers are increasingly using online communication tools to bring together learners from different countries, and offer them social interaction opportunities to learn a new language or a new skill via Virtual Exchange (VE). While there is some mostly anecdotal evidence of VE on satisfaction and improving language skills, few studies have investigated the impact of VE on pre-service teachers' TPACK development using mixed methods. To remedy this gap, in this study we used a robust pre-post design of TPACK in two VEs with 55 pre-service teachers to explore its impact on their perceived TPACK development. Using k-means cluster analysis of TPACK, we identified three groups of participants who reported high-medium-low TPACK gains. We then triangulated these gains with the actual lived experiences and reflections of 25 participants by analysing over 400 online diary entries. Our findings indicated that most participants reported positive TPACK gains but the narratives of their VE experiences differed widely. The results of this study can inform the design of VE and can help identify pre-service teachers who might need more support when learning and collaborating online.

*Keywords*: Virtual Exchange; online collaboration; pre-service teachers; perceived TPACK development; technology integration; mixed method

**Introduction**

The importance of integrating the use of technology into teacher training has been widely recognised (e.g., Garcia-Esteban, Villarreal & Bueno-Alastuey, 2019; Raig, 2015; Teo et al., 2019). Almost all existing frameworks of the skills critical for success in the twenty-first century include technological competencies (Ananiadou & Claro, 2009). At the same time research evidence suggests that among the factors that influence pre-service teachers' adoption of technology is not simply their access to technology, but their self-efficacy in working with it (e.g., Farjon, Smits & Voogt, 2019; Yildiz Durak, 2019). Thus, it has been argued that pre-service teachers need to be explicitly encouraged to develop their own practices for technology integration (Yildiz Durak, 2019).

One recognized model for understanding the effective use of technology in teaching is the technological pedagogical content knowledge (TPACK) model (Mishra & Koehler, 2006). In line with the TPACK model, many argue that the preparation of teachers for technology integration should provide them with practical experience in applying technology to specific content areas and pedagogical approaches (e.g., Author B, 2013). One possible way of fostering pre-service teachers' TPACK skills is to involve them in Virtual Exchange (VE). VE is a method of engaging students within their programmes in online international collaboration projects with partner classes (Author C, 2016). In the context of teacher training, pre-service teachers are expected to work together online with their VE partners, discuss issues related to their curricula, and collaborate in using technology to create learning resources and activities.

A number of studies have shown that VE has the potential to contribute to TPACK skills as perceived by pre-service teachers, and thus contribute to sustained technology use in their future teaching (e.g., Author B, 2019; Bueno-Alastuey, Villarreal & García Esteban, 2018; Dooly & Sadler, 2013;). However, most existing research on VE has so far focused on language and intercultural rather than technological competencies (Dooly, 2017). Moreover,

most VE studies have predominantly used descriptive or qualitative research approaches (e.g., Antoniadou, 2011; Bueno-Alastuey, Villarreal & García Esteban, 2018; Dooly & Sadler, 2013).

There is abundant evidence that pre-service teachers do not feel adequately prepared to integrate technology in their future teaching (e.g., Raig, 2015; Tatli & Kilic, 2016; Teo et al., 2019). It is therefore important to examine the impact of specific technology integration practices, such as VE, on pre-service teachers' perceived TPACK development, thus testing the empirical basis for the inclusion of such practices within the teacher training curriculum.

To that end, in this study we aim to explore the impact of two VEs on pre-service teachers' perceived TPACK development. Our particular contribution lies in our use of mixed methods. Quantitative TPACK questionnaire data from 55 pre-service teachers were triangulated with qualitative accounts of lived experiences from the online diaries of 25 pre-service teachers. This permitted a fine-grained comparison of the views of VE participants across different levels of reported TPACK gains.

**Literature review**

*Perceived TPACK development in Virtual Exchange (VE)*

VE offers a dialogic space where pre-service teachers can use digital technologies to (co-)design and evaluate learning resources while reflecting on the affordances and constraints of such tools, thereby improving their TPACK competencies. Several studies exploring the development of pre-service teachers' technological skills within VE found a positive effect for VE practices on technological skills and/or TPACK (e.g., Antoniadou, 2011; Chen, 2012; Dooly & Sadler, 2013). Among the three most highlighted positive outcomes are pre-service teachers' realisation of the educational value of technology (e.g., Chen, 2012), development of self-efficacy in working with technological tools, and the development of critical thinking

when working with technology (e.g., Dooly & Sadler, 2013; Bueno-Alastuey, Villarreal & García Esteban, 2018).

