

Examining pre-service teachers' design capacities for web-based 21st century new culture of learning

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Although there is an established body of work arguing that teachers' technological pedagogical content knowledge (TPACK) is necessary for designing ICT-integrated lessons, little is known about the relationships among teachers' beliefs about learning, their design dispositions, learning design practices and TPACK. Critical inquiry in this aspect is timely as a new culture of learning is emerging from the informal contexts of learning and challenging how school-based learning should be designed to foster 21st century competencies. In this study, a survey instrument was developed to assess and investigate the relationships among pre-service teachers' beliefs about the new culture of learning and school-based learning, their design dispositions, learning design practices and relevant factors of TPACK. Based on the sample size of 223 pre-service teachers in Singapore, the validation shows that the relevant factors pertaining to TPACK, teachers' beliefs and design were distinctive. The study shows that teachers' beliefs about learning and their design capacities changed along with their TPACK efficacy. It also identified factors that might affect teachers' competencies needed to design lessons that could cultivate a new 21st century culture of learning. Implications of the relationships among teachers' beliefs about learning, their design capacities and TPACK to foster 21st century competencies are discussed.

Introduction

With rapid changes in web-based technologies researchers have questioned and challenged the assumptions of traditional practices of teaching (Collins & Halverson, 2010; Greenhow, Robelia, & Hughes, 2009). Today's students can easily obtain high quality information and tutorials, attend lectures from well-established experts, participate in special interest groups and publish their digital works, if they know how to harness the digital environments productively. Following Thomas and Brown's (2011) argument that young people and adults are constructing emerging learning practices and culture of learning, Kim, Tan, and Bielaczyc (2015) explain that the new culture of learning is participatory, collaborative and learner-defined, and technology use encompasses more than learning about a specific field of knowledge. To participate and thrive in the new culture of learning, learners are expected to exhibit skills and dispositions that are widely acknowledged as 21st century competencies, which include technology, information and media literacies, collaboration and communication skills and problem-solving abilities (Dede, 2010; Voogt & Roblin, 2012). Despite the thrust for the new culture of learning, teachers' ability to exploit the affordances of digital environments for realising it remains questionable. To date, there has been widespread dissatisfaction about teachers' ability to design lessons that can engage students in 21st century learning activities (Kohen & Kramarski, 2012; Kopcha, Ottenbreit-Leftwich, Jung, & Baser, 2014; Lee & Kim, 2014).

The argument that 21st century teachers should be competent at designing lessons that harness technologies to constitute a new culture of learning is one with which we concur. In this study, we developed a

methodologically sound instrument that assessed pre-service teachers' beliefs about the new culture of learning and their beliefs about school-based learning, their design dispositions and learning design practices, and the relevant factors of technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006). We argue that these factors are essential for teachers to be engaged in designing lessons that cultivate the new culture of learning in the 21st century. In our study, the pre-service teachers' developments in beliefs, design and TPACK after completing a course on the use of information and communication technology (ICT) for meaningful learning were assessed through the pre- and post-course surveys to address possible ways of promoting these factors among the pre-service teachers. In addition, multiple regressions were also performed to determine the significant predictors of the pre-service teachers' TPACK.

New culture of learning in the 21st century

The new culture of learning is significantly different from traditional school-based learning (Kim et al., 2015). Traditional practices of school-based learning rely on structured delivery of information by the teacher whereby the instruction is organised around prescribed curriculum and resources (Kim et al., 2015). Learning is a matter of acquiring knowledge along a pre-determined trajectory, targeted towards a summative evaluation where most questions tend to have one correct answer (Kim et al., 2015; Voogt, 2010). Kim et al. (2015) explain that the new culture of learning is largely learner-directed without prescribed syllabi or learning trajectories. The learning resources tend to be online and digital and they are assembled by the learners themselves, usually involving collaborations with others who share similar interests. In the new culture of learning, Kim et al. (2015) argue that learners are driven by the need to create meaningful digital artefacts; learning is predominantly participatory in nature. Evaluation of learning is in essence formative with ongoing online public feedback for constant improvements (Gee & Hayes, 2011; Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006; Thomas & Brown, 2011).

Although the new culture of learning emerges from informal learning in the online world, it does not directly negate the importance of traditional school-based learning. The collective wisdom of educators today seems to advocate an evolutionary path of reform to formulate policy, restructure curriculum and design lessons that draw on the merits of the new culture of learning and appropriate it for formal learning (Tan & Kim, 2015; Voogt, Estrad, Dede, & Mishra, 2013). Concrete reform efforts that are targeted at promoting 21st century competencies seem to be promoting a comparable set of competencies displayed by learners participating in the new culture of learning. Works in the last decade that compare and consolidate the various 21st century frameworks have identified the common competencies as ICT and media literacies, collaboration skills, authentic knowledge construction and problem-solving, self-directed learning and metacognitive self-management of the social and epistemic processes involved (Dede, 2010; Tan & Koh, 2014; Voogt & Roblin, 2012). Such competencies are also evident among children who thrive in the new culture of learning when teachers create opportunities to appropriate it for formal learning (Choy, Deng, Chai, Koh, & Tsai, 2016).

This study aimed to contribute to the current reform efforts by designing a survey instrument to better understand teachers' beliefs about the new culture of learning and school-based learning. It also studied the relationships among these beliefs, teachers' TPACK and their design thinking. Teachers' beliefs are important areas of research that many researchers have identified as an important factor for ICT integration (Ertmer, Ottenbreit-Leftwich, & Tondeur, 2015). To our knowledge, there has been no survey investigating teachers' beliefs about the new culture of learning and school-based learning. We argue that understanding teachers' beliefs in these aspects are necessary before any pedagogical intervention that works towards infusing the new culture of learning in formal learning is recommended.

TPACK for 21st century learning

The TPACK framework is one of the leading frameworks that provide explanations and guide research in ICT integration. The framework postulates that teachers need to actively synthesise several domains of knowledge in order to design high quality ICT-integrated lessons, that is, their technological knowledge, pedagogical

knowledge, content knowledge and the overlapping knowledge derived from the interactions among these forms of knowledge (Mishra & Koehler, 2006). The overlapping knowledge consists of the technological pedagogical knowledge, technological content knowledge and pedagogical content knowledge and TPACK. Existing knowledge that teachers possess in respect to these domains of knowledge, known as the seven factors of TPACK can be regarded as epistemic resources that teachers draw on when engaging in design thinking to create ICT-integrated lessons (Koh, Chai, Hong, & Tsai, 2015). Chai, Koh, and Tsai (2010) found that teachers' content knowledge, technological knowledge and pedagogical knowledge were indicative of their TPACK, and pre-service teachers' efficacies of these domains of knowledge improved significantly with medium effect sizes when they were compared at the start and end of an education technology course that emphasised learning by design. Put differently, based on this study, it is defensible to conclude that the quality of ICT-integrated lessons designed by the teachers is dependent on their existing level of TPACK and their design thinking (Chai et al., 2010).

Wide applications of the TPACK framework have repeatedly shown that building teachers' TPACK through 'learning by design' can help to enhance teachers' abilities and self-efficacy to integrate ICT (for review, see Chai, Koh, & Tsai, 2013; Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013). Various models of supporting teachers' TPACK development include Angeli and Valanides's (2009) technology mapping, Kramarski and Michalsky's (2010) self-regulated approach that builds on and enhances the technology mapping models and Tee and Lee's (2011) problem-based design approach. Although these studies have reported impressive outcomes about teachers' abilities in integrating ICT in general, less is known about their ability to design ICT-integrated lessons that specifically promote 21st century competencies (Kohen & Kramarski, 2012; Kopcha et al., 2014; Lee & Kim, 2014). Educational technology courses focusing on teachers' abilities to design lessons for 21st century learning are pertinent, yet such a focus has been identified as a gap in TPACK research (Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Koh et al., 2015; Voogt, Knezek, Cox, Knezek, & Brummelhuis, 2013).

Teachers' beliefs and their relations with TPACK have received attention from researchers as an area that needs future research (Voogt, Fisser, et al., 2013). It is a crucial factor that influences teachers' ICT integration (Ertmer et al., 2015). Sang, Valcke, van Braak, and Tondeur (2010) reported that pre-service teachers' beliefs about constructivist teaching and their attitudes towards computers in education are predictors for their prospective use of ICT. However, research has only established some significant but weak correlations (ranging from .19 to .34) between teachers' constructivist teaching, traditional pedagogical beliefs and TPACK factors among Chinese language teachers (Chai, Chin, Koh, & Tan, 2013). As Pajares (1992) argues, teachers' beliefs are 'messy' constructs. Therefore, it is necessary to be specific about the facets of beliefs that are being measured in order for researchers to interpret the results with confidence. In this study, we investigated pre-service teachers' beliefs about school-based learning and their beliefs about the new culture of learning and conducted multiple regression analysis to assess whether these two types of beliefs were significant predictors for their TPACK. Our hypothesis, based on the studies reviewed above, was that teachers' beliefs about the new culture of learning would significantly predict their TPACK and their beliefs about school-based learning might not be a significant predictor since focus towards traditional pedagogy could prevent teachers from designing constructivist use of ICT (Chai, 2010).

