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An Exploratory Analysis of TPACK Perceptions of Pre-Service Science Teachers: A Regional Australian Perspective

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ABSTRACT

Four distinct constructs were identified from a survey of a sample of pre-service science teachers at a regional Australian University. The constructs emerged after employing Exploratory Factor Analysis (EFA) on respondents' perceptions of pedagogical practices incorporating the use of Information Communication and Technology (ICT). The key components of the survey were derived from a Technological Pedagogical and Content Knowledge (TPACK) survey developed for a national project. For future investigations of TPACK application in university contexts, a four-construct configuration of pre-service teacher TPACK perceptions is proposed requiring empirical confirmation. This inquiry depicts a portrait of emerging domains of TPACK. The relevance of the findings and their implications for universities that rely heavily on ICT in the delivery of are discussed, especially in relation to improving teaching practices.

KEYWORDS

Australia, Factor Analysis, Regional, Pre-Service Teachers, TPACK

INTRODUCTION

Research findings reported in this study were based on data collected in 2011 in a regional Australian university which had 20,119 students enrolled. Of these students, there were approximately 20% enrolled to study on-campus and 80% off-campus (online or by distance). Students who chose to study on-campus resided in or nearby a regional centre in New South Wales, and attended lectures, workshops and tutorials in a face-to-face setting. All students received their study materials through a Learning Management System (LMS). When studying in off-campus mode, study materials were in the form of html pages, downloadable PDF documents, podcasts, videos, discussion boards, chat rooms, blogs, wikis and a variety of other interactive materials. Students in on-campus mode benefited from access to the LMS (just like their off-campus counterparts) as well as face-to-face teaching with their lecturers. During the period when the research was undertaken, the School of Education (SoE) of the regional university had just over 4,000 students enrolled with a larger percentage enrolled in

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off-campus mode than the university average. This paper focuses on a sample of off-campus students enrolled in pre-service education under the sciences discipline.

LITERATURE REVIEW: TPACK IN AN AUSTRALIAN CONTEXT

This inquiry uses the TPACK framework as a lens to examine pre-service teachers' knowledge of the technology, pedagogy and content interface. This exploratory analysis provides insights into how respondents make sense of TPACK as a result of the learning environments of courses, workshops, and other pre-service experiences. This paper provides an emerging portrait of TPACK perceptions of pre-service teachers in the subject domain of science. This becomes especially illuminating as it is situated within this regional university that is known as a leader in the provision of online courses and education.

What is TPACK?

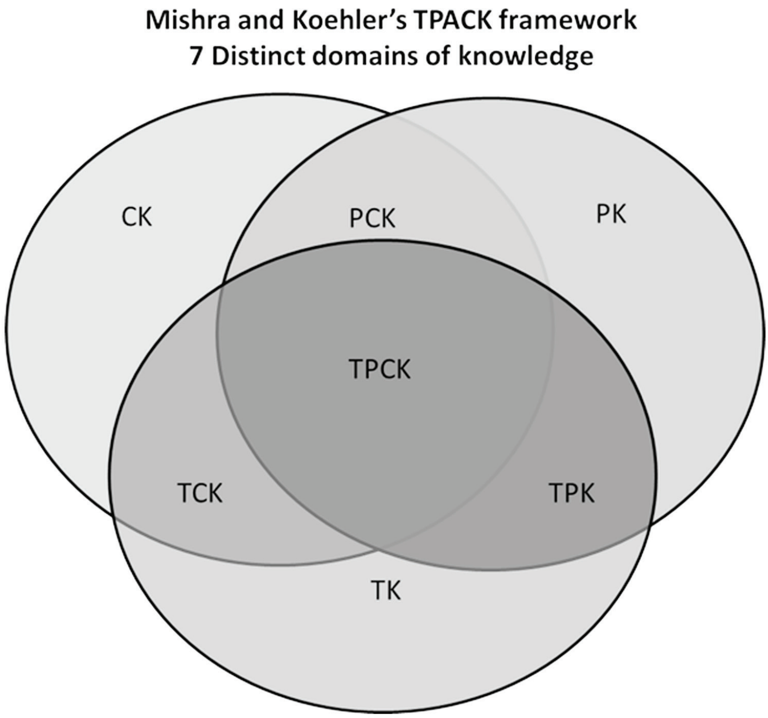
Technological Pedagogical and Content Knowledge, or the TPACK framework, is an emerging research are that has shown increased scholarly attention. Koehler and Mishra (2006) originally theorized TPACK illustrating seven domains of knowledge constituting the knowledge base that teachers need in order to teach effectively with technology. TPACK is based on Shulman's (1986) Pedagogical Content Knowledge (PCK) who contended that effective teachers possess a distinctive knowledge, the pedagogical content knowledge (PCK), enabling them to use pedagogy appropriately for effective learning and teaching in a particular discipline. Koehler and Mishra (2005) proposed that TPACK recognise interactions between technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPCK) (Koehler & Mishra, 2005).