Though mixed, emerging evidence suggests a possible relationship between TPACK knowledge and pre-service teachers' conceptual and critical thinking. For example, Antoniadou (2011) showed that while pre-service teachers generally perceived their VE experience as positive, some of them reported difficulties of using technology as part of VE. Their lack of experience in using technology hindered pre-service teachers from developing a conceptual understanding of its pedagogical value. In contrast, Hao & Lee (2017) found that pre-service teachers who had greater knowledge of technology and a higher awareness of Web 2.0 tools showed more concern around how to use these tools to maximise the benefits for learners.

However, while VE has generally been recognised as a potent tool for learning, as pointed out by Antoniadou (2011) VE participants face a number of challenges that may affect their VE experience. While investigations of TPACK development as part of VE are limited, most reported challenges are social and cultural in nature, rather than technology-related. Some of these studies highlight complexities in the nature of VE collaboration, which requires establishing a common representation of the problem at hand, as well participants' personal commitment to VE and their willingness to build relationships (e.g., Barron, 2000; Lee, 2009). Other reported VE challenges include differences in participants' timetables and communication patterns, as well as the fact that pre-service teachers' participation in VE is not always recognised or rewarded as an accredited part of their teacher training programmes (Helm, 2015; O'Dowd & Ritter, 2013).

**TPACK**

TPACK is an established model that describes three basic areas of teacher knowledge (content, pedagogy and technology) while the overlapping parts of the model show integrations between these three areas (Mishra & Koehler, 2006). TPACK has been widely used in educational research and formed the basis of a number of validated instruments (e.g., Schmidt et al., 2009). Increased research attention to the TPACK model has also helped identify some weaknesses. Most critical evaluations of the model focus on its reliance on self-report (e.g., Dobozy & Campbell, 2016). Another criticism of the TPACK model (e.g., Koh, Chai & Tsai, 2013; McGrath, Karabas & Willis, 2011) concerns the limited empirical evidence of the interrelationships between TPACK constructs and the extent to which these constructs overlap. For example, Koh et al. (2013) showed that in-service teachers' perceptions and conceptualisations of TPACK were not as evident as technological knowledge and pedagogical knowledge. Despite these criticisms TPACK remains one of the most widely accepted frameworks for understanding teaching with technology (e.g., Rosenberg & Koehler, 2015).

Studies in the emergent field of VE research have predominantly used descriptive or qualitative approaches. There has been limited focus on the TPACK development of pre-service teachers. A notable exception is the study of Author B (2020) with 622 pre-service teachers in 23 VEs using pre-post TPACK testing as part of Blinded XYZ project. The study found that although participants on average increased their TPACK during their VE, perhaps surprisingly this growth in TPACK did not differ significantly from that of a control group, which received no exposure to VE. Although this study provided some supportive large-scale quantitative evidence that VE facilitates TPACK development, the study fell substantially short of explaining why some pre-service teachers benefited from VE more than others, which might account for this finding.

*Research questions (RQ)*

The present mixed methods study attempts to fill the current gap in understanding the impact of VE on pre-service teachers' perceived TPACK development, by using more fine-grained qualitative approaches (i.e., diary analysis) across two specifically selected VEs from Blinded XYZ project (Author B, 2020), to explore how perceived TPACK gain influenced their views on VE and on the use of technology in the classroom. As such, the RQs of this study are as follows:

1. What impact do pre-service teachers believe VE has made on their TPACK skills development?

2. To what extent do pre-service teachers at different levels of perceived TPACK gain report different experiences of working in the VE, and why?

