Developing Indonesia teachers' technological pedagogical content knowledge for 21st century learning (TPACK-21CL) through a multi-prong approach

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Abstract

The need for schools to develop workers with 21st century competencies such as critical and creative thinking as well as social, cultural and technological literacies is globally recognised (e.g. PS21, 2009). Teachers face the challenge of engendering 21st century learning (21CL) experiences to help students develop such competencies (Koh, Chai, Wong, & Hong, 2015). Driven by information and communication technology (ICT), 21CL can be described as technology-supported learning experiences that are active, authentic, constructive, collaborative, and intentional in nature (Howland, Jonassen, & Marra, 2013). However, 21CL experiences where students use ICT to support higher-order thinking and active learning are still not prevalent in schools as teachers struggle to go beyond using ICT as content instruction tools (Ertmer & Ottenbreit-Leftwich, 2013; Heitink, Fisser, Verplanken & van Braak, 2017). Teachers therefore need to develop technological pedagogical content knowledge (TPACK), their professional know-how for ICT integration. TPACK refers to the ways in which teachers integrate their technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK) to create ICT-integrated lessons (Mishra & Koehler, 2006). Koh et al. (2015) assert that teachers need to develop TPACK

for integrating ICT in ways that support 21CL, that is, TPACK for 21st century learning (TPACK-21CL).

Teacher education programmes in TPACK-21CL are becoming important (see Chai & Koh, 2017; Koh, Chai, & Lim, 2017). TPACK-21CL programmes are also relevant for developing countries where ICT-driven pedagogies have been used to support educational reform and social progress (Kozma & Vota, 2014). This mixed methods study describes 80 Indonesian teachers' TPACK-21CL development and their learning outcomes throughout a two-day professional development workshop. It also discusses how a TPACK-21CL development approach supported with multiprong pedagogical reasoning activities could be relevant for supporting teacher professional development in an international context and its implications.

Keywords: 21st century learning, TPACK, international teacher development

Literature review

Dimensions of TPACK-21CL

Numerous propositions of 21CL indicate common dimensions including ICT competencies, collaboration, authentic problem-solving and self-management of learning (see Dede, 2007; PS21, 2009; Voogt & Roblin, 2012). Chee and Chai's (2017) framework of 21st century quality learning encapsulates four critical dimensions that could be used with ICT-integrated tools to actualise the 21CL practices: (1) authentic learning to engage and develop students' problem solving ability (2) collaborative learning around and through computers to strengthen students' capacities to work in social settings (3) reflective learning that engages students' self-diagnosis and adjustment of learning strategies, and (4) active learning that involves knowledge construction of digital artefacts through the use of ICT as cognitive tools. These four dimensions form the pedagogical anchors for TPACK-21CL adopted in this study.

Principles for developing TPACK-21CL

Mishra and Koehler's (2006) TPACK framework proposes that teachers formulate TPACK from the three basic knowledge forms of TK, PK, and CK, which are depicted as three inter-locking circles with TPACK as the intersecting area. Three intermediary knowledge sources of technological pedagogical knowledge (TPK), technological content knowledge (TCK) and pedagogical content knowledge (PCK) can also arise from the intersections among TK, PK, and CK. TPACK is therefore an emergent knowledge form and the following considerations are critical for developing TPACK-21CL.

1. Pedagogical understanding of TPACK-21CL dimensions
   Establishing clear pedagogical understanding (PK) appears to be most critical (Koh et al., 2017) as evidenced in ICT professional development programs seeking to foster ICT innovation (Somekh, 2007). Where pedagogical understanding is shallow, teachers typically enact surface level pedagogical change (Windschitl, 2002).

2. Linkage to teachers' existing pedagogical practices
   While PK and CK are distinct knowledge sources in Mishra and Koehler's (2006) framework, studies of teachers' ICT lesson design talk by Koh and Chai (2016) found that teachers rarely considered PK and CK separately but focused on the synthesised knowledge form of PCK. PCK encapsulates teachers' pedagogical practices without using ICT and their understanding of curriculum and student learning needs and teachers. To be relevant, TPACK-21CL must be relatable to teachers' existing pedagogical practices (Chai & Koh, 2017).

3. Understanding the affordances of ICT tools
   Teachers need to understand how ICT tools support the pedagogical aspects of 21CL. This is a crucial step in building the teachers' TPK. In fact, tinkering with ICT tools to understand its pedagogical affordances is a staple feature of many TPACK programmes (e.g. Jang, 2010; Koh & Divaharan, 2013). This process enhances teachers' TK, exposes them to content-related technology tools (TCK) and helps teachers to identify the pedagogical affordances of different tools (TPK) which are critical building blocks to TPACK-21CL.

4. Designing
   There is much recognition that design-driven approaches provide the context for teachers' TPACK to emerge during teacher professional development as they synthesise technological, pedagogical, and content considerations into a coherent ICT-integrated solution (Koehler, Mishra, & Yahya, 2007; Koh & Divaharan, 2013). Rather than providing teachers with designed solutions, such an approach treats teachers as knowledge creators for their classroom practices. Such an approach also allows the teachers to be 21st century learners themselves. Therefore, opportunities for the design and refinement of lesson ideas are important for supporting TPACK-21CL development.

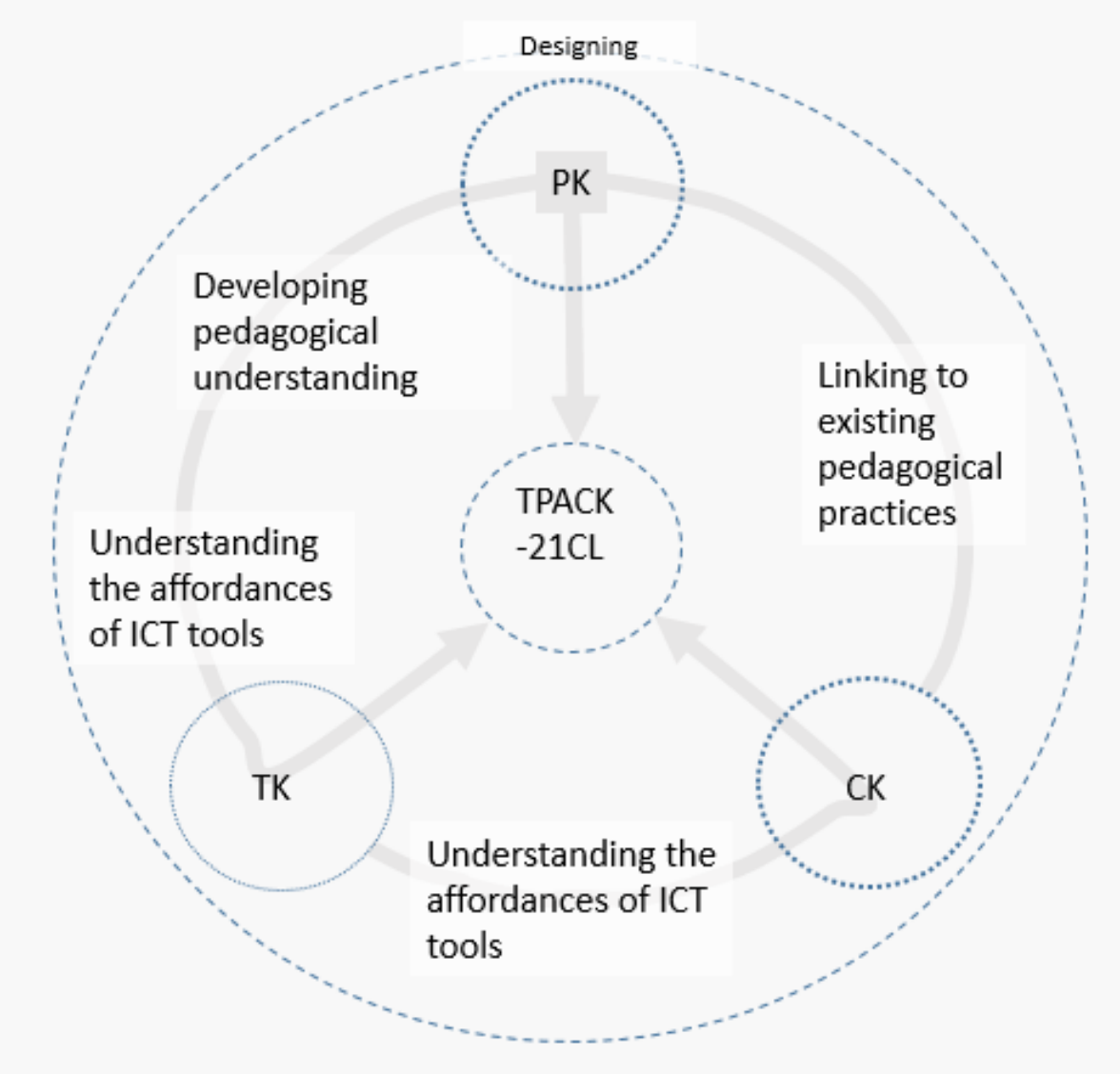
TPACK-21CL in Indonesia

A review of the literature found a dearth of TPACK studies in Indonesia. The few studies of teachers' ICT professional development show that there are varying levels of ICT competencies among Indonesian teachers (Widodo & Riandi, 2013). It is also expected that teachers may be unfamiliar with TPACK-21CL dimensions as the use of ICT for content presentation is predominant even within Indonesia's teacher education institutions (Yusuf, 2016). This suggests a prevailing teacher-centred pedagogical culture.

A multi-prong TPACK-21CL approach for Indonesian teachers

The four considerations for developing TPACK-21CL derived from the literature undergirded the design of a two-day workshop for Indonesian teachers. Teacher education institutions in countries such as USA and Singapore typically develop teachers' TPACK through constructionist approaches whereby teachers are heavily engaged in lesson design and reflection (see Chai &Koh, 2017; Koh et al., 2017, & Kohler et al., 2007). Considering the profile of Indonesian teachers, we adopted a guided multi-prong approach (See Figure 1) where teachers are supported to develop interim pieces of TPACK-21CL from the perspectives of PK, CK, followed by TK before they engaged in full-fledged lesson design. The workshop was conducted in English with available on-site translation to Bahasa Indonesia.

Figure 1: A multi-prong TPACK-21CL development approach



The programme sequence is as follows:

Day 1

1. Developing pedagogical understanding of TPACK-21CL dimensions (PK->TPACK-21CL)