Research on TPACK has steadily increased (Wu, 2013). Empirical research has traditionally been focused on pre-service educators and how they perceive TPACK. This inquiry engages with the ongoing area of research focused on pre-service educators. Koh, Chai and Tsai (2010) derived five constructs, namely Technological Knowledge, Content Knowledge, Knowledge of Pedagogy, Knowledge of Teaching with Technology and Knowledge from Critical Reflection while carefully analysing pre-service teachers' perceptions of technology and pedagogy interaction in Singapore. Angeli and Valanides (2009) extended the analyses by proposing the notion of Information Communication Technology-Technological Pedagogical Content Knowledge (ICT-TPCK) while empirically testing variants of this model on pre-service teachers in Europe. Carefully reviewing contemporary literature on TPACK unequivocally identifies seven constructs that have emerged as a basis for what can be argued as quintessentially representative of the interaction of technology, pedagogy and content. These are: (1) Technological Knowledge - knowledge of how to operate digital devices and using software; (2) Pedagogical Knowledge - knowledge of theories and methods of learning and teaching; (3) Content Knowledge - knowledge of the subject matter; (4) Technological Pedagogical Knowledge (TPK) - knowledge of how technology can be appropriately used for teaching and learning; (5) Technological Content Knowledge (TCK) - knowledge of how technology can represent the subject matter; (6) Pedagogical Content Knowledge (PCK) - knowledge of how appropriate teaching methods can be applied to teach a particular discipline; and (7) Technological Pedagogical Content Knowledge (TPCK) - knowledge of how technology and pedagogy can be used fittingly for effective teaching and learning of a particular discipline (Mishra & Koehler, 2006). Figure 1 provides a graphic of the overlapping domains of the TPACK construct.

Teaching Teachers for the Future (TTF) Project

In Australia, a common educational aspiration is that students leave school with the necessary ICT skills and knowledge enabling them to be productive community members (Doyle & Reading, 2012). "Teaching Teachers for the Future" (TTF) was a national project designed to build the Information

Figure 1. Mishra and Koehler's TPACK framework (2006)



and Communication Technology in Education (ICTE) capacity of pre-service teachers in Australian institutions. The national project participated in by all the 39 teacher education institutions was led by Education Services Australia (ESA), partnering with the Australian Learning and Teaching Council (ALTC), the Australian Institute for Teaching and School Leadership (AITSL), the Australian Council of Deans of Education (ACDE) and the Australian Council for Computers in Education (ACCE). TTF targeted systematic change in the ICTE proficiency of graduate teachers, by building up the ICTE capacity and developing resources to provide digital exemplar packages to facilitate professional learning. A fundamental aspect was the system-wide initiative undertaking institutional mapping of curriculum, pedagogies and assessment, and supporting innovative changes in tertiary teaching practices. This initiative focused on Technological Pedagogical Content Knowledge (TPCK) informing the use of ICT in the educative process and was implemented in four disciplines, English, Mathematics, Science and History, developed in the first phase of the new national Australian Curriculum (Romeo, Lloyd, & Downes, 2012) for schools. Each institution was expected to direct the TTF project resources towards supporting innovation in two of these four disciplines.

The Regional University Context

Understanding the scope and breadth of how TPACK practices are carried out by students and lecturers in this regional university is absolutely vital. Taking into consideration that a large number of students are enrolled in distance education courses and the fact that there is a vast geographical dispersion necessitates the extensive reliance on technology use to reach them. It becomes extremely important therefore that ICT is integrated widely. In such a context, an informed awareness of the levels of TPACK practices of students and lecturers is indispensable.

A recent review of pre-service teacher education units at the host university (Reading & Doyle, 2012b) provided ideal conditions within the SoE to re-consider the place of ICT in Education and to address the lack of explicit teaching of TPACK. Discussion of teaching practices at the university from a TPACK perspective can be found in Reyes, Reading, Gregory and Doyle (2014).

At the university, the TTF project support for innovative use of ICT in teaching and learning focused on both Science and Mathematics. This inquiry only reports on the Science implementation. The research context was a compulsory secondary science education unit in the Graduate Diploma of Education. Most of the 49 pre-service teachers initially enrolled were science graduates studying by distance to become secondary science teachers. The lecturers re-designed a unit component to incorporate immersion in a multi-user virtual environment (MUVE) for both teaching and assessment. The MUVE (or commonly referred to as a virtual world) chosen was *Quest Atlantis.* It was a safe environment especially designed for school students which had pre-designed science-based learning environments. Through MUVE, pre-service teachers gain training and experience towards obtaining suitable certification to teach school students in the virtual world. Although pre-service teachers were encouraged to complete the study module incorporated in the MUVE, there was an alternate choice for those not wishing to participate. For more information about the actual implementation and the pre-service teacher increased awareness of the potential of MUVEs in science education see Quinn, Doyle and Lyons (2012a).

Two main sources of data were collected to evaluate the implementation of this innovative teaching and learning experience: a TPACK Survey completed by pre-service teachers; and Most Significant Change (MSC) Stories created for both pre-service teachers and teacher educators. This paper uses data from the TPACK Survey. The Most Significant Change Stories were based on a research requirement of the national TTF project and have been reported elsewhere for pre-service teachers (Doyle & Reading, 2012) and teacher educators (Reading & Doyle, 2012a). As expected, there were challenges with such an innovative approach to tertiary teaching and these are discussed in Quinn, Doyle and Lyons (2012b).

SIGNIFICANCE OF THE STUDY

This inquiry is particularly important because it investigates the experiences of pre-service science teachers with the various domains of TPACK in a context where teaching and learning relies heavily on the integration and use of ICT. Harris, Mishra and Koehler (2009) have suggested the need to plot how teachers perceive the ways in which they employ TPACK in their teaching practice highlighting the need to conceptualise and present these "in terms of their specific disciplinary discourses, and in conjunction with their technological affordances" (p. 405).

METHODOLOGY

A total of 49 pre-service teachers enrolled in an off-campus science education unit during 2011 constituted the sample. Ten did not complete the TPACK survey for various reasons including opting out from the MUVE experience or withdrawing from the unit. The 39 pre-service teachers who engaged with the MUVE teaching and learning experience then completed the detailed TPACK survey. This survey was adapted (including the addition of a section focusing specifically on their experience with the MUVE) from the TTF Project TPACK survey that was sent to all pre-service teachers in Australia earlier in 2011.

The survey contained four main sections: (1) demographics; (2) learning context; (3) familiarity with ICTs; and (4) perceptions of TPACK. Section 1, demographics, contained three categorical items: gender, age and science study major. The other three sections all contained polytomous variables measured on a Likert Scale. Section 2, learning context, contained two items each on a three-point Likert Scale (response options shown in brackets): *I have developed a Personal Learning Network (PLN) for my teacher Professional Development?* (don't know; no; yes) and *How confident are you in learning about new ICTs?* (somewhat; very; extremely). Section 3, familiarity with ICTs, contained

30 items (see Table 1) each on a four-point Likert Scale of familiarity (not heard of; heard of but not used; used a few times; used many times). Section 4, perceptions of TPACK, contained 32 items each with a statement requiring a response on a five-point Likert Scale (strongly disagree; disagree; neither agree nor disagree; agree; strongly agree).

Data Collection and Analysis

The analytical approach used for this inquiry was Exploratory Factor Analysis (EFA). For this inquiry, EFA was used primarily as an "exploratory" tool in discovering underlying factors in relation to a given data set (Costello & Osborne, 2005, p. 8). EFA is a suitable analytical approach particularly when "there is relatively little prior theory and empirical evidence" (Fabrigar, Wegener, MacCallum, & Strahan, 1999, p. 282), as in the case for this inquiry. Although an impressive body of scholarly work has been dedicated to the creation and validation of TPACK constructs using factor analysis (see for example Yurdakul et al., 2012), and with a focus on pre-service science teachers (see for example Graham et al., 2009), very little has been undertaken on pre-service science educators in regional Australian settings. Using EFA on a sample located in regional Australia, this inquiry contributes to the challenge of searching for consistent definitions of TPACK constructs (Graham, 2011). Table 2 provides descriptive information about the sample. For this inquiry, the collected data was explored for the possibility of identifying not-so-obvious latent characteristics conforming to the idea that "factor analysis can be thought of as a variable-reduction procedure in which many variables are replaced by a few factors which summarize the relations among the variables "(Goldberg & Digman, 1994, p. 216).

In using EFA for variable reduction procedures, this inquiry employed Principal Components Analysis (PCA) where data generally represented by inter-correlated variables are extracted revealing "a set of new orthogonal variables called *principal components* (emphasis in the original)" (Abdi & Williams, 2010, p. 433). PCA is an attempt at condensing the magnitude of a large number of related variables into a coherent set of principal components or factors. An essential step in PCA is the manner in which the data-reduction, described in EFA and PCA literature as rotation, is implemented. For this inquiry, the assumption was that the variables in the data set were correlated, consequently an oblique rotation was employed.

Table 1. Pre-service teacher familiarity with ICTs

Word Processing Software	Smart Phones
Spread Sheet Software	Tablets
Presentation Software	eBooks
Photoshop	Wikipedia
Social Networks	Interactive Whiteboards
Twitter	Digital Data Projectors
Youtube	Blogs
TeachTube	Wikis
Skype	Ning
Learning Federation	Online games or simulations
TaLE	ePortfolios
GoogleDocs	RSS Feeds
Flicker	Chat Rooms
Adobe Connect	Educational Applications
Video Conferencing	Second Life

Table 2. Frequency distribution- Unit of analysis (N=39)

		Number	Percent %
Gender	Male	21	53.8
	Female	18	46.2
	Total	**39**	**100.0**
Age Range	18-21	5	12.8
	22-25	9	23.1
	26-29	4	10.3
	30-33	3	7.7
	34-37	9	23.1
	38-41	6	15.4
	42-45	2	5.1
	46-49	0	0
	50 and up	1	2.6
	Total	**39**	**100.0**
Student respondents' major area of study	Chemistry	9	23.1
	Biology	16	41
	Physics	2	5.1
	Chemistry and Biology	4	10.3
	Biology and Environmental Science	5	12.8
	Chemistry and Biochemistry	1	2.6
	Physics and Chemistry	1	2.6
	Physics, Chemistry and Biochemistry	1	2.6
	Total	**39**	**100.0**

RESULTS

Thirty-two (32) items from the TPACK Students' Diagnostic Survey were subjected to PCA to assess data dimensionality. The Kaiser-Meyer-Olkin was .599 which is considered an acceptable level (Taherdoost, Sahibuddin, & Jalaliyoon, 2014) and the Bartlett's test of Sphericity reached statistical significance (p= .000) indicating the correlations were sufficiently large for exploratory factor analysis.

Four factors were extracted explaining 70.156% of the variance. This was decided based on eigenvalues, cumulative variance and inspection of the scree plot. Factors were obliquely rotated using Oblimin rotation and their interpretation with the dimensions theorised by Chai, Koh, Tsai, and Tan (2011). Items loading on the first dimension suggests it represents Technological Knowledge, the second dimension suggests it represents Content Knowledge, the third Pedagogical Knowledge and the fourth is Technological Pedagogical Content Knowledge (TPCK).

From data analysis, four latent constructs (factors) were identified from the 39 pre-service educators of the survey. Table 3 provides information about the constructs. Although the N is relatively small, scholars and practitioners argue that sample size is not critical provided that the factors are over determined with high communalities (Budaev, 2010). After conducting the first round of rotation and looking at the communalities, items that were below 0.40 were discarded consistent with good cut-off figures (Pedhazur & Schmelkin, 1991). The communalities for the final factor rotations are all above the .40 rate. As can be seen in the EFA results, all four factors are over determined. Tests of

Table 3. Emerging constructs

Constructs / Items	Loadings
Factor 1 ("TK")	
I know how to solve my own technical problems	.80
I can learn technology easily	.88
I keep up with important new technologies	.90
I know about a lot of different technologies	.64
I have the technical skills I need to use technology	.70
Cronbach's alpha = .913	
Factor 2 ("CK")	
I have sufficient knowledge about science	.88
I can use a scientific way of thinking	.84
I have various ways and strategies of developing my understanding of science	.77
Cronbach's alpha = .808	
Factor 3 ("PK")	
I can adapt my teaching style to different learners	.86
I can use a wide range of teaching approaches in a classroom setting	.56
I know how to organise and maintain classroom management	.57
I can select effective teaching approaches to guide student thinking and learning in science	.72
Cronbach's alpha = .747	
Factor 4 ("TPCK")	
I know about technologies that I can use for understanding and doing science	.67
I can choose technologies that enhance students' learning for a lesson	.87
I can adapt the use of the technologies that I am learning about to different teaching activities	.63
I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn	.81
I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom	.42
I can choose technologies that enhance the content for a lesson	.73
I can teach lessons that appropriately combine science, technologies and teaching approaches	.50
Cronbach's alpha = .885	

reliability were conducted on the four factors (Cronbach Alpha), producing robust results (Iacobucci & Duhachek, 2003).

Are these Four Factors Distinct from Each Other?

A series of Multiple Analysis of Variance (MANOVA) tests were undertaken to determine whether the four constructs are indeed distinct from one another. As a multivariate test statistic, MANOVA can be used to test hypotheses about group differences that may or may not exist among variable combinations (Huberty & Olejnik, 2006). More importantly, MANOVA becomes useful in interpreting a "set of measures as they represent some underlying constructs" (Bray & Maxwell, 1985, p. 10). For the analysis, two stages of MANOVA were undertaken:

Using the extracted factors as a basis, four hypotheses were tested for this analysis. Do the four TPACK constructs have a multivariate main effect on selected perceptions of ICT usage, specifically: (1) Confidence levels in learning about new ICT; (2) Familiarity with Educational Applications? And do the four TPACK constructs have a multivariate main effect on selected perceptions of pre-service teachers' lecturers' teaching practices, specifically: (3) Ability of my science education lecturers to appropriately model the combination of content, technologies and teaching approaches; and (4) The magnitude of teacher education lecturers (in general) who model the combination of content, technologies and teaching approaches?

DISCUSSION

Confidence Levels in Learning about New ICTs

A one-way MANOVA was used to test for differences in relation to the question "Do the four TPACK constructs derived from the EFA have a multivariate main effect on confidence levels in learning about new ICT"? MANOVA revealed a significant multivariate main effect for Technology and Knowledge Perceptions (TPACK Constructs), Wilks' $\lambda = .296$, $F\ (8, 66) = 6.925$, $p <. 000$, partial eta squared = .456. As can be seen from the results, there is a main effect on the perception of ICT usage (i.e. there is a statistically significant basis for stating that differences exist). Given the significance of the overall test, the univariate main effects were examined. Significant univariate main effects for TPACK constructs were obtained for TK, $F\ (2, 38) = 29.23$, $p <. 000$, $\acute{\omega}^2 = .59$; for CK, $F\ (2, 38) = 3.25$, $p <. 050$, $\acute{\omega}^2 = .59$ and for TPCK, $F\ (2, 38) = 4.42$, $p <. 019$, $\acute{\omega}^2 = .15$. The omega squared ($\acute{\omega}^{2)}$ effect sizes range from moderate to large.

Content Knowledge-CK and Pedagogical Knowledge-PK register statistically significant differences (with moderate effect sizes) among the survey respondents. However, the mean scores registered in their confidence levels are not too far apart. It is the construct of Technological Knowledge – TK, that provides interesting findings. Aside from having a wide spread in the mean scores of their confidence levels, these differences are statistically significant and are accompanied by very large effect sizes.

As seen in Table 4, it is argued that pre-service science teachers acquire their knowledge about technology differently depending on their self-perceived confidence with new technologies. Assuming that the last factor (TPCK) constitutes knowledge of integrating technology in teaching and learning a particular content, then we make this key point: While there is widespread disparity among the levels of TK but not of CK and PK; the authors argue that TK as a domain of knowledge may not be specifically and purposefully targeted in the educational programs and is entirely up to the student

Table 4. How confident are you in learning about new ICTs?

How confident are you in learning about new ICTs?						
Perceptions on ICT practices	Not Confident N=8	Somewhat Confident N=15	Very Confident N=16	F	*p*	$\acute{\omega}^2$
Technological Knowledge TK	2.70	3.74	4.35	29.23	**.000**	**0.59**
Content Knowledge CK	4.16	4.33	4.68	.25	**.050**	**0.10**
Pedagogical Knowledge PK	3.96	3.96	4.07	.340	.714	0.04
TPCK	4.03	4.05	4.41	4.42	**.019**	**0.15**

Effect sizes metric: ω^2 <= .01 (small); ω^2 =.06 (moderate); ω^2 >.16 (large) to learn about it. This could be reflective of the way the units are structured with massive exclusive emphasis on content and pedagogy. It would seem that it is up to the learner to develop their own confidence in learning so as to increase their knowledge of TK.

Familiarity with Educational Applications

One way MANOVA was employed to test differences in relation to the question "Do the four TPACK constructs derived from the EFA have a multivariate main effect on familiarity with educational applications"? The tests of hypotheses revealed a significant multivariate main effect for Technology and Knowledge Perceptions (TPACK Constructs), Wilks' $\lambda = .504$ F (12,84.956) =.2.090, $p <. 026$, partial eta squared = .204. As can be seen from the results, there is a main effect on the perceptions of ICT usage (i.e. there is a statistically significant basis for stating that differences exist). Given this significant overall result, univariate main effects were examined. Significant univariate main effects for TPACK constructs were obtained for TK, F (3, 38) = 4.51, $p <. 009$, $\acute{\omega}^2 = .21$; and PK, F ((3, 38) = 2.92, p <. 047, $\acute{\omega}^2 = .13$. The omega squared ($\acute{\omega}^2$) effect sizes range from moderate to large.

Pedagogical Knowledge – PK registers statistically significant differences (with moderate effect sizes) among the survey respondents. The mean scores registered in their confidence levels are also not too far apart (ranging from a low of 3.81 to a high of 4.40). However, the construct of Technological Knowledge – TK, provides intriguing results. Not only are the differences statistically significant, these are also supported by large effect sizes and more importantly, the registered mean scores -- in relation to familiarity with Educational Applications -- cover a wide range.

The results in Table 5 reinforce the argument about the current model of teaching and learning that govern the educational programs at the host university: teach content and teach pedagogy. The findings suggest that there is a tacit assumption that pre-service teachers would be able to acquire/develop the other domains of TPACK along the way. Moreover, if technological knowledge is added to the mix, then what emerges could be a confusing picture from the perspective of pre-service teachers.

Pre-Service Science Teachers' Perceptions of Science educator's TPACK

One-way MANOVA was used to explore whether differences exist in the question "Do the four TPACK constructs derived from the EFA have a multivariate main effect on "pre-service teachers' perceptions of how their science education lecturer appropriately model the combination of content, technologies and teaching approaches in the way they teach"? The analysis revealed a significant

Table 5. Familiarity with educational applications

Familiarity with Educational Applications (Apps)							
Perceptions on ICT practices	I have not heard of this ICT technology N=7	I have heard but never used N=15	I have used this a few times N=12	I have used this many times N=5	F	*P*	$\acute{\omega}^2$
Technological Knowledge TK	2.97	3.77	4.15	4.04	4.51	**.009**	**.21**
Content Knowledge CK	4.19	4.62	4.36	4.46	1.13	.348	.01
Pedagogical Knowledge PK	4.00	4.05	3.81	4.40	2.92	**.047**	**.13**
TPCK	3.95	4.19	4.23	4.48	1.69	186	.05

Effect sizes metric: $\omega^2 <= .01$ (small); $\omega^2 = .06$ (moderate); $\omega^2 > .16$ (large) multivariate main effect for Technology and Knowledge Perceptions (TPACK Constructs), Wilks' λ = .462, *F* (8, 66) = 3.882, *p* <. 001, partial eta squared = .320. As can be seen from the results, there is a main effect on the perception of Lecturers' Impact. Given the significant overall test, univariate main effects were examined. Significant univariate main effects for TPACK constructs were obtained for PK, *F* (2, 38) = 8.33, *p* <. 001, $\acute{\omega}^2 = .27$; and TPCK, *F* (2, 38) = 3.25, p <. 051, $\acute{\omega}^2 = .10$. The omega squared ($\acute{\omega}^2$) effect sizes range from moderate to large.

TPCK registers statistically significant differences (with moderate effect sizes) among the survey respondents. The mean scores registered in their confidence levels are not too far apart. However, the construct of Pedagogical Knowledge – PK, provides an insightful picture. Not only are the differences statistically significant, these are also supported by large effect sizes. Even more interesting is the fact that the registered mean scores -- in relation to students' perceptions of how their science lecturers model TPACK teaching -- covers a relatively wide range.

Table 6, depicting students' perceptions of lecturers TPACK practices, reveals that TPCK and PK are some of the TPACK domains that pre-service students identify. However, it can be argued that from their perspective, what emerges as a blurred portrait is partially caused by the students' understanding of these domains as separate. In other words, our respondents manifested an underdeveloped understanding of the TPACK framework.

Pre-Service Science Teachers' Perceptions of Other Educator's TPACK

In order to test for differences in the question "Do the four TPACK constructs derived from the EFA have a multivariate main effect on "pre-service teachers' perceptions of how non-science educators appropriately model the combination of content, technologies and teaching approaches in the way they teach," a one way MANOVA was used. The tests revealed a significant multivariate main effect for Technology and Knowledge Perceptions (TPACK Constructs), Wilks' λ = .423 *F* (16,95.344) =.423, *p* <. 026, partial eta squared = .193. As can be seen from the results, there is a main effect on the perception of lecturers' impact. Given the significance of the overall test, univariate main effects were examined. Significant univariate main effects for TPACK constructs were obtained, particularly for TPCK, *F* (2, 38) = 4.15, *p* <. 008, $\acute{\omega}^2 = .24$. The omega squared ($\acute{\omega}^2$) effect sizes indicate a very large effect size.

All the other domains, except for TPCK, did not provide statistically significant differences. However, TPCK registered statistically significant differences (with very large effect sizes). More

Table 6. Science education lecturers appropriately modelling TPACK

My science education lecturers appropriately model combining content, technologies and teaching approachesin their teaching						
Perceptions on ICT practices	Neither Agree or Disagree N=6	Agree N=17	Strongly Agree N=16	F	p	$\acute{\omega}^2$
Technological Knowledge TK	3.60	3.61	4.02	1.34	.273	.02
Content Knowledge CK	4.33	4.43	4.50	.202	.819	.04
Pedagogical Knowledge PK	4.08	3.76	4.25	8.33	**.001**	**.27**
TPCK	4.09	4.05	4.39	3.23	**.051**	**.10**

Effect sizes metric: $\omega^2 <= .01$ (small); $\omega^2 = .06$ (moderate); $\omega^2 > .16$ (large) importantly, the mean scores reflected in the respondents' perceptions of how their lecturers (in general) modelled TPACK practices registered a relatively varied spread of mean scores.

Table 7 results, indicating levels of lecturers' TPACK modelling, reinforce an earlier point about the apparent lack of specificity in providing pre-service students unequivocal knowledge of TPACK constructs. Consequently, if the pre-service teachers are unaware of what to look for (i.e. TPACK), then their ability to accurately detect it may be questionable. We argue that the pre-service teachers' perceptions of the different domains of knowledge (i.e. an actual understanding of what it actually means to integrate technology with content and pedagogy), is underdeveloped and therefore, they cannot identify its occurrence when it happens or when lecturers model it.

Theorising Four TPACK Domains of Pre-service Science Teachers

Undertaking EFA revealed the existence of four latent constructs: Technological Knowledge-TK, Content Knowledge-CK, Pedagogical Knowledge-PK and TPCK. This is consistent with findings generated by Chai et al. (2011) in a pre-service education context in Singapore and with Graham et al. (2009) in a North American in-service cohort of pre-service science teachers. Both empirical studies generated four constructs analogous to those that emerged from this inquiry.

Findings provide an interesting counterpoint to existing international scholarship on TPACK perceptions of pre-service teachers. Figure 1 provides an image of how Mishra and Koehler's (2006) TPACK framework is represented. This exploratory analysis reveals that respondents have a blurred portrait of the TPACK domains. This blurred portrait is represented in Figure 2.

CONCLUSION

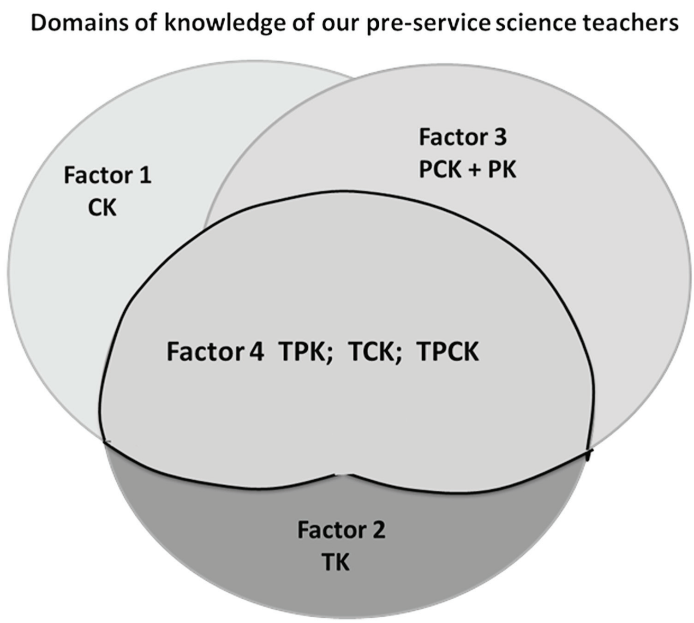
This exploratory analysis investigated the experiences of pre-service science teachers with TPACK. Using a sample of 39 students, and employing a 32-item self-reported survey questionnaire, yielded four tentative knowledge domains within the general TPACK framework. However, far from faithfully replicating Mishra and Koehler's (2006) TPACK framework, the portrait of the domains of knowledge emerging reveals a blurred image of TPACK. The authors argue that the blurred vision is due primarily to an expectation from lecturers that the domains of teachers' knowledge are tacit and should not necessarily be taught explicitly. Being exploratory in nature, the authors, explicitly state that further investigations are needed to explore whether this assumption has permeated the design and delivery of

Table 7. Education lecturers (in general) appropriately modelling TPACK

In general, approximately what percentage of your teacher education lecturers have provided an effective model of combining content, technologies and teaching approaches in their teaching?								
Perceptions on ICT practices	25% or less N=2	25% to 50% N=9	51% to 75% N=8	76% to 100% N=9	No answer N=11	F	p	ώ²
Technological Knowledge TK	3.10	3.53	3.97	3.77	3.96	.855	.501	.02
Content Knowledge CK	3.66	4.62	4.45	4.29	4.54	1.62	.191	.06
Pedagogical Knowledge PK	3.87	4.11	3.96	4.16	3.86	.901	.474	.01
TPCK	3.42	4.25	4.23	4.47	4.05	4.15	**.008**	**.24**

Effect sizes metric: ω^2 <= .01 (small); ω^2 =.06 (moderate); ω^2 >.16 (large)

Figure 2. Domains of knowledge of our pre-service science teachers



teaching and learning units. Findings from this exploratory analysis could provide some educational policy and practice usefulness in teaching TPACK. For educational policy, an explicit strategy of imparting how technology, pedagogy and content can be taught to pre-service students in increasingly integrated as well as discipline-specific online environments, is essential. For pedagogical practice, lecturers must scaffold and role model how technology, pedagogy and content is implemented. At the host university, this is already a practice of most lecturers. What is needed is to explicitly impart this to pre-service teachers. Follow-up investigations carefully mapping TPACK practices in regional universities extensively employing ICT in teaching and learning could be undertaken in order to shed greater analytical illumination into the domains of knowledge of all relevant stakeholders.

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