TPACK in action: A study of a teacher educator's thoughts when planning to use ICT

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In this paper, we discuss how a university lecturer (pseudonym: James) drew on his technological pedagogical and content knowledge (TPACK) when planning to integrate technology in teaching. The main purpose of the study was to use real-life planning observations to understand James's TPACK. The data were obtained through think-aloud sessions in which James planned a course that is offered to undergraduate initial teacher education (ITE) students in a research-intensive Australