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ORIGINAL RESEARCH ARTICLE

Putting design into practice: An investigation of TPACK scores of lecturers in a networked institution

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Demand for blended and online learning environments is increasing and concurrent with this is the changing competencies required for teachers to be able to facilitate learning in both face-to-face and virtual space. The Technological Pedagogical Content Knowledge (TPACK) is a measure of teachers pedagogical, content and technical knowledge and their skill to embed technology in practice. Using the TPACK framework, this study explores the relationship between technical skills, learning design and how these relate to pedagogy. The study also investigates how TPACK varies by subject area, teaching qualification, and employment. A survey of 112 lecturers from a multi-campus university was conducted. We found that lecturers who have high TPACK tend to use more varied and interactive learning activities. TPACK did not significantly vary by subject area. It did not also vary between those who received a few trainings over the past year in comparison to those who didn't. However, significant differences in TPACK were found in terms of nature of employment and teaching qualification in higher education. These findings suggest that there is a need to provide a varied approach to develop staff competencies.

Keywords: blended learning; online learning; TPACK; learning design; technology integration; teachers

Introduction

Universities have been moving aggressively to expand their online offerings over the past few years either through massive open online courses (MOOCs), distance learning courses delivered via virtual learning environments (VLEs), or through a mixture of traditional face-to-face contact and online learning. Concurrent with this change are the shifting competencies required for teachers to be able to facilitate learning in both virtual and face-to-face environments.

The range of learning activities that can be carried out with technology varies. Conole (2007) provided a taxonomy of e-learning activities or learning mediated with technologies: assimilative (such as reading, viewing and listening), information handling, communicative, productive (such as creating, writing and synthesizing) and experiential (such as investigating and performing). These different tasks require a range of tools and strategies that vary by learning space. For example, to simulate the assimilative activities in the classroom in an online learning environment, a lecturer could either use the VLE as an online repository or use the virtual classroom software to simulate the classroom experience.

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For experiential learning activities, activities could either be in the form of inquiry-based learning such as webquests or the use of virtual labs that simulate science experiments. The shift into blended and online learning requires lecturers to be able to design learning activities that can be delivered in both virtual and physical learning spaces. Anderson, Barham and Northcote (2013) added that 'a lecturer's knowledge of how to select and appropriate different technologies to facilitate a variety of learning tasks influences the quality of learner experience in an online course' (p. 550).

Teaching expertise goes beyond subject knowledge and now includes having technological competency (Benson and Ward 2013). However, previous research has shown that there is still a gap in lecturers' knowledge of the use of learning technologies. JISC (2017) noted that 'there are huge differences among teaching staff use of digital technologies to support learning, even within the same college departments'. To address the gap in lecturers' information and communications technology (ICT) skills, educational institutions typically roll out technology training in the form of workshops/tutorials (e.g. workshop on how to use the VLE). But while these trainings provide staff with the skills for using various software, training on how to align the use of technology with content is essential to allow teachers to appropriate technology in their learning design (Foulger, Graziano, and Schmidt-Crawford 2017; Rienties *et al.* 2013). In a systematic review of strategies for teacher training on technology, one of the recommendations was to use an integrated approach to training – one that models how technology can be used in teaching activities (Kay 2006).

Previous research has shown that a successful integration of ICT in education follows a strategy that aligns technology use with a pedagogical approach (Mishra and Koehler 2006; Rienties *et al.* 2013). Meadows and Henry (2008) noted that 'because the online world is a categorically different environment, a particular blend of skills and knowledge is necessary' (p. 6). Benson and Ward (2013) added that 'effective online teaching and learning requires an understanding of the unique ways in which technology interacts with subject matter expertise and pedagogical skills to promote student learning' (p. 154).

The technological pedagogical content knowledge (TPACK) framework (Mishra and Koehler 2006) is one strategy used to map lecturers' use of educational technology. TPACK is built-on Schulman's (1986) argument that content knowledge (CK) and pedagogical knowledge (PK) are needed to deliver effective teaching. TPACK extends Schulman's model by adding the technology domain, such that it is the intersection of these three knowledge domains that facilitate effective use of technology for learning and teaching.