**Methods**

*Setting and participants*

This mixed methods study aimed to analyse the data from two VEs with 55 pre-service teachers. These two VEs were part of the large-scale European Blinded XYZ project carried out in 2017/2018, which collected and analysed data from 23 VEs involving over 1000 pre-service teachers in 34 universities (Author B, 2019). For a detailed description of how the VEs were designed, implemented, supported, assessed and evaluated, see Author B (2019, 2020). In this study we particularly focused on two distinct VEs (i.e., mother tongue vs. lingua franca). In line with Robinson (2014), we aimed to use the data from multiple VEs to obtain heterogeneity in participant profiles and contexts aiming to produce more generalisable conclusions about the commonalities and differences found across the two diverse VEs.

VE1 involved seven Portuguese and five Brazilian master's level pre-service teachers studying special needs education. In both classes most participants were in part-time

employment. The VE was carried out over three months, with Portuguese as the working language. The main tasks the pre-service teachers had to complete as part of VE1 were as follows: (1) preparing individual videos of one another to introduce themselves to their VE partners which they posted on Moodle; (2) exploring the selected educational topic in the context of the two countries; (3) collaboratively preparing a presentation.

VE2 was a substantially larger implementation relative to VE1 between 36 second-year undergraduate Spanish and seven Swedish students studying to become primary school teachers. The VE lasted six weeks, with English as the working language. The main tasks for VE2 were structured in a similar way to VE1: (1) exchanging information and resources within their classroom-based programme; (2) comparing and analysing cultural practices; (3) preparing a joint lesson plan.

Both VEs used Moodle to coordinate learning activities and for the pre-service teachers to share their work. VE participants were also encouraged to use other tools (e.g., Skype, Google Docs) to communicate with each other during the VE.

### *Instruments*

TPACK was measured at the beginning and end of each VE using an online questionnaire (see Author B, 2019) adopted from Schmidt et al. (2009). The original questionnaire was shortened to 17 items, as participants also had to complete four diary entries. In this study the TPACK instrument consisted of one overall TPACK construct, and four main sub-constructs, whereby a Likert response scale of 1 (=totally disagree) to 5 (=totally agree) was used. The Cronbach's alpha scores for the four subconstructs ranged from $\alpha = .73$ to $\alpha = .85$.

Besides the pre- and post- questionnaires, participants completed a learner diary at four stages during the VE with prompts focusing on the online collaboration experience and its

relationship to the development of TPACK (*see Appendix*). The use of diaries allows researchers to gain an in-depth understanding of reflective and lived experiences of participants while they are engaging with and reflecting on tasks (Beckers, van der Voordt, & Dewulf, 2016; Wallin & Adawi, 2018). While there are common self-report and recall issues with diaries, a wealth of studies have found that diaries can complement other methods in unpacking the complex, diverse learning experiences of learners.55 pre-service teachers who took part in the study made 1100 diary entries in total, leading to 41566 words. 240 entries were made by VE1 participants, and 860 entries were made by VE2 participants.

### *Procedure and data analysis*

We first analysed the quantitative self-reported TPACK scores for the 55 pre-service teachers at the beginning and at the end of the two VEs. As the two selected VEs were diverse in terms of their cultural composition and language use, we then compared the relative total TPACK gain between VE1 and VE2 using an independent-sample T-test in SPSS 24.

Next, we conducted k-means cluster analysis in line with Author B (2018) and Author A (Submitted), to ensure that a representative sample was selected for further qualitative analysis. Cluster analysis enabled us to divide the sample of 55 participants into three clusters based on their reported TPACK gain. The resulting clusters are indicated in Table 1.

➔ *Insert Table 1 about here*

Cluster 1 (12.73% ($n$ = 7), TPACK gain ranging between 0.8 - 1.8) included participants with high perceived TPACK gain. Cluster 2 (56.36% ($n$ = 31), TPACK gain ranging between 0.0 - 0.8) contained participants with medium perceived TPACK gain. Participants with low perceived TPACK gain were included in cluster 3 (30.90% ($n$ = 17), TPACK gain < 0.0). All participants in Cluster 3 reported negative TPACK gains.

A sample quota, based on cluster and number of VE participants, was then used to select the learner diaries completed at all four stages of the VE for qualitative analysis. Following recommendations by Author B (2018), we aimed to balance the number of participants in each of the three respective clusters. As the pre-service teachers reporting low and medium TPACK gains outnumbered the pre-service teachers who reported high gains, all participants identified as having high perceived TPACK gains ($n = 7$) were included in the analysis. Thus, the learner diaries of 25 participants were selected. Of the 25 participants, 7 were in cluster 1 with high perceived gains (29%), 9 were in cluster 2 with medium perceived gains (36%) and 9 were in cluster 3 with low perceived gains (36%).

A deductive thematic analysis (Braun & Clarke, 2006) of the qualitative diary entries of the selected participants in the three clusters was conducted in NVIVO 11. 465 diary entries were analysed in total. An independent researcher (first author) unrelated to Blinded XYZ project initially analysed and coded the data. The development of codes was theoretical and structural, meaning they were formulated according to the two research questions, TPACK and VE. The codes and analyses was then discussed for sense checking and contextualisation with the second and third author who were part of the research team of Blinded XYZ project.

Altogether, our thematic analysis identified 177 codes which were divided into five larger themes. The unit of analysis in our coding system was one entry (one full response to a question in the diary, 30 words in length on average), and the entries could be given multiple codes. Descriptions of the themes as well as the number of codes per theme and cluster are given in Table 2.

➔ *Insert Table 2 about here*

**Results**

*RQ1: What impact do pre-service teachers believe VE has made on their TPACK skills development?*

Across VE1 and VE2, 69% of participants reported positive TPACK gains, while 31% reported negative TPACK gains over time. Similar scores were recorded across the other 21 VEs (Author B, 2019; Author B, 2020), indicating that, from a quantitative perspective, these two VEs were representative. Figure 1 illustrates the scatterplot of pre-test TPACK and TPACK growth using the k-means cluster analysis. Cluster 1 with high perceived TPACK gains is coloured in green, Cluster 2 with medium perceived gains – in blue and Cluster 3 with low perceived gains – in red.

➔ *Insert Figure 1 about here*

As can be seen in Figure 1, most VE participants were within the low and medium TPACK gain clusters, the high TPACK gain cluster was numerically the smallest. An independent sample T-test compared the mean total TPACK gain between VE1 and VE2, showing that the perceived mean score was higher for VE1, which was conducted in pre-service teachers' mother tongue. However, this difference in TPACK gain between VE1 (M = .42, SD = .58) and VE2 (M = .26, SD = .50) was not statistically significant (t (53) = 0.57, p = .36).

As is evident from Figure 1 as well as from the standard deviations in the T-test, there was substantial variation in terms of perceived TPACK growth. Such observed variation highlights that even though many participants indicated a positive development, this development was not universal, or linear. Therefore, it was important to explore the lived experiences of the pre-service teachers who took part in the VE to understand whether there were any shared or different experiences between them. These are discussed next.

### *Common themes from the diaries across all clusters*

Two themes were common to all 25 selected participants in their 465 diary entries, irrespective of whether they were in the high, medium or low perceived TPACK gains cluster. The most frequent theme across the sample was *positive about technology*. As is highlighted in Table 2, 38% of comments were related to this theme. Even the clusters with low and medium perceived TPACK gains were not entirely negative about the tools they used during the VE. There was an overall perception among participants that certain features of technology could be of value for their personal use and for teaching and learning.

Participants in all three clusters mentioned that VE helped them to develop technological literacy. This was exemplified in such statements as *"learning how to set up a Google doc"* or learning *"how to use different means to present information"* (Diary 2, Participant 254, female, Spain, VE2, low TPACK gain). Among other frequent insights was the observation that VE enhanced other skills, such as critical thinking or information management.

*Firstly, I learned how to create a Google Docs. Secondly, I learned how to put ideas together and how to connect them.* (Diary 3, Participant 28, female, Spain, VE2, high TPACK gain)

Besides an insight into the affordances of technology for personal use, facilitated by VE, participants in all three clusters were also able to relate the technology they used to their teaching practice. This corroborates findings from earlier VE studies (e.g., Chen, 2012). However, when describing their expectations of the VE in diary 1, only nine participants out of 25 framed these in terms of learning about technology – the expectations of participants mainly concerned learning about the culture of their VE partners and improving their language

skills. Learning about technology for pedagogical use turned out to be a valuable "by-product" of VE that participants reflected on in its later stages. Participants commented on the potential of technology to make the learning content more visual, facilitate a more student-centred pedagogical approach, and give access to more/different perspectives on the educational issues being discussed.

*Studying using ICTs and being able to visualise things is easier. For example, using digital screens in class to explain the material better.* (Diary 1, Participant 254, female, Spain, VE2, low TPACK gain)

Alongside statements in praise of technology, participants in all three clusters also shared their reflections on the processes to consider when teaching with it. This reinforces the findings of Dooly & Sadler (2013) who concluded that participation in a VE enhanced pre-service teachers' critical thinking and reflection. In this study VE seemed to increase participants' awareness concerning the selection and integration of technology in their own teaching. Participants frequently talked about the care needed to choose the right tool for the classroom and adapt the technology to the level of their learners.

*It's important to be able to choose the technology that helps students learn. For example, a YouTube video could be used for natural sciences, but it would make more sense to use a specific website for maths to allow students to practise maths problems.* (Diary 2, Participant 28, female, Spain, VE2, high TPACK gain)

Yet, despite the commonalities described in this section, there were several key differences between participants in the three clusters. These are discussed in the following section.

***RQ2: To what extent do pre-service teachers at different levels of perceived TPACK gain report different experiences of working in the VE, and why?***

As can be seen from Table 2, the first differentiating theme between the three clusters was the extent to which they contributed to the theme *negative about VE*. Participants in cluster 1 with high perceived TPACK gain expressed the fewest negative comments (4%) about the VE, whereas cluster 3 participants with low perceived TPACK gain contributed the most (73%) to this theme.

*Regarding the first assignment, I didn't learn anything new. In addition, I don't use this type of technologies in the grade levels I teach.* (Diary 2, Participant 319, female, Portugal, VE1, high TPACK gain)

Here in the earlier stage of the VE Participant 319 with high perceived TPACK gain talked negatively about the technology used in the VE, as she found VE more relevant to higher education rather than the primary education context in which she planned to work. However, there was a notable shift in her perspective on the pedagogical use of the technology towards the end of the VE, as she acknowledged its potential value:

*This virtual experience allowed me to recognise that we can often employ more engaging and facilitating approaches to learning.* (Diary 4, Participant 319, female, Portugal, VE1, high TPACK gain)

The negative comments of cluster 3 participants concerned mainly their conclusion that they could not learn much from the VE. The reasons included the view that they had not substantially developed any skills during the VE, were already very experienced in using the tools, and/or faced a lack of commitment and engagement from their VE partners.

*In my group we used google drive in order to share our presentation with our partner group. I have used this system before, so I don't feel like I learned anything new from that.* (Diary 2, Participant 722, female, Sweden, VE2, low TPACK gain)

*We didn't understand why they [VE partners] decided to work on a different task and did not try to contribute ideas.* (Diary 4, Participant 313, female, Spain, VE2, low TPACK gain)

As the comments above show, "real life" experiences of online collaboration incurred *challenges* that most participants had to face. Our analysis suggested that the second differentiating theme between the three clusters was their ability to overcome such challenges. Cluster 1 participants frequently described so-called *breakthroughs* they made during the VE. Comments under this theme included participants' positive stances towards the difficulties they faced, and specifically their descriptions of how they managed to resolve them. One of the examples of this theme included overcoming anxieties towards technology and breaking the negative stereotypes about technology participants had before the VE.

*I already feel a bit awkward regarding new technologies.* (Diary 1, Participant 617, female, Portugal, VE1, high TPACK gain)

*The major challenge was to learn how to use technologies which I wasn't comfortable with, namely, Facebook. To overcome the difficulties, I asked for help from a colleague.* (Diary 4, Participant 617, female, Portugal, VE1, high TPACK gain)

Here in the diary completed at the beginning of the VE Participant 617 with high perceived TPACK gain, commented on her lack of technological self-confidence, and the fear of using new kinds of technology. This fear of using new technology is commonly found in the research literature (e.g., Eryilmaz & Cigdemoglu, 2019; Powell, 2013). In the diary completed at the end of the VE she again mentioned her unease with social media, but now in the past tense, and in relation to the steps she took to overcome her anxiety. Her recourse to a colleague to overcome the challenge once again emphasises how collaborative a VE can be.