   Given that teacher-directed learning with ICT is more commonly practised even in Indonesian teacher education institutions (Yusuf, 2016), the team wanted to ensure that teachers had the same baseline experience of 21CL dimensions during workshop. To set the tone for a highly facilitated, collaborative, and self-directed learning culture throughout the workshop,

teachers were engaged in group activities right from the beginning. Group activities not only modeled the collaborative dimension of 21CL, it could also mitigate demand and strain on bandwidth requirements. Therefore, in Activity 1, teachers watched and discussed a series of videos about 21CL in subject-specialisation groups of four to six with a scribe in each team to explicate their group's understanding of 21CL on a Padlet™ wall with initial lesson ideas. Their responses were then related to a lecture about the rubric used to assess the four pedagogical anchors of TPACK-21CL covered in the course: active, reflective, authentic, and collaborative learning (Chee & Chai, 2017). This rubric was developed from the meaningful learning dimensions of Howland et al. (2013) and the work of Koh (2013) and Koh, Chai, and Lim (2017). Each pedagogical anchor was rated on a scale of 0 to 4 as follows:

- Active learning relates to the engagement of students in higher-order thinking of subject content. The rubric ranges from 0 (Students passively receive content through media) to 4 (Students produce multimodal representations of knowledge with ICT by working creatively, critically, and divergently with content knowledge).
- Reflective thinking emphasises students examining and reflecting about their learning gaps and how these could be improved. The rubric ranges from 0 (Students do not use ICT tools to support their diagnosis and improvement of learning gaps) to 4 (Students continually use ICT tools to support the diagnosis and improvement of learning gaps).
- Authentic learning relates to engendering learning in real-world contexts. The rubric ranges from 0 (Real-world examples not used in lesson activities) to 4 (Students use ICT tools to support the analysis and solution of real-world problems).
- Collaborative learning relates to learning through social interaction as a means of meaning-making. The rubric ranges from 0 (No collaboration through ICT tools) to 4 (Students work through or around the computer engaging in divergent discussions of lesson content).

2. Linking to teachers' existing pedagogical practices (PCK-> TPACK-21CL)
   Teachers' existing pedagogical practices are encapsulated in their current lesson plans. In Activity 2, teachers each examined a lesson plan they brought to class which constituted their existing PCK. Teachers rated this

lesson plan with the TPACK-21CL rubric that was taught earlier and chose the dimensions that they wished to improve.

3. Understanding the affordances of ICT tools (TK, TCK, TPK → TPACK-21CL)
   Activity 3 was designed to take care of the uneven ICT competencies among Indonesian teachers (Widodo & Riandi, 2013). In this activity, teachers worked in their subject specialisation groups to examine a website comprising 14 groups of ICT tools including those for visualisation, online assessment, sketching, comic creation, computer-aided design, and video tools. Drawing upon the curriculum and student problems pertinent to their subject area, teachers explored the functionalities of relevant tools by searching for YouTube videos and tinkered with the tool. Teachers then generated ideas of how the tools they explored could support the four TPACK-21CL dimensions for their curriculum topics.

Day 2: Designing

Day 1 activities helped teachers to build some initial forms of understanding about TPACK-21CL. This was further developed at an integrative level through a design challenge as depicted by the outer circle in Figure 1. Each subject-based group had to create a GoogleSite that could be used as an e-lesson for 21CL in their subject area. Design scaffolds were provided to the teachers as follows:

- Technological scaffolds. Teachers were provided with a basic e-lesson template and a short demonstration of GoogleSite features that could support TPACK-21CL dimensions such as inserting videos, integrating Google Forms, and page comments.
- Pedagogical scaffold. A lecture on the Scaffolded TPACK Lesson Design Model (Chai & Koh, 2017) was conducted. It is a lesson design process with guiding questions to support teachers' pedagogical reasoning for each TPACK component. For example, for PCK, teachers were asked to consider "What are the learners' difficulties with learning the topic? What are the usual misconceptions? What are the strengths and weaknesses for the existing ways of teaching the topic?" In terms of TPK, teachers were asked to consider "What are some good practices associated with the chosen technology? Any considerations for cyberwellness?" These guiding

questions were designed to prompt teachers to activate relevant knowledge that they already possessed or developed during Day 1. The design processes are thus treated as a design-oriented knowledge synthesis process where contextualised TPACK is created (Koh et al., 2015) in the form of a GoogleSite supported lesson ready for implementation.

At the end of the design challenge, teachers did a gallery walk among different groups and collected feedback for improvement. The facilitators also invited groups to present their work for critique.

Research questions

These research questions were examined:

1. How did Indonesian teachers' TPACK-21CL develop throughout a multi-prong development approach?
2. What was Indonesian teachers' TPACK-21CL confidence development and the outcome of their lesson design at the end of the programme?

Methodology

In this, a mixed methods study, content analyses of teachers' lesson artefacts and statistical analyses of TPACK-21CL surveys were used to answer the research questions posed.

Study participants

The study participants were 80 pre-service, in-service and university professors from Indonesia. There were 24 male and 56 female teachers with a mean age of 28.9 (SD=8.9). Teachers were pre-arranged into subject-based groups of four to six members each.

Instrumentation

The questionnaire used to survey the teachers' pre-post self-efficacy is an expanded version of the validated instrument for a 21st century TPACK survey (Chai, Koh, Natarajan, Tsai, Ramli & Widodo, 2017). The original instrument consisted of 6 subscales, three of which are relevant to this study (i.e. Active Learning, Authentic Learning, and Collaborative Learning). This study

expanded the scales with Reflective Learning. To ascertain the validity and reliability of the scales, exploratory factor analysis was conducted with Principal Component Analysis (Varimax rotation) on another sample of Indonesian teachers and lecturers (N=187). The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.95 and Bartlett's Test of Sphericity was significant, indicating acceptable sampling. Four factors were identified as hypothesised, explaining 78% of the variances. The overall reliability of the 20 items was 0.97. Sample items and subscale reliability are provided in Table 1. For convenience, this four-factor scale is labelled as the TPACK-21CL survey. Unlike other TPACK scales that are usually constituted by the seven TPACK factors, this scale focuses on the intersections among technology, pedagogy and content with respect to the four dimensions of 21CL. The scale is scored with a Likert scale with 1 indicating strongly disagree and 7 indicating strongly agree.