Jaikaran-doe and Doe (2017) summarise the TPACK model as follows: CK which covers knowledge of a the subject area; PK refers to knowledge of teaching methods; *technological knowledge* (TK) refers to knowledge of various technology; *pedagogical content knowledge* (PCK) refers to the knowledge of teaching methods with respect to the subject matter; *technological content knowledge* (TCK) refers to the knowledge of how technology can be integrated to facilitate learning; *technological pedagogical knowledge (TPK)* refers to knowledge of how teaching changes as a result of using various technologies. An illustration of the TPACK model is shown in Figure 1.

Several instruments have been developed to analyse the TPACK framework (Archambault and Crippen 2009; Schmidt *et al.* 2009). Of particular interest to the current study is Archambault and Crippen's (2009) survey due to its focus on online learning. However, criticisms of TPACK surveys highlight the fuzzy boundaries between the seven domains (Archambault and Barnett 2010). For example, in

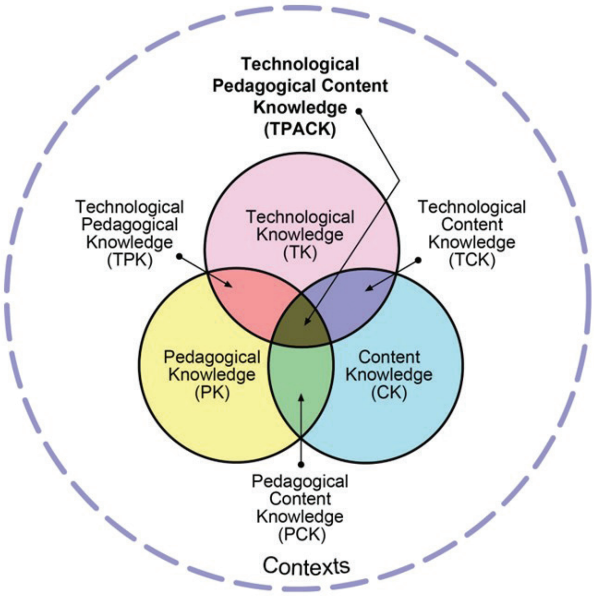

Figure 1. TPACK model (Mishra & Koehler 2006) (Reproduced by permission of the publisher © 2012 by tpack.org).

Archambault and Barnett's factor analysis of Archambault and Crippen's (2009) 24-item TPACK instrument, only three factors emerged in their analysis: PCK, technological-curricular content knowledge (TCCK) and TK. Cubeles and Riu's (2018) study of TPACK profiles of Spanish university professors using an adopted version of Schimdt's instrument also resulted in three factors. In both cases, CK was integrated into PK, whereas TPK and TCK were combined into a single factor. Only the original TK remained as a separate factor. Cubeles and Riu simplify these groupings as: knowledge on teaching without technology, knowledge on teaching with technology and TK (p. 346). These groupings map to Archambault and Barnett's three factors. As there are several studies that point to the three factors rather than the original seven, and Archambault's instrument is more aligned to online learning, we carried out this analysis using Archambault and Barnett's three-factor instrument.

Using the TPACK framework, the goal of this article is to investigate lecturers' skills in embedding technology into their design of online learning environments. By looking at the relationship between the various components of TPACK, the study aims to explore if there is a relationship between technical skills and design and how this relates to content and pedagogy. Lastly, this article aims to explore differences in TPACK scores of lecturing staff based on different demographic factors such as nature of employment and subject area. Specifically, this study aims to answer the following research questions:

1. To what extent do lecturers demonstrate TPACK knowledge?
2. What is the relationship between TPACK and design of learning activities?
3. How does TPACK vary by nature of employment, teaching qualification and subject area?

Literature review

Studies published on TPACK tend to focus on pre-service teachers or teachers of Kindergarten to Grade 12 (K-12). Few studies have unpacked TPACK in the higher education (HE) sector (Anderson *et al.* 2013; Benson and Ward 2013; Cubeles and Riu 2018). In a case study with three HE professors, Benson and Ward (2013) illustrated different TPACK profiles and how lecturers operationalise the framework, showing the different degrees of technological, pedagogical and content knowledge. They found that PK is the enabling force in developing higher levels of technology integration skills, more so than TK on its own. This raises questions about the standalone technology training delivered as workshops/seminars to improve lecturers' capacity to use technology. However, this does not mean that TK is not important. Anderson *et al.*'s (2013) study of TPACK profile of lecturers found TK as an enabling force in delivering online programmes. The challenge for lecturers was how to emulate their teaching strategies in face-to-face modules to the online environment. So, while PK precedes TK, this shows that online learning requires a standard level of TK to be able to provide an engaging online learning environment.

Lecturers also vary in their beliefs about the role technology plays in the classroom, which correlates to their use of technology and perceived competence to use technology (Lee and Tsai 2010; Marcelo and Yot-Domínguez 2018). Marcelo and Yot-Dominguez's study found that lecturers' use of technology is associated with their confidence in using technology. Those who do not have the confidence in their ability to use technologies veer from using them as they feel this affects their ability to offer a student-focused teaching. Reyes *et al.* (2017) noted that technology integration is more than a dichotomy of lecturers who use technology and those who do not. Instead, profiles can be categorised into three: those who are able to integrate technology into their teaching; those who have the technological skills but not the confidence to teach with it; and those who are hesitant towards technology. Therefore, competence alone is not the decisive factor, rather it is confidence, both in terms of being able to utilise existing skills and being able to acquire those skills.

Support is an important factor in developing lecturers' capacity to use technology. Studies that implemented training interventions to improve lecturers' skills in teaching with technology found significant improvement in the lecturers' TPACK scores before and after the intervention (Brinkley-Etzkorn 2018; Rienties *et al.* 2013). In Koh, Chai and Tsai's (2014) study, it was found that teachers who are supported by an educational technologist developed higher levels of TPACK in comparison to lecturers who were not. Continuous technology training has been consistently highlighted in teacher training literature, but supporting teachers in the use of technology is not only about providing training on how to use technology, but also includes providing continued support and guidance as lecturers navigate the use of technology in the classroom.

Studies that investigated TPACK found that scores tend to vary based on various demographic variables such as teaching experience and subject area. Several studies have found that teachers with more experience in using technology had higher measures of self-efficacy in using technology for teaching (Corry and Stella 2018; Cubeles and Riu 2018). These findings are not surprising as there is an overwhelming anecdotal evidence that when it comes to technological skills, experience facilitates competence. Jang and Tsai's (2012) study of more than 800 teachers found that TPACK subscale scores except for TK varied by years of teaching experience, with these scores positively correlated to years of teaching service. In Cheng and Xie's (2018) study, age and experience were positively correlated with PCK, but negatively correlated with TK. Several other studies noted that experienced teachers were less confident about integrating technology (Koh *et al.* 2014; Lee and Tsai 2010).

In Jang and Tsai's (2012) study, TK was lowest in comparison to the other subscales and did not vary by years of teaching experience. The TK scores were also lower in comparison to the other subscale scores. Several studies echo this finding. Scores for PCK and TCCK (in reference to either the original subscale or the combined subscales) were higher than TK (Benson and Ward 2013; Cubeles and Riu 2018). This suggests that both novice and experienced teachers do not feel as confident with their TK as they do with their PCK.

The demand to use technology and the nature of technology use tend to vary by subject area. For example, in an investigation of the different ways HE lecturers use technology in their teaching, and it was found that social science lecturers tend to use technology to present information, engineering lecturers use experiential learning activities and health science lecturers use it more for communicative learning activities (Marcelo and Yot-Domínguez 2018). Cubeles and Riu's (2018) study of HE lecturers did not find significant differences in PCK and TCCK of lecturers from business administration, engineering and architecture lecturers. However, there was a significant difference in the TK scores of engineering lecturers in comparison to architecture lecturers. HE lecturers have achieved a certain degree of subject expertise in their field, which could account for the parity of PCK and TCCK scores. However, different subject areas would vary in their use of technology, hence the significant TK scores between the two faculties. Two studies on primary/secondary teachers also found that subject area has a moderating effect to TPACK scores (Jang and Tsai 2012; Nelson, Voithofer, and Cheng 2019).

Development support has been shown to improve TPACK and support can be in the form of technology training, providing guidance on the use of technology, or development support in terms of improving pedagogy. Lecturers would need different levels of support based on various factors. Lecturers coming into HE teaching from a commercial background would likely need pedagogical training. Jaikarandoe and Doe's (2017) comparison of TPACK scores of HE engineering lecturers was significantly lower than pre-service teachers' TPACK scores. Nature of employment (whether full-time or part-time) also dictates the support needs (Beaton and Gilbert 2013). Studies in relation to TPACK on this regard are few and point to contrary findings (Chukwuemeka and Iscioglu 2017; Voithofer *et al.* 2019). Voithofer *et al.* found that TPACK did not vary by tenure, whereas Chukwuemeka and Iscioglu found TK and TPK to be higher for part-time staff.

This section has drawn together findings on TPACK- and HE-focused studies as well as differentiation of TPACK scores based on demographic variables. Research that assesses TPACK in higher and further education (FE) is few. Findings on differentiation of TPACK scores by various factors such as subject area and experience have also shown contrasting results. In addressing this gap in the literature, the current study investigates the TPACK scores of lecturers in a dual-nature institution and will explore how these scores relate to the design of learning activities.

Methodology

Setting

The study was carried out in a multi-campus university that offers both FE and HE programmes. Due to the dual nature of the institution, some lecturers teach both FE and HE subjects ranging from Level 4 to Level 12 in the Scottish Credit and Qualification Framework. The university consists of different academic partners (FE colleges and research centres) dispersed across the region. There are two faculties within the university: Faculty of Arts, Humanities and Business, under which subjects on arts, social sciences and business are contained; whereas science-related disciplines and engineering are under the Faculty of Science, Health and Engineering. Degree programmes are delivered across the network, and as such students who are part of the same cohort are not necessarily from the same campus. In such cases, teaching is delivered synchronously in the different campuses via videoconferencing or similar virtual classroom technology.

Data were collected via online survey. A total of 112 lecturers participated in the survey. Of the respondents, 58 (52%) were teaching HE only modules, while the rest (n = 54; 48%) had dual roles both as an FE and HE lecturer. Of the lecturers, 65 (59%) were from the arts, humanities and social sciences background, while the rest (n = 45; 41%) were from the science and engineering disciplines. Sixty-one of the lecturers (55.5%) were employed full time, while the other lecturers were on part-time employment contracts (n = 49; 44.5%).

Instrument

The survey was divided into three parts: (1) TPACK inventory, (2) design of online learning and (3) relevant training. Demographic information was also asked in the survey. The TPACK inventory was adopted from Archambault and Barnett (2010) and uses the combined three factors rather than Mishra and Koehler's (2006) original seven factors. PCK combines the items from PK and CK into one subscale. TCCK is the combination of the TCK and TPK into one subscale. TK reflects all the items in the original Archambault and Crippen's (2009) instrument. Computed internal reliability Cronbach's alpha values for the three constructs were: 0.927 for PCK, 0.936 for TPCK and 0.910 for TK. Sample TPACK items and corresponding subscales are listed in Table 1. Lecturers rated their ability in doing the tasks listed in Table 1 using a five-point Likert scale, with a higher score reflecting higher skill. Lecturers were also asked to identity strategies and the type of media they use in the VLE. Responses to these open-text questions were used to categorise the level of interactivity of their learning design. Staff were also asked to identify the training they received in the last 12 months. Finally, demographic information was sought, including subject area, subject-level taught (HE, FE or both) and membership to professional bodies such as the Higher Education Academy. The membership to Higher Education Academy (now Advanced HE) was used as a proxy measure for identifying HE teaching qualification.

Table 1. Descriptive statistics of TPACK scores.

TPACK item and subscales	Mean	SD
Pedagogical content knowledge (PCK)	**3.67**	**0.71**
My ability to comfortably produce lesson plans with an appreciation for the topic.	4.02	0.87
My ability to use a variety of teaching strategies to relate various concepts to students.	3.66	0.86
My ability to determine a particular strategy best suited to teach a specific concept.	3.6	0.9
Technological curricular-content knowledge (TCCK)	**3.11**	**0.84**
My ability to implement the curriculum in an online environment.	3.43	1.05
My ability to implement different methods of teaching with technology.	3.22	1.01
My ability to create an online/blended learning environment which allows students to build new knowledge and skills.	3.21	1.09
Technical knowledge (TK)	**2.58**	**1.14**
My ability to address various computer issues related to software (e.g. downloading appropriate plug-ins, installing programmes	2.71	1.28
My ability to assist students with troubleshooting technical problems with their personal computers.	2.56	1.2
My ability to troubleshoot technical problems associated with hardware (e.g. network connections)	2.46	1.22

Procedure and data analysis

Ethical permission was sought prior to the start of the survey. Consent was also sought from the developers of the TPACK instrument. The survey was administered using an online survey and participants completed the survey within the first 6 weeks of the semester.

TPACK scores for each subscale were computed using the average score of the items corresponding to each subscale (Table 1). The level of interactivity was analysed using the responses on the questions that asked what type of activities and strategies lecturers implement in their online/blended learning environments. Conole's (2007) taxonomy of e-learning tasks was used to categorise the level of interactivity into low or high. Responses that identified assimilative and communicative tasks were categorised as low-level interactivity (e.g. use of word/PDF documents concurrent with the use of discussion board). Responses that combine the use of assimilative, communicative and productive tasks (synchronous and asynchronous communication tools, interactive quizzes and online activities) were categorised as high-level interactivity. To analyse the relationship of the different TPACK subscales, Pearson's correlation was used. Relationship between TPACK and level of interactivity was tested using Kendall's Tau (Table 4). Multivariate analysis of variance (MANOVA) was used to compare the lecturers' TPACK scores based on subject area, teaching qualification, nature of employment, recent training and the level of interactivity of the blended/online learning module (Tables 2 and 3).

Table 2. Descriptive statistics of TPACK scores between the two faculties.

Dependent variable	Faculty	HE teaching qualification	Mean	SE
PCK	Arts, Humanities and Business	No	3.386	0.239
		Yes	3.903	0.122
	Science, Health and Engineering	No	3.320	0.175
		Yes	4.220	0.200
TCCK	Arts, Humanities and Business	No	2.610	0.285
		Yes	3.304	0.145
	Science, Health and Engineering	No	2.760	0.209
		Yes	3.700	0.239
TK	Arts, Humanities and Business	No	2.190	0.416
		Yes	2.623	0.212
	Science, Health and Engineering	No	2.295	0.305
		Yes	2.567	0.348

Table 3. Descriptive statistics and *p*-values by demographic variables.

		TPACK subscales			MANOVA	
		PCK	TCCK	TK	*F*	*p*
Nature of employment	Full time	3.88 (0.64)	3.28 (0.76)	2.52 (1.16)	7.619	0.000
	Part time	3.36 (0.64)	2.78 (0.75)	2.53 (1.05)		
Training	Training	3.72 (0.65)	3.03 (0.81)	2.34 (1.16)	0.896	0.446
	No training	3.62 (0.72)	3.09 (0.82)	2.63 (1.07)		

Table 4. Correlation between TPACK variables and learning design.

	1	2	3	4
1. PCK	1.00	0.657**	0.167	0.210*
2. TCCK		1	0.594**	0.314**
3. TK			1	0.211*
4. Interactivity (low, high)				1

*$p < 0.05$, **$p < 0.01$.

Results

TPACK scores

Descriptive statistics for the TPACK subscales were computed by averaging the individual item scores for each subscale. Lecturers' scores on the TPACK subscales of PCK, TCCK and TK were highest for PCK [mean = 3.67; standard deviation (SD) = 0.71] followed by TCCK (mean = 3.11; SD = 0.84) and lowest for the TK (mean = 2.58, SD = 1.14). The scores demonstrate that lecturers have a good to very good PCK, good TCCK and fair to good TK, based on a five-point Likert scale. At item level, lecturers were mostly confident about their ability to produce lesson plans (mean = 4.02; SD = 0.87) but least confident on their skills to troubleshoot technical problems (mean = 2.46; SD = 1.22). Table 1 shows the item and subscale-level descriptive statistics of the TPACK scores.

A two-way MANOVA was run between the faculty groupings and teaching qualification as the independent variables and PCK, TCCK and TK as dependent variables. The combined TPACK subscales were used to assess lecturers' TPACK scores. Assumptions for running MANOVA were met. There was no statistically significant interaction effect between faculty grouping and teaching qualification on the combined dependent variables: $F(3, 51) = 0.469$, $p = 0.705$, Wilks' $\Lambda = 0.973$, partial $\eta^2 = 0.027$. There was a statistically significant main effect for HE teaching qualification on the combined dependent variables: $F(3, 51) = 5.975$, $p < 0.001$, Wilks' $\Lambda = 0.740$, partial $\eta^2 = 0.260$. Follow-up univariate test was conducted, and the main effect of teaching qualification was considered. There was a statistically significant main effect of teaching qualification for PCK, $F(1, 53) = 14.097$, $p < 0.0005$, partial $\eta^2 = 0.210$, and for TCCK, $F(1, 53) = 13.136$, $p = 0.001$, partial $\eta^2 = 0.199$ but not for TK, $F(1, 53) = 1.392$, $p = 0.289$, partial $\eta^2 = 0.021$. PCK was 0.517 [95% confidence interval (CI), −0.021 to 1.054], higher for those with a teaching qualification in HE in the Faculty of Arts, Business and Humanities lecturers, but this difference was not statistically significant, $p = 0.896$. For the lecturers in Faculty of Science, Health and Engineering, PCK was higher by 0.900 (95% CI, 3.67 to 1.433), $p = 0.001$. TCCK was 0.694 higher for those with teaching qualification in HE for the lecturers in the Faculty of Arts, Business and Humanities, $p = 0.035$, and 0.940 higher for Science, Health and Engineering lecturers, $p = 0.005$. Table 2 shows the descriptive statistics of the TPACK scores of the two faculties, further grouped by those with teaching qualification in HE and those who do not. Overall, these results suggest that subject area/faculty does not influence TPACK scores but teaching qualification does, particularly for PK and CK. Interestingly, both faculty and teaching qualification have little impact on TK, in contrast to Cubeles and Riu's (2018) study which found TK scores varied by subject area. A likely reason for this relates to the university's faculty grouping being only two, which means that the groupings were not sensitive enough to measure and compare distinct subject areas that may use technology differently (i.e. anatomy and literature).

A comparison of TPACK was also considered for attendance to training and by nature of employment (full time vs. part time). This was initially considered to be included in the MANOVA above, but as the assumptions for adequate sample size and multi-collinearity were not met, multiple MANOVA was run instead. There was no statistically significant difference between staff who attended training in the previous academic year and staff who did not on the TPACK subscales, $F(3, 107) = 0.896$, $p = 0.446$ (see Table 3).

There was a statistically significant difference between full-time and part-time lecturing staff on combined TPACK subscales, $F(3, 105) = 7.619$, $p < 0.0005$. This difference was statistically significant for the subscales PCK ($p < 0.0005$) and TCCK ($p = 0.001$) with lecturers in full-time employment having higher TPACK scores for PCK and TCCK subscales (see Table 3) but not for TK.

TPACK and learning design

Correlations between the different TPACK subscales are shown in Table 4. PCK was correlated to all other variables except TK, ranging from low to strong correlation. TCCK was correlated to all other variables except for the pedagogical-layer score, with a strong correlation with TK. TK was only significantly correlated to TCCK and level of interactivity. Table 4 further shows the correlation of the TPACK scores

Table 5. Levels of interactivity and TPACK subscales.

Level of interactivity	TPACK subscales			MANOVA	
	PCK	TCCK	TK	*F*	*p*
Low	3.52 (0.63)	2.77 (0.60)	2.30 (1.00)	4.511	0.006
High	3.86 (0.70)	3.40 (0.85)	2.79 (1.11)		

to the level of interactivity provided in the course design. This variable was measured as a dichotomous variable derived from coding the responses to the open-ended question asking lecturers what strategies and resources they use in the design of their VLE. The data suggest that these subscales are tapping into a similar overall ability of teaching proficiency, and that lecturers who have higher TPACK scores tend to use more varied and interactive learning activities (such as the use of synchronous and asynchronous communication tools, in addition to active learning activities) in their design of the VLE.

To further explore the relationship of TPACK with learning design, a MANOVA was run on the combined TPACK subscales. There was a significant difference in the combined TPACK scores of staff who have higher levels of interactivity in their learning design versus staff who incorporate learning designs with low levels of interactivity, $F(3, 84) = 4.511$, $p = 0.006$ (see Table 5). This difference was statistically significant for PCK ($p = 0.027$), TCCK ($p = 0.036$) and TK ($p = 0.041$), suggesting that those who employ more interactivity in their learning designs also have higher TPACK.

Discussion

Technology adoption is facilitated by various factors such as lecturer's ability, the demands of the subject to use technology and support. Using TPACK as a way to measure how lecturers assess their own ability to integrate technology into their practice, we found that lecturers in our study had high PCK, but fair to average TK. This pattern is consistent with other TPACK studies (Cubeles and Riu 2018; Jang and Tsai 2012). However, we found that PCK and TCCK vary between those with a teaching qualification in HE and those who do not. A similar study that compared TPACK scores of pre-service teachers and HE lecturers attributed the higher TPACK scores of pre-service teachers to the pedagogical training they received (Jaikaran-doe and Doe 2017). This links back to the importance of PCK driving TPACK development.

Effective teaching in online learning environments is characterised by student-centred learning activities, interactivity and social connectivity (Pelz 2003). In our study, we found that lecturers with higher TPACK were able to promote these learning activities with more interactivity in their learning design. Previous research on TPACK noted that pedagogical skill is core in the development of TPACK (Benson and Ward 2013). The characteristics of effective online learning environments highlighted by Pelz illustrate the importance of putting pedagogy before technology. Puentadura (2006) categorised the use of technology into two main themes: the use of technology to enhance learning activities, mostly to substitute or augment existing forms of practice, and the other is the transformative use of technology where technology allows task redesign or creating new task that was previously inconceivable.

Effective learning design starts with the learning objective, followed by an exercise to match these strategies with a suitable technology. Knowledge of the different capacities of technology and how it can be integrated into learning and teaching allow lecturers to realise design of learning activities that move technology use from enhancement to transformative.

TPACK did not significantly vary by attendance to training (with participants grouped into those with 1–3 training or those without). This shows that a few training sessions are not enough to raise TPACK overall. Studies that incorporated training to improve TPACK have found significant increases in the lecturers' pre- and post-intervention TPACK scores (Brinkley-Etzkorn 2018). It is worth noting that these studies incorporated a longer period of training over time. The training received by staff in the current study were mostly workshops that lasted only for a few hours and varied in terms of offerings (i.e. content-specific training or sessions on how to use a software), so this contrary finding is not surprising. Therefore, while formal training seems to have an impact on TPACK (particularly for PCK and TCCK), this benefit does not translate from shorter, perhaps more informal courses. Rienties *et al.* (2013) noted that an integrated approach to training is needed to facilitate improvement.

We found that the TPACK of full-time lecturers was significantly higher than that of part-time lecturers. A possible reason is the opportunities and support made available to part-time staff. For example, it might be that some professional development days are scheduled outside working hours of part-time lecturers, and so those in part-time employment tend to miss these opportunities. The difference in TPACK scores of part-time and full-time staff suggests a need to revisit the support offered to part-time staff in terms of training and development and this is supported by Nelson *et al.*'s (2010) study that found that perceived institutional support contributes to TPACK.

Knowledge of the different system functionalities of the VLE allows lecturers to adopt a wider range of tools for the learning environment. Anderson *et al.*'s (2013) study discussed the importance of TK in facilitating the transition from traditional face-to-face teaching to the online environment. In assessing the relationship between the different TPACK subscales to the level of interactivity used in online learning environments, we found a correlation between TPACK and level of interactivity, for all three subscales. A higher level of interactivity in the design of learning materials was implemented by staff with higher TPACK and vice versa. This reiterates the need to provide sustained developmental support to lecturing staff to facilitate design of interactive learning activities.

Conclusion

This study is a positive response to the gap in TPACK studies at HE level. Our study set out to identify the skills of lecturers in integrating technology into their learning and teaching as measured by the TPACK instrument. We found that those with higher TPACK scores tend to apply more interactive learning designs into their modules. We investigated how TPACK varies by subject area, employment status, training attendance and teaching qualification and found nature of employment and teaching qualification in HE to be moderating factors. Several limitations can be found in this study. The dual nature of the institution means that we have surveyed lecturers' teaching in both HE and FE courses, which is likely to have a confounding effect in how lecturers embed technology into their practice. Our use of HEA status as a proxy measure to teaching qualification in HE is another limitation as there would be staff who obtained their HE teaching qualification via other routes. We have found teaching qualification and employment status to influence TPACK scores, although it may be worth exploring the nature of training and experience further to ensure that these results are reliable. These two variables are indirectly related to years of teaching experience which we have not accounted for in our design, so it would be worthwhile looking into this further.

In our study, we found that TK scores of lecturers are lower overall, but their PCK and TPK scores were higher. This was regardless of the demographic factors investigated. It is thus important to offer technology training that will help align their TK scores with PCK and TCCK, building on what they know and are confident with. For example, aligning technology training with a specific teaching strategy, providing context and examples of how technology can be used for their respective subject areas. Support to align TPACK of part-time lecturers and those who transition into teaching is also needed to bridge the skills gap. Knowing the TPACK profile of lecturers can facilitate the design of training that would support the development of staff competencies.

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