Participants in cluster 2 and cluster 3 also frequently talked about the *challenges* they faced during the VE, however, in contrast to cluster 1, they framed these as difficulties they were unable to resolve. While cluster 3 participants, as seen earlier, mainly talked about the lack of commitment from their VE partners, most of the challenges reported by cluster 2 participants were difficulties associated with asynchronous communication. These included delay in exchanging messages (i.e., Moodle did not send message notifications), having to wait to receive an answer from the VE partners, and having fewer cues to understanding a message in the absence of visual feedback from VE partners. As the VEs were based in different countries and in the case of VE1 – on different continents, participants frequently talked about the difficulty of time management and scheduling meetings from different time zones.

*My use of the foreign language has improved, I cannot complain. Although, I would have liked to talk to them [virtual partners] in person or by videoconference* (Diary 4, Participant 593, female, Spain, VE2, medium TPACK gain)

Participants in cluster 2 also reported having to complete an overabundance of tasks as a challenge. This was especially prominent in VE2 which lasted only six weeks. Participants felt that with a heavy workload there was not enough time to get to know their VE partners as well as they would have liked. These participants' comments corroborate the findings from the earlier studies on collaboration (e.g., Barron, 2000; Lee, 2009) which showed that collaboration is effective when the teams have enough opportunities to create common frames of reference and a shared conception of a problem.

Against expectations, it was cluster 2 participants who contributed most to the theme *readiness to use technology in future*. They seemed to view the challenges they faced as a learning experience, unlike those in cluster 3. This theme included comments about participants' willingness to use technology in their classroom after the VE, or to take part in a similar VE. All these statements appeared in the diary completed at the end of the VE and were supported by references to the perceived pedagogical affordances of technology, or the acknowledgement that participants gained experience of tools they hadn't used before. The truly collaborative nature of VE also manifested itself in comments from cluster 2 participants about their future teaching practice. These mentioned that they not only intended to integrate technology into their own classroom, but also to encourage their students and colleagues to use technology.

*I might use this way of interacting with people from other cultures again, both for my own benefit and for that of my students or even recommend it to people.* (Diary 4, Participant 759, female, Spain, VE2, medium TPACK gain)

The evidence of cluster 2 participants talking about going beyond using technology in their own future teaching and encouraging their students and colleagues to use it highlights the potential of VE to act as a community building tool.

**Discussion and conclusion**

Across the globe students are joining virtual exchanges (VEs) to learn a different language, cultural context, or new digital skills. However, who and which types of learners mostly benefit from these practices has received limited attention. This study is, to the best of our opinion, the first mixed methods study that analysed pre-post TPACK scores of 55 pre-service teachers in two distinct VEs and compared their learning experiences by using both cluster analysis and a follow-up qualitative analysis of 465 diary entries compiled over four time periods. RQ1 in this study was concerned with the impact pre-service teachers believe VE has made on their TPACK development. Our analysis revealed that most participants (69%) in the two VEs reported positive TPACK gains. Similar evidence came from our qualitative analysis which showed that the most frequent theme across the sample was that of being *positive about technology* within which participants commented on their growing awareness of its uses and affordances. This finding strengthens the evidence from earlier qualitative studies on VE (e.g., Chen, 2012; Dooly & Sadler, 2013), which reported that the experience gave pre-service teacher participants an opportunity to unpack and scrutinise the educational value of technology.

Our study further showed that when describing their TPACK growth, participants in all three clusters mainly referred to developing technological knowledge (e.g., learning how to set up a google doc) and developing technological pedagogical knowledge (e.g., reflecting on the type of technology that can be used for a specific pedagogical approach). There was, however, very little mention of technological content knowledge (the use of technology to teach a specific subject), another construct of the TPACK theoretical framework (Mishra & Koehler, 2006). Some previous studies have commented critically on the current limited understanding of the inter-relationships between TPACK constructs, (e.g., Koh, Chai & Tsai, 2013; McGrath, Karabas & Willis, 2011). More studies that explore perceived TPACK growth, particularly in online settings, are clearly needed.

VE has been shown in general terms to contribute to pre-service teachers' TPACK skills in this and earlier studies (e.g., Author B, 2020; Bueno-Alastuey, Villarreal & García Esteban, 2018; Dooly & Sadler, 2013). Our findings in response to RQ1, based on the triangulation of data, revealed that perceived TPACK development among pre-service teachers in the two analysed VEs was not linear. Our cluster analysis identified relatively few participants with high perceived TPACK gain. While mixed methods evidence for the impact of VE on pre-service teachers' TPACK is very scarce (Dooly, 2017), a similar finding of non-linear TPACK development is reported by Author B (2020). Together these studies indicate that learning in online settings does not automatically guarantee consistently high levels of TPACK development as reported participants.

RQ2 sought to unpack this finding, by scrutinising the extent to which pre-service teachers at different levels of perceived TPACK gain report different experiences of working in the VE, and the potential reasons for this. Thematic analysis of 465 diary entries across four time periods across the three clusters of participants showed that the reported ability to overcome challenges and/or anxieties during the VE was a key differentiating theme between

the clusters. Most of the challenges identified in this study provide strong corroboration of findings from earlier studies (e.g., Helm, 2015; O'Dowd & Ritter, 2013). Our study further showed that these challenges can be technology-related rather than social or cultural, as highlighted in previous studies.

Another finding that can potentially explain the differences in reported TPACK growth between cluster 1 (i.e., high growth) and cluster 3 (i.e., low growth) participants relates to the expectations they had of VE and their prior knowledge of technology. Cluster 3 participants indicated that they did not learn from VE as much as they had expected to. This lack of reported learning may in part be ascribed to a potential ceiling effect, whereby several participants in cluster 3 already had a relatively high TPACK score at the outset, which might not have allowed them to make further significant gains. At the same time cluster 2 participants with medium perceived TPACK gain had the most mixed experiences of VE among the three clusters. Cluster 2 participants faced some challenges they could not resolve, but they found positive aspects in the process, which encouraged them to use technology in the future. These findings corroborate those of Hao & Lee (2017) who found a positive relationship between pre-service teachers' prior knowledge of technology and the level of their concern at using it in teaching. Our study goes further in showing that negative learning experiences in VE may be linked to both higher levels of reflectivity around technology use and lower reported learning gains.

### *Limitations and practical implications*

One obvious limitation of this study arises from the self-reported nature of the both quantitative (i.e., pre-post test TPACK) and qualitative data (i.e., four diaries per participant). The TPACK model and its accompanying scales have been criticised for their reliance on self-report (e.g., Dobozy & Campbell, 2016). Arguably, in this study, the fact that pre-service

teachers are trained to reflect on practice, as well as the substantial sample size and robust evidence-based design with longitudinal data collection may have helped to overcome some of these limitations. Given the lack of previous empirical research on the impact of VE in pre-service teachers' TPACK development, more research that combines quantitative methods with fine-grained qualitative analyses are important avenues through which to explore what "works" in VE and what impact it has.

As the key differentiating theme between the three clusters was their ability to resolve challenges faced in the VE, the first implication derived from this study concerns the importance of identifying such challenges in the early stages of online collaborative projects. Where VE facilitators know the profiles, likely anxiety levels, or prior TPACK skills of their learners well, they are recommended to raise the awareness of learners about likely challenges and how to overcome them. This potentially could be done by automated processes of diagnostic tests and learning analytics approaches of initial engagement (e.g., Author B, 2018), but also by more hands-on approaches by teachers having open and perhaps 1-2-1 conversations with participants about their learning needs and how to maximise their learning potential.

A second implication to be drawn from the study concerns the importance of providing clear expectation management in respect of what the VE aims to achieve, and perhaps more importantly, what it does not. This might help some of the participants in cluster 3, who had (unrealistically) high expectations of the VE, and were disappointed when these were not met.

Finally, cluster 1 participants with high perceived TPACK gain highlighted the power of collaboration to solve the challenges they met. This suggests another set of pedagogical implications, including: the desirability of strengthening collaboration between VEs by encouraging more communication between participants; providing appropriate tools for synchronous communication; explicit discussions of home group organization and the

implications of task work; how to deal with unequal contributions. These measures too may help more participants achieve higher TPACK gains.

## Disclosure statement

## References

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**Table 1** Average TPACK gain by cluster

| Cluster | Number of VE participants | Average TPACK gain |
|---|---|---|
| Cluster 1: High perceived TPACK gain | 7 | 1.23 |
| Cluster 2: Medium perceived TPACK gain | 31 | 0.38 |
| Cluster 3: Low perceived TPACK gain | 17 | −0.24 |

**Table 2** Summary and definition of themes with corresponding number of codes per theme and cluster (N = 25)

| Theme | Definition of theme | % of codes from Cluster 1 (high, n = 7) | % of codes from Cluster 2 (mid, n = 9) | % of codes from Cluster 3 (low, n = 9) |
|---|---|---|---|---|
| Positive about technology (38% codes, *n* = 69) | Statements related to the features of technology participants found of value for personal and pedagogical use | 53 | 33 | 14 |
| Challenges (28% codes, *n* = 49) | Statements about the unresolved difficulties participants experienced with the project | 20 | 39 | 41 |
| Readiness to use technology in future (17% codes, *n* = 30) | Statements related to how participants want to use technology more in their classroom after VE and/or encourage their students and colleagues at work to use technology | 27 | 58 | 15 |
| Negative about VE (12% codes, *n* = 21) | Statements with negative feelings participants had about VE | 4 | 23 | 73 |
| Breakthroughs (5%, *n* = 8) | Statements related to how participants overcame a challenge they faced during VE or an anxiety they had had before the VE | 89 | 11 | 0 |

**Figure 1**

Scatterplot with three clusters for VE1 and VE2

## Appendix

Diary questions

| First diary at start of VE |
|---|
| D1Q1: Can you give a concrete example of how the use of technology has enhanced teaching or learning (a situation where you were either a learner or a teacher)? What was the topic and which tools were used? <br><br> D1Q2: Have you ever used online technologies before to communicate or work with people from other cultures? If so, give a concrete example. <br><br> D1Q3: How would you describe your cultural background? <br><br> D1Q4: What do you hope to achieve or learn from this VE? |

| Second diary after the end of task 1 |
|---|
| D2Q1: In your first task you used different online tools for communicating and presenting information. What have you learned about selecting technologies that enhance what you teach and how you teach? Use a concrete example to illustrate your answer. <br><br> D2Q2: What have you learned from your first task about selecting technologies that enhance what students learn and how they learn? Use a concrete example to illustrate your answer. <br><br> D2Q3: After working together on this first task, what are your initial impressions of your VE partners? |

| Third diary after the end of task 2 |
|---|
| D3Q1: Often the way an online tool is being used changes depending on what learners are supposed to do while carrying out the task. What have you learned about the need to adapt online tools to how learners use tasks in your subject area? Give a concrete example to illustrate your answer. <br><br> D3Q2: How do you feel about the interactions with your VE partners so far? What are you finding easy or difficult? What steps do you think you could take to improve the interactions? <br><br> D3Q3: What have you learnt about the topics that you investigated? What cultural differences and similarities did you notice between the way your topic is dealt with in the two contexts? |

| Fourth diary after the end of task 3 and completion of VE |
|---|

D4Q1: What have you learned so far about how technology influences your teaching approach? Give concrete example to illustrate your answer.

D4Q2: How do you feel about working in an intercultural team?

D4Q3: Describe any challenges you faced in your group work. What do you think the causes were? How did you try to solve them?

D4Q4: Has this project affected in any way how you will use online tools and environments in your own teaching career in the future?

D4Q5: After having collaborated with your partner/s in designing different online tasks, what is the most important thing you feel you have learned about how online tools and environments should be used for teaching? Give a concrete example.

D4Q6: Please describe how doing this course collaboratively with international partner(s) impacted your learning experience?

D4Q7: Given your online interactions with students from another country, describe any key changes that occurred in how you view the world?

D4Q8: What was the most important thing you learned from this experience?

D4Q9: Is there anything that has positively affected your VE experience? If so, please describe this in the textbox below.

D4Q10: Is there anything that has negatively affected your VE experience? If so, please describe this in the textbox below.

Based upon Author B (2019). Note that a detailed description of how the diaries were conceptualised, designed and implemented is described by Author B (2019). p.20-24.