Table 1: Sample Items with Alpha Reliability

Sample Items	Alpha Reliability
Authentic Learning (AuL) 1. I can use technologies to scaffold students' in solving complex problems arising from the topics that I teach. 2. I am able to create real world problem scenarios for my teaching subject using online web site creators.	0.93
Reflective Learning (ReL) 1. I can guide students in diagnosing their knowledge gaps with various forms of online feedback systems (quizzes, analytics, etc.). 2. I can help students to review the strength and weaknesses of their ICT-supported learning for the subject I teach.	0.93
Collaborative Learning (COL) 1. I am competent in prompting students to talk deeply about the content knowledge in online platforms. 2. I can use a range of web-based tools to facilitate students' knowledge building discourse for the subject matter.	0.95

Active Learning (AcL) 1. I can engage students in constructing deep understanding about the subject matter with various forms of technology (e.g. GoogleSite, concept maps, etc.) 2. I know how to choose appropriate technologies based on the topics I am teaching for students to perform student-centred enquiry.	0.91

Data collection and analysis

Research question 1: Teachers' TPACK-21CL development

Content analysis (Weber, 1990) was used to analyse artefacts uploaded by teachers for Activities 1 to 3 to the class GoogleSite. Each post was broken into functional meaning-based units (Herring, 1996). The postings were categorised to identify key themes that emerged through teachers' articulation of various notions related to TPACK-21CL throughout the programme. For the design challenge, the e-lessons designed by each group were broken down by its distinct lesson activities as a unit of analysis. All coding was corroborated by two coders to resolve all differences.

Research question 2: Programme outcomes

Teachers' TPACK-21CL confidence was examined through paired-sample t-tests of teachers' pre and post TPACK-21CL survey ratings. Teachers' lesson design outcomes were examined through expert rating of each e-lesson on GoogleSites using the TPACK-21CL rubric. Each e-lesson was rated independently by two coders and all discrepancies were resolved.

Findings

Research question 1: Teachers' TPACK-21CL development

Activity 1: From PK to TPACK-21CL

Table 2 shows teachers' initial conceptions of TPACK-21CL after completing Activity 1.

Table 2: TPACK-21CL after Activity 1 (Posted by 20 subject-based groups)

21CL lesson ideas	No. of coded units	%
Problem-based or enquiry-based, multidisciplinary lessons	7	15.22
TPACK-21CL		
Teacher content presentation and resource dissemination with technology	14	30.43
Content mastery and assessment with technology	8	17.39
Lesson using specific ICT tools (e.g. Google classroom, mindmapping, social media, simulation, augmented reality)	6	13.04
Collaboration and discussion with technology	5	10.87
Use technology to learn anytime, anywhere	4	8.70
Self-directed and self-regulated learning with technology	1	2.17
Technology for artefact design	1	2.17
Total	46	100.00

Besides lesson ideas related to problem-based, enquiry-based, and multidisciplinary lessons without mention of ICT which constituted about 15% of the coded units, teachers' Activity 1 lesson ideas were predominantly related to TPACK-21CL. About 48% of teachers' lesson ideas involved using technology for content mastery, assessment, content presentation and resource dissemination, indicating fairly teacher-directed uses to technology. Another 13% of teachers' TPACK-21CL associated 21CL with using specific ICT tools while about 9% involved technology for anytime and anywhere learning. Teachers have not been introduced to the TPACK-21CL dimensions at this point but it can be seen that about 11% of the comments indicated some notions of technology for collaboration and discussion whereas there was sporadic mention of the reflective dimension. These results indicated teachers' initial conceptions of TPCK-21CL.

Activity 2: From PCK to TPACK-21CL

Teachers rated their own lesson plan for each TPACK-21CL dimension in Activity 2 as follows: Active (M=2.16, SD=1.07), Authentic (M=2.35, SD=1.04), Reflective (M=1.60, SD=1.16), Collaborative (M=1.67, SD=1.32). As per the rubric, teachers' mean rating of 2.16 for the Active dimension indicated that their lessons were designed to engage students in some form of divergent knowledge expression with ICT whereas the Authentic dimension rating implied that teachers perceived their lesson activities to engage students in the investigation of real-world problems with ICT but not at the level where students were articulating their personal experiences of real-world phenomena or solving real-world problems. In terms of the Reflective dimension, teachers perceived that they generally undertook responsibility for diagnosing students' learning gaps rather than engaging students to self-diagnose and resolution of their learning gaps. Teachers perceived that their ICT-supported Collaborative activities largely engaged students in convergent rather than divergent knowledge expressions. These results indicate that prior to the workshop, the participating teachers do have some elementary notions of 21CL incorporated within their pedagogical practices.