Besides teachers' beliefs, another contributor to teachers' ICT integration effort is their design capacities. Tsai and Chai (2012) have argued that teachers' design capacities are third-order barriers that hinder ICT integration besides the first-order barriers (e.g., access to technology) and second-order barriers (i.e., teachers' beliefs). Studies from many developed countries have shown that despite good access to technology and teachers' support in ICT use, teachers' integration of ICT is still limited, especially for constructivist-oriented use (e.g., Vrasidas, 2015). This phenomenon is not surprising, as contextually, teachers are required to design specific lessons for the group of students who have particular learning trajectories and relationships with the teacher. In other words, standardised curriculum and one-size-fits-all instruction should not be expected if there is genuine intention to implement a learner-centred and constructivist-oriented new culture of learning. Teachers would have to be creative designers who possess higher-order transdisciplinary skills to empower their students to acquire the same repertoire of skills (Koehler et al., 2014).

Koh et al. (2015) argue that teachers' design capacities consist of lesson design practice and design dispositions. Drawing on the literature on design, Koh et al. (2015) postulate that there are design practices and design dispositions that teachers possess to either facilitate or constrain the design of lessons. Teachers who are open to new experiences, sensitive to their students' needs and are comfortable to ambiguous situations and conflicting ideas are better suited to engage in design (Cross, 2011; Michlewski, 2008). In addition, experimenting with ideas, allowing diverse ideas to coexist and evolve over time as well as avoiding premature idea fixation are design practices that are more likely to result in strong design (Cross, 2011; Lawson, 1997). Using confirmatory factor analysis (CFA), Koh et al. (2015) validated a survey instrument that measured teachers' lesson design practice, design dispositions and TPACK and ascertained that both lesson design practice and design dispositions were significant predictors for teachers' TPACK in their structural equation model (SEM). However, their pilot study was limited as only three constructs were being investigated and the sample consisted of both in-service and pre-service teachers. Whether lesson design practice and design dispositions are significant predictors when they are assessed with more variables, including teachers' beliefs and other TPACK factors, is yet to be determined. Further research is necessary to investigate whether teachers' design dispositions and lesson design practice can change when teachers are engaged in learning by design. Within educational research, comprehensive investigations of the relationships among design-related variables (lesson design practice and design dispositions), knowledge-related factors (technological knowledge, pedagogical knowledge and content knowledge), beliefs about learning (beliefs about the new culture of learning and school-based learning) and teachers' TPACK are scarce. Such inquiries are crucial for clarifying and identifying variables that are associated with teachers' TPACK (Voogt, Fisser, et al., 2013). In addition, while there is general consensus among teacher educators on the importance of teachers' beliefs, examination of teachers' initial beliefs is often neglected or generally not addressed in preparatory courses (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Fives & Buehl, 2012). Few studies have reported how preservice teachers' beliefs (especially the relationship among the beliefs) change after going through a learning by design ICT integration course grounded by the TPACK framework. Answers to these questions have the potential to improve the design of teacher professional development activities as they inform teacher educators of the variables that need urgent attention. This study therefore attends to the following research questions:

- (1) Can the survey questionnaire that assesses the teachers' beliefs about the new culture of learning (BNCL), beliefs about school-based learning (BSBL), lesson design practices (LDP) and design dispositions (DD) and selected factors of TPACK be validated with the participants?
- (2) How do the measured variables change after the participants have engaged in a course that emphasises learning by design?
- (3) What are the significant predictors of teachers' TPACK before and after their participation in the learning by design course?

Methods

Participants

The invited participants ($N = 223$) were from the 2013 June intake of pre-service teachers who were enrolled into the postgraduate diploma in education courses and tutored by the authors. They had completed their basic degrees. There were 165 female teachers, and their average age was 24.2 years ($SD = 4.09$). As part of the course requirement, they had to complete an education course known as *ICT for Meaningful Learning*. Participation was voluntary, and ethics clearance was obtained from the university.

ICT for meaningful learning

ICT for Meaningful Learning is a compulsory course for all pre-service teachers in Singapore. The course aims to enable pre-service teachers to use technologies for constructivist-oriented learning. The course is

taught over a period of 12 weeks, with each session lasting 2 hours. In the first four weeks of the course, the pre-service teachers in the study were introduced to the Singapore Ministry of Education Masterplans for ICT (Singapore Ministry of Education, 2008) and its 21st century learning framework (Singapore Ministry of Education, 2016). In the course, students engaged in discussions related to the use of technologies for collaborative and self-directed learning, which are two of the 21st century skills the Ministry of Education has identified. They also explored a range of technologies for solving authentic problems and other facets of meaningful learning – active, constructive, collaborative, intentional and authentic learning from Howland, Jonassen, and Marra (2012). This model of meaningful learning was the theoretical framework employed to equip the pre-service teachers with the necessary pedagogical knowledge to anchor the use of technologies for content learning. The framework was also consistent with the 21st century new culture of learning reviewed earlier. In the last eight sessions, various technologies were introduced and explored with the purpose of evaluating the pedagogical affordances of the technologies. The pre-service teachers were expected to plan and generate lesson ideas that could facilitate meaningful learning among students, using Dick and Carey's (1996) instructional planning model.

When the survey was implemented, the pre-service teachers started to work in groups to design lesson ideas at least two or three times before they designed a complete lesson for final submission. In other words, the pre-service teachers were engaged in at least three cycles of lesson design activities within the structured tutorials. Experiencing meaningful learning and learning by design were the two design principles that undergirded the course. To pass the course, the individual lesson designs must be viable for classroom implementation.

Instrument

The survey instrument was adapted from several sources. First, the survey items for the web-based technological knowledge (WTK), content knowledge (CK), pedagogical knowledge (PK) and the TPACK items were adapted from a previously verified TPACK instrument (Koh et al., 2015). As the course did not explicitly discuss the TPACK framework and help students to understand the overlapping factors of technological pedagogical knowledge, technological content knowledge and pedagogical content knowledge, these factors were not measured. Second, the LDP and DD items were adapted from the study of Tan and Kim (2015). Finally, items to assess teachers' BNCL and BSB were created for this study based on the literature reviewed above. The items were scored on a 7-point Likert scale (1 for *strongly disagree* to 7 *strongly agree*). The assembled instrument was subjected to review by three professors in educational technology, and necessary amendments were made accordingly.

Data collection and analysis

An online survey was administered during the first and last week of the course. The participants took 15–20 minutes to complete it. The response rate was 80.5% as some of the pre-service teachers chose not to participate and/or missed either the pre-course or post-course survey. Only responses from the participants who had participated in both surveys were analysed.

To answer the first research question, the data were analysed first to assess the validity and reliability of the newly assembled instrument. To avoid problems with the psychometric properties of the TPACK instruments, it was important to ensure that the instrument was methodologically robust even though most factors were adopted from previously validated instruments (Brantley-Dias & Ertmer, 2013; Koehler et al., 2014). To this end, the pre-course data was subjected to exploratory factor analysis (EFA) while the post-course data was subjected to CFA. Alpha reliabilities were computed for both sets of data. To answer the second research question, paired *t*-tests were subsequently conducted to determine any significant differences in the pre-service teachers' perceptions before and after the course. To answer the third research question, multiple stepwise regression analyses were performed. Specifically, for both pre- and post-course data, teachers' TPACK was treated as a dependent variable, while the other seven constructs were used as predictors.

Findings

In this section, we present the findings for this study in order of the research questions. The EFA employing the principal component analysis with varimax rotation yielded 8 factors with eigenvalues greater than 1 on the data from the pre-course survey. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was at .92, $p < .001$, indicating that the data were suitable for factor analysis. Several items were removed (two WTK and two school-based belief items) due to insufficient factor loadings ($> .50$) or they were loaded to other factors. Total variances explained by the eight factors were 77.9%. The finalised list of items is provided in Table 1. To further verify the above 8-factor structure, CFA was conducted on the post-course data. According to the criteria suggested by Hair, Black, Babin, and Anderson (2010), satisfactory model fit was recognised: $\chi^2 = 1251.223$, $df = 674$, $\chi^2/df = 1.856$ (< 3.0), $p < .001$, $TLI = .915$ ($> .90$), $CFI = .923$ ($> .90$), $RMSEA = .062$ ($< .07$) This suggests that the 8-factor survey questionnaire possesses adequate construct validity for future use. Besides, the overall alpha reliabilities of both pre- and post-course data for the survey were .93 and .93; and individual factor reliabilities ranged from .77 to .94 for the pre-course data and .84 to .95 for the post-course data. These results indicate that the questionnaire exhibited very good construct reliability.

Table 1
Factors loadings and alpha reliabilities for pre-course data

BNCL ($\alpha = .92$)	
1. Today's learners should be able to remix relevant resources to publish their ideas.	.826
2. Remeshing digital resources responsibly is a good way to learn.	.804
3. Online collaboration should be part of students' personal competencies.	.801
4. Managing personal online learning resources is a desirable skill.	.794
5. Students should be able to choose relevant digital resources for self-initiated learning.	.761
6. Producing creative digital works is a meaningful task.	.749
BSBL ($\alpha = .77$)	
1. Direct instruction is an effective teaching method to ensure students' understanding about the content.	.831
2. The most important job of teachers is to help students to pass examinations.	.815
3. Students should be provided with correct answers when they are learning in school.	.812
4. Step-by-step instruction helps students to master the right procedures in completing assignments.	.807
CK ($\alpha = .88$)	
1. I have sufficient content knowledge about my teaching subject.	.871
2. I am confident to teach the content knowledge for my teaching subject.	.832
3. I can think about the content knowledge of my teaching subject like a subject matter expert.	.796
4. I am able to gain a deeper understanding about the content knowledge of my teaching subject on my own.	.789
WTK ($\alpha = .83$)	
1. I am able to use social media (e.g., Blog, Facebook, and Twitter).	.878
2. I am able to use communication tools (e.g., MSN Messenger, Skype, online chat).	.870
3. I am able to use web-based collaboration tools (e.g., Wiki, Google Doc).	.827
PK ($\alpha = .92$)	
1. I am able to guide my students to manage their own learning.	.806
2. I am able to help my students to reflect on their learning strategies.	.774
3. I am able to facilitate students to engage in in-depth discussion of learning content among themselves.	.750
4. I am able to help my students in designing solutions for real-world problems.	.743
5. I am able to guide my students to construct knowledge collaboratively.	.732
6. I am able to stretch my students' thinking by engaging them with real-world problems.	.695

TPACK ($\alpha = .94$)	
1. I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g., simulations, web-based materials).	.769
2. I can structure activities to help students to construct different representations of the content knowledge using appropriate ICT tools (e.g., Webspiration, Mindmaps and wiki).	.761
3. I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools. (e.g., Google Sites, CoverItLive).	.723
4. I can design lessons that appropriately integrate content, technology and pedagogy for student-centered learning.	.694
5. I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g., blogs, webquests).	.688
6. I can identify real-world problems about the content knowledge and represent them through computers to engage my students.	.660
DD ($\alpha = .87$)	
1. I am constantly seeking to turn constraints into opportunities.	.828
2. I am comfortable with occasional failures from trying out new approaches for teaching.	.815
3. I am comfortable to explore conflicting ideas.	.788
4. I am comfortable to deviate from established practices.	.783
5. I am comfortable with the presence of uncertainty.	.751
LDP ($\alpha = .88$)	
1. When designing an ICT lesson, I start by playing with a few lesson ideas.	.802
2. When designing an ICT lesson, I consider several lesson ideas to see if they adequately address students' learning problems before choosing one idea.	.775
3. When designing an ICT lesson, I consider the consequences of adopting particular lesson ideas before working out its details.	.736
4. When designing an ICT lesson, I continually refine my lesson ideas as I develop new understandings throughout the design process.	.666
5. When designing an ICT lesson, I allow conflicting lesson ideas to coexist until I feel that I have adequately understood the learning problems.	.621

Table 2 reports the differences in pre-service teachers' beliefs and their TPACK before and after the course. All other factors were significantly changed after the course. Medium to large effect sizes (Cohen's d s > .50) were detected among factors related to the knowledge and practice of design (CK, WTK, PK, TPACK and LDP), whereas small effect sizes were detected for belief-related factors (BNCL, BSBL and DD).

Table 2
Descriptive data and results of paired-sample t -test

Measured factors	Pre-study survey		Post-study survey		t	Cohen's d
	M	SD	M	SD		
BNCL	5.71	.76	5.95	.68	4.33***	.33
BSBL	4.62	1.08	4.77	1.14	2.10*	.14
CK	5.19	.89	5.61	.76	7.19***	.51
WTK	5.40	1.03	6.13	.73	11.48***	.82
PK	4.91	.77	5.60	.66	12.32***	.95
TPACK	4.00	1.12	5.61	.71	21.06***	1.72
DD	5.44	.87	5.65	.75	3.40***	.26
LDP	5.24	.65	5.65	.75	8.65***	.69

*** $p < .001$ * $p < .05$

As a precursor to the stepwise regression, correlations between the factors were studied, as shown in Table 3. Consistently, BSBL was not correlated to DD, WTK and BNCL, and it was weakly related to other factors for both pre- and post-course surveys. The rest of the factors were positively correlated. These results suggest that BSBL was peripheral to the constructivist-oriented pedagogies supported by ICT.

Table 3
Pre- and post-course correlations among the factors

	BNCL		BSBL		WTK		CK		PK		TPACK		DD	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
BSBL	.042	.097												
WTK	.300**	.468**	.113	.095										
CK	.171*	.321**	.137*	.146*	.379**	.255**								
PK	.250**	.496**	.200**	.159*	.384**	.445**	.514**	.607**						
TPACK	.185**	.596**	.222**	.207**	.602**	.522**	.265**	.516**	.488**	.718**				
DD	.477**	.395**	.048	.043	.291**	.379**	.269**	.193**	.297**	.366**	.200**	.464**		
LDP	.452**	.621**	.163*	.247**	.358**	.416**	.242**	.346**	.371**	.510**	.355**	.577**	.436**	.476**

** $p < .01$, * $p < .05$

For both pre- and post-course tests, WTK, PK, CK, BNCL, BSBL, LDP, and DD were used in a stepwise regression analysis to predict TPACK. For the pre-test, the prediction model contained only three of the seven predictors and was reached in three steps with no variables removed. The model was significant, $F(3, 219) = 60.30$, $p < .001$ and explained approximately 45% of the variance of TPACK ($R^2 = .45$, Adjusted $R^2 = .44$). As significant predictors, WTK, PK and BSBL uniquely accounted for about 36%, 8% and 1% of the variance of TPACK. Partly different results were obtained for the post-test. With five significant predictors (i.e., PK, BNCL, WTK, DD and CK) identified, the regression model was significant, $F(6, 216) = 66.61$, $p < .001$ and explained about 64% of the variance of TPACK ($R^2 = .64$, Adjusted $R^2 = .63$). Among these five predictors, PK accounted for most (51%) of the variance of TPACK, while the rest explained 8%, 2%, 1% and 1% respectively. More details about the two regression models are presented in Table 4.

Table 4
Stepwise regression results for pre- and post-course tests

Regression model	R^2 change	F change	B	SE	β	Pearson r
<i>Pre-test</i>						
Constant			-1.38	.43		
WTK	.36	125.91***	.52	.06	.48	.60
PK	.08	30.63***	.41	.08	.28	.49
BSBL	.01	4.79*	.12	.05	.11	.22
<i>Post-test</i>						
Constant			-.53	.33		
PK	.52	234.91***	.43	.06	.40	.72
BNCL	.08	44.92***	.21	.06	.20	.60
WTK	.02	11.56**	.15	.05	.16	.52
DD	.01	7.37**	.16	.06	.14	.58
CK	.01	5.31*	.11	.05	.12	.52

*** $p < .001$, ** $p < .01$, * $p < .05$

Discussion and conclusion

This study aimed to determine if the newly assembled instrument was valid and reliable. It also aimed to find out how the measured factors changed over time (i.e., before and after the course) and investigate the relationships among the factors, especially the significant predictors for the pre-service teachers' TPACK. The following discussions highlight the results and explain their implication for theory and practice for teacher education.

Instrument validation for investigating the relationships among TPACK, teachers' beliefs and design disposition

First, the EFA and CFA, and the alpha reliabilities computed confirmed that the newly assembled instrument could be considered an adequate measure to assess the pre-service teachers. It possessed both construct validity and strong reliabilities. Creating such an instrument to assess the teachers' BNCL and BSBL, their TPACK efficacy and their LDP and DD is important. Measurement issues have been raised about TPACK (Brantley-Dias & Ertmer, 2013), and theoretical questions about how TPACK is related to teachers' beliefs have also been raised to make links between TPACK research and research on teachers' beliefs (Voogt, Fisser, et al., 2013). The newly assembled instrument shows that the items adopted from previous research (i.e., CK, WTK, PK, TPACK, LDP and DD) such as in the studies done by Chai, Ng, Lee, Hong, & Koh (2013) and Koh et al. (2015) continued to be stable when they were studied with factors related to the teachers' beliefs (i.e., BNCL and BSBL).

More importantly, the validation shows that the factors pertaining to TPACK, teachers' beliefs and design disposition were distinctive. The validation of the assembled instrument built a measurement basis for unpacking the relationships among teachers' TPACK, teachers' beliefs and their design thinking, which were identified as essential for teachers' professional development for ICT integration (Ertmer et al., 2015; Tsai & Chai, 2012; Voogt, Estrad, et al., 2013). The two forms of teachers' beliefs that we created in this study were directly related to the approaches to learning that teachers might encounter in the 21st century classrooms, and they were akin to the two metaphors of learning that Sfard (1998) proposed; that is, learning through participation mediated by web-based technologies and learning in school for standardised testing should be complementary and can be designed to form such relationships. The lack of correlation between these two forms of beliefs among the teachers might indicate that the teachers viewed these two approaches to learning as unrelated. Bridging the emerging learning practices in informal learning spaces with formal learning is likely to be an important area of work that schools and educators need to consciously formulate. The emerging research in seamless learning seems to offer promising ideas in this direction (see, for example, Sharples, 2015).

Relationships among TPACK, beliefs about the new culture of learning and school-based learning, lesson design practices and design dispositions

Second, the pre-post surveys indicated that the *ICT for Meaningful Learning course* had improved the pre-service teachers' TPACK efficacy. The positive outcomes were generally consistent with research that employed the TPACK framework to develop teachers' TPACK (Angeli & Valanides, 2009; Kramarski & Michalsky, 2010; Mishra & Koehler, 2006; Tee & Lee, 2011). In comparison with past research (Chai, 2010) where only medium effect sizes were recorded, the effect sizes produced by this study course was larger, ranging from medium to large. The largest effect was on the teachers' TPACK. Although the course structure did not change substantially as compared to the 2010 course, the current course emphasised the design of lesson activities more than technological skills (TK). The larger effect sizes (see Table 2, WTK, PK and TPACK) could also be a result of the tutors gaining expertise in facilitating pre-service teachers' TPACK development.

This study shows that the teachers' BNCL and BSBL both gained significantly along with their LDP and DD. Except for the medium effect size of the LDP, which was a measure of the pre-service teachers' perception of their design practice, the teachers' BNCL, DD and BSBL recorded only small changes in terms of its effect sizes. Nonetheless, the results provide empirical support that the pre-service teachers' beliefs about learning and their design thinking did change along with their TPACK. The contributing factors for the change in the teachers' BNCL could be due to the fact that they experienced meaningful learning themselves in the course, which advocated similar forms of learning as the new culture of learning (Gee & Hayes, 2011; Kim et al., 2015). For example, in the last 8 sessions of the course, the pre-service teachers chose the technology they wished to explore, formed interest groups to study the affordances, designed lesson activities and engaged in online and face-to-face peer critique. However, the 24-hours *ICT for Meaningful Learning course*, along with

many other courses for the 9-month postgraduate diploma program, did not afford time for the tutors to engage the pre-service teachers in discussing their beliefs. The teacher educator's efforts to scaffold the pre-service teachers to articulate their beliefs could surface some entrenched beliefs that necessitated deeper reflections. We argue that this may consequently foster deeper changes among the pre-service teachers but further research is required to empirically test this hypothesis.

Third, with respect to the relationships among the teachers' TPACK, beliefs and design thinking, the correlations obtained indicates that they were generally positively related to each other. The results therefore provide some empirical evidence that teachers' beliefs and design thinking were related to their TPACK. Traditional pedagogical beliefs have been reported to predict the use of computers for information delivery rather than the constructivist use of computers for knowledge construction (Chai, 2010). Research has also shown that teachers' beliefs about constructivist teaching are only weakly correlated to their TPACK (Chai, Chin, et al., 2013). However, in this study, BNCL was associated more strongly with the teachers' TPACK and design thinking, especially in the post-course survey. Teachers' BSBL, which were more akin to traditional pedagogical practices, were also positively, though rather weakly, related to the teachers' TPACK. We thus argue that beliefs about learning may have more direct influence on teaching practice than beliefs about teaching.

Further exploration of the relationships among the factors through regression analyses revealed that at the beginning of the course the pre-service teachers only perceived WTK, PK and BSBL as significant predictors for their TPACK. The post-course survey, however, revealed that WTK, PK, CK, DD and BNCL were significant predictors of the teachers' TPACK. In terms of the knowledge factors that predicted TPACK, this study was consistent with Chai's (2010) study. However, in terms of the predictor LDP, the results of this study are inconsistent with those in the study conducted by Koh et al. (2015). In their study, in-service teachers were included, and only three factors (DD, LDP and TPACK) were considered in the structural equation model. They reported that LDP was a significant predictor for teachers' TPACK and DD had both direct and indirect influence (through LDP) on teachers' TPACK.

In this study, more factors were considered, and DD emerged as a significant predictor for the post survey. Given that the LDP was significantly related to all other factors for both the pre- and post-course surveys, the result suggests that LDP might exert its influence through some mediating factors. It requires structural equation models to unpack the relationships among these factors, and this should be a focus for future research. Nonetheless, this study reveals that the factors that predicted the pre-service teachers' TPACK changed as teachers engaged in lesson design activities. The inclusion of BNCL and the exclusion of BSBL in the post-course survey reveal that the set of beliefs that drove the pre-service teachers' design of ICT-integrated lesson had changed towards fostering the students 21st century skills rather than preparation for examination. The importance of PK, which replaced WTK as the most significant predictor, also indicates a change in how they considered ICT integration. These changes are significant in that they reveal the structural changes of interrelationships in terms of the predictors of the pre-service teachers' TPACK. As highlighted in the literature review, teacher educators are generally concerned about teachers' beliefs (Ertmer et al., 2012; Fives & Beuhl, 2012), but there is a general lack of studies about how the relations among beliefs and knowledge change when teachers are engaged in design-related activities. This study provides quantitative evidences that teachers' beliefs do change when they acquire TPACK through design activities. Future research may be needed to further unpack the change through qualitative analysis of the teachers' design talk over time.

Moving forward

There are several limitations that this study faced. First, factors that were argued as more crucial for TPACK, including technological pedagogical knowledge, pedagogical content knowledge and technological content knowledge, were not investigated. This was partly due to our consideration not to use long surveys that could lead to survey fatigue and thus inaccurate findings. Second, the pre-service teachers in this study were not introduced to the TPACK framework explicitly as many tutors of this prescribed course were not familiar

with the framework. There was also no opportunity for the pre-service teachers to reflect and articulate why and how their beliefs about NCL had changed throughout the course.

Despite these limitations, in this study, we constructed and validated a survey instrument to assess and investigate the relationships among pre-service teachers' beliefs about a new culture of learning and school-based learning, their design capacities and relevant factors of TPACK. It has provided empirical support to the notion that pre-service teachers' beliefs about learning and their design capacities do change along with their TPACK. There is a dearth of empirical studies on teachers' abilities to design lessons to foster the new 21st century culture of learning in current TPACK research. Our study is one of the pioneering studies within TPACK research that has provided empirical data to identify the factors that may affect teachers' competencies to design lessons that cultivate the learners' culture of learning. Future research may consider studying how teachers teaching in different types of school, for example, well-equipped elite schools versus poorly funded inner schools, may differ in their beliefs about the new culture of learning and school-based learning. Similarly, the relationships among their TPACK, beliefs about the new culture of learning and school-based learning, lesson design practices and design dispositions could be investigated and compared.

The New Media Consortium Horizon Report (Johnson, Adams, & Cummins, 2012) has identified the emerging technologies that have impacts on learning, and these changes suggest a reconceptualisation of design practice. While we focus on teachers' beliefs about the new culture of learning, we emphasise the equal importance of understanding learners' beliefs about the new culture of learning as well. Ethnographic studies have provided rich accounts of how young people are appropriating a range of technologies to shift the way they learn and engage with technologies (e.g., Chai, Koh, et al., 2013; Kim et al., 2015; Tan, 2013). Nevertheless, without large-scale surveys conducted with methodologically sound instrument, it is difficult to ascertain how widespread the new culture of learning is. Consequently, it is difficult to formulate policies and curriculum reforms to cater to students' needs. This study therefore advocates that future research should investigate students' beliefs towards the new culture of learning through both quantitative and qualitative means and how they take hold of their formal and informal learning spaces. We believe that this is crucial for the continuous evolution of education for the 21st century (see Collins & Halverson, 2010).

While we have noted that the culture of learning and beliefs about learning are shifting, an important challenge in this evolution is managing the tension in appropriating the new culture of learning that arises from informal learning to formal learning. As raised earlier in this paper, quantitative studies that investigate teachers' beliefs about the new culture of learning and school-based learning are lacking in educational research. It is our intention for our study to contribute to the emergence of critical literature in this inquiry. Although we agree that identifying best practice' in designing for the new culture of learning is important, we argue that first and foremost we should identify the competencies teachers need before that can be realised in the educational landscapes.

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