Table 3 shows teachers' plans for improving their lesson design as articulated in Activity 2.

Table 3: Areas for improvement (Posted by 43 teachers)

Activity 2 - Areas for improvement	No. of coded units	%
Improve bandwidth or ICT facilities in school	3	4.29
Improve personal ICT and facilitation skills	3	4.29
Use more ICT tools	2	2.86
No changes needed	1	1.43
TPACK-21CL dimensions		
Reflective learning	19	27.14
Authentic learning	16	22.85
Collaborative learning	15	21.43
Active learning	11	15.71
	70	100.00

It is encouraging that perceptions about the need to improve school infrastructure or feelings that no changes are needed in their lesson plan only constituted 5.72% of the total comments. About 87% of the comments were related to improving a TPACK-21CL dimension. Consistent with their self-ratings, the largest proportion of comments were related to the Reflective dimension that had the lowest self-rating. For example, teachers shared ideas about engaging students to "map their thoughts" about what they learnt. Through this activity, it appeared that teachers were able to identify the TPACK-21CL dimensions that were lacking in their lesson plans with the descriptors of the rubric.

Activity 3: From TK, TCK, and TPK -> TPACK-21CL

In Activity 3, teachers were asked to explore different ICT tools and consider their affordances with respect to the different TPACK-21CL dimensions. Table 4 shows teachers' conceptions of the different kinds of ICT pedagogies that could support each TPACK-21CL dimension after they explored different ICT tools.

Table 4: Lesson ideas by TPACK-21CL dimensions (Posted by 20 subject-based groups)

TPACK-21CL	Active		Authentic		Collaborative		Reflective		Total	
	N	%	N	%	N	%	N	%	N	%
Simulated practice	1	10	1	6.25	1	25	0	0	3	8.11
Artefact production to convey solutions	2	20	2	12.5	3	75	1	14.29	8	21.62
Peer feedback	0	0	1	6.25	0	0	1	14.29	2	5.41
Technology as content resource	3	30	6	37.5	0	0	0	0	9	24.32
Concept analysis & improvement	2	20	0	0	0	0	2	28.57	4	10.81
Idea visualisation	1	10	2	12.5	0	0.00	1	14.29	4	10.81
Data collection and analysis	0	0	3	18.75	0	0	2	28.57	5	13.51
Independent research	1	10	1	6.25	0	0	0	0	2	5.41
Total	10	100	16	100	4	100	7	100	37	100

N- No. of coded units

About 70% of the lesson ideas pertained to using technology to support the Active and Authentic dimensions. Teachers perceived that using technology for artefact production could support all the TPACK-21CL dimensions whereas using technology as content resources could help them support both Active and Authentic learning. Teachers envisaged that the Collaborative dimension could

be supported through technologies enabling simulated practice and artefact production, whereas the Reflective dimension could be supported through technologies related to artefact production, peer feedback, concept analysis and improvement, idea visualisation, and data collection and analysis. The results show that teachers' were able to generate more concrete notions of how they may enact TPACK-21CL practices with different ICT tools. Teachers' ideas of TPACK-21CL were more diverse and concrete as compared to those articulated at the beginning of the workshop in Table 2.

Design challenge

Table 5 shows the different types of lesson activities that the 20 subject groups created for their e-lesson during the design challenge.

Table 5: Lesson activities created

Lesson activities designed	No. of coded units	%
Technology as content resource	24	23.30
Artefact production	20	19.42
Reflection	17	16.50
Concept analysis	9	8.74
Assessment	9	8.74
Peer feedback	8	7.77
Internet search	8	7.77
Idea visualisation	6	5.83
Simulated practice	2	1.94
Total	103	100

The use of online content resources comprised about 23% of the activities designed. Another 19% of the activities were related to the production of artefacts such as reports in GoogleDocs, PowerPoint presentations, and video clips. While notions of student reflection were largely missing in Table 2, teachers were able to incorporate reflection into about 17% of their lesson activities for students to articulate their learning points or their thoughts after viewing YouTube videos about subject content. The use of concept mapping

tools for idea visualisation and concept analysis, online whiteboarding tools such as Padlet™ to gather peer feedback, internet search, GoogleForms for assessment of understanding, and simulations to support Science instruction were the other lesson activities that teachers designed.

Research question 2: Programme outcomes

Teachers' TPACK-21CL confidence

Paired sample t-tests were used to examine if the multi-prong TPACK activities had enhanced the participating teachers' TPACK-21CL efficacies (See Table 6).

Table 6: Paired-sample t-test and effect sizes

Measured factors	Pre-study survey M	SD	Post-study survey M	SD	*t*-test	Cohen's *d*
ACL	4.90	1.10	5.60	0.83	2.31*	0.47
COL	4.54	1.26	5.45	0.83	2.68*	0.55
AUL	4.67	1.22	5.60	1.07	2.74*	0.55
RL	4.41	1.34	5.39	1.36	2.56*	0.52

N=24, *p<0.001

As indicated in Table 6, teachers' confidence for the four dimensions TPACK-21CL have been significantly improved with medium effect sizes of around 0.5. The professional development activities are likely to have served their purposes well.

Expert rating of lesson design

An expert rating of teachers' e-lessons with the TPACK-21CL rubric derived the following: Active (M=1.98, SD=1.09), Authentic (M=1.52, SD=1.35), Reflective (M=0.86, SD=1.08), Collaborative (M=1.73, SD=1.26). On a range of 0-4 for each dimension, the mean ratings indicate that the lesson plans designed by teachers were strongest in terms of the Active and Collaborative dimensions.

The mean ratings for the Active dimension show that teachers were able to support some degrees of divergent knowledge expression with ICT. For example, a Psychology lesson required students to search and compile

information of psychology theories into a mindmap. However, only a few groups were able to design activities at level four of the Active dimension which would have involved, as designed by one group, an application of psychology theories related to cognitive development to design a programme that helps parents to enhance the cognitive development of their children. Even though teachers were able to design computer-supported collaborative work, the activity structure did not demand highly divergent knowledge expression from students. Therefore, the mean score for the Collaborative dimension also did not go beyond a rating of 2. The mean score of the Authentic dimension indicates that teachers were able to design lesson activities that went beyond using ICT to present real-world examples. An example is a Physics lesson where students were asked to observe simple harmonic motion from several YouTube videos, discuss their observations in groups and post their responses through a Google Form. However, only two groups were able to design level four Authentic activities that involved solving real-world problems. For example, a Science group had students analyse the uses of plastic materials in daily life and to produce a video teaching people to manage the effects of plastic use in their lives.

Teachers were weakest in designing activities for the Reflective dimension even though Table 6 indicated that teachers had incorporated reflection activities. The mean Reflective score indicated that lesson activities minimally involved students in diagnosing, strategising and improving their learning gaps. This is because teachers typically engaged student reflection through self-assessment online quizzes or had students post learning reflections on blogs. Only one group reached level four where they provided students with multiple opportunities to write, gather feedback, and to improve their drafts of news reports. Through this process, students engage in continual self-regulation to analyse and plug their learning gaps.

Discussion

This study demonstrated a multi-prong approach that improved teachers' confidence for the Active, Authentic, Reflective and Collaborative dimensions of TPACK-21CL. Content analysis of lesson artefacts showed qualitative

improvements in teachers' conception of TPACK-21CL throughout the programme. Teachers' ICT lesson designs showed that they were able to move beyond teacher-directed instruction through engaging students in some level of divergent knowledge expression and reflection. Nevertheless, there was still uneven development among groups since only a few groups were able to reach the highest levels of each TPACK-21CL dimension. We suggest the following implications for ICT teacher professional development in an international context.

A multi-prong approach improves teachers' conceptions of TPACK-21CL

Activity 1 shows that teachers entered the programme with fairly teacher-directed notions of ICT integration, as per the findings of Yusuf (2016). The four TPACK-21CL dimensions helped teachers to refine their understanding of TPACK-21CL and these ideas were further concretised in Activity 3 where they explored and related the functionalities of ICT tools to each. While the use of technology as content resources still dominated teachers' conception of TPACK-21CL, teachers began to appreciate how ICT could engender divergent knowledge expressions through artefact production, concept analysis, and idea visualisation. The design challenge shows that teachers were able to apply these new forms of TPACK-21CL as they designed different kinds of student-centred activities including reflection, concept analysis, peer feedback, and idea visualisation. Between Activity 1 and the design challenge, it can be seen that teachers developed new ideas about the different TPACK-21CL dimensions that they attempted to incorporate into their lesson design. The pre-post survey findings seem to corroborate the qualitative content analysis, thereby providing further support that the multi-prong professional development activities are helpful. Given that these outcomes were achieved in two days, the results are encouraging because after a one-year professional development programme, Lim, Tondeur, Nastiti, and Pagram (2014) found that only three out of 12 Indonesian master teachers indicated changes to their pedagogical beliefs and practices.

Challenges with TPACK-21CL

Teachers' self-ratings of their own lesson plans were higher than the expert ratings of their group-based e-lesson designed during the workshop and only

a few groups were able to design activities that progressively support students to develop high levels of divergent knowledge creation, authentic problem-solving, and continual self-regulation. One reason could be that some TPACK-21CL dimensions such as Reflective Learning could be new to the teachers and they could be attempting to incorporate new pedagogical ideas for first time during the e-lesson. Analysis of extant literature found that the pedagogical challenges faced by the workshop participants when attempting to engender 21CL are not uncommon. In semester-long studies of pre-service teachers (Koh, 2013; So & Kim, 2009) as well as year-long studies of in-service teachers (Koh et al., 2017), difficulties with creating authentic problems, divergent learning activities, and supporting student self-regulation were also highlighted. This appears to be common challenge that extant teacher ICT professional development approaches do not adequately address. Furthermore, design expertise generally develops across iterative and continuous practice. To develop teachers' TPACK-21CL, it may be necessary for school leaders and ministries of education to consider providing structured time for teachers to continue implementing or adapting the lessons that were developed. However, we would suggest that external help such as inviting teacher educators from teacher education institutes to participate in the structured lesson design, implementation and review processes is necessary as teachers may overrate their lesson design. External challenge and support could help to ensure that surface adoption is prevented.

Contextual considerations

The study results need to be interpreted against its implementation context. Indonesian teachers' preference for face-to-face instruction (Widodo & Riandi, 2013) influenced the pace with which teachers adapted to the facilitative nature of the workshop. The large class size of 80 created pressure on the network capacity of the training site. While the use of subject-based groupings mitigated the problem somewhat, slow connection was a problem that affected the participants' work with various online tools and activities. Even though there was on-site translation for the lecture segments, one-to-one instructor consultation during lesson design was somewhat affected in groups where teachers were more comfortable conversing in Bahasa Indonesia than in English. Given that problems with technology infrastructure are typically

encountered in ICT professional development developing countries (Kozma & Vota, 2014), the ability of teachers to articulate and enact deepened understandings of TPACK-21CL show the potential of better results with the multi-prong approach if the class size could be better managed to reduce pressure on the network.

In addition, the teachers for this study chose the lesson they wanted to create and they worked within the two days dedicated for the workshop. In school settings, teachers could face additional challenges as they may be designing alone, needing to consider semester schedules and syllabi, in addition to multiple demands on their time. Teacher educators and policy makers need to take this into consideration when interpreting the results. Koh et al. (2017) has highlighted the need for school leaders to dedicate collaborative design time for teachers.

Limitations and future research

The limitations of this study also provide opportunities for future improvement. Firstly, the study aims to examine a multi-prong approach for TPACK-21CL development. Comparative studies can examine this vis-a-vis other TPACK development approaches. Secondly, the study participants comprised pre-service and in-service teachers as well as university lecturers. The relative effects on different target groups could be examined in future studies. Thirdly, the short duration of the workshop coupled with the pressure on the network through the large class size could have influenced what teachers were able to explore technologically. It would be useful to follow-up with the teachers to find out how they have developed these initial lesson ideas after the workshop as this would be a more useful way of assessing the long-term impact of the workshop. Finally, network problems affected the response rate for pre and post course surveys. If future studies were to be conducted in the context of a developing country, funding for mobile access to participants during the workshop duration could be considered to mitigate some of the technology problems encountered.

Conclusion

This study showed that through using a multi-prong approach, understandings of TPACK-21CL could be developed and implemented through a short span of two-days in a developing country context. The viability of different approaches for engendering TPACK-21CL practices in international contexts need to be further explored and documented, especially for methods that can bring about high levels of divergent knowledge construction, authentic problem-solving, and student self-regulation. These are critical areas for supporting continued ICT pedagogical innovation in schools and teacher development, especially in the context of developing countries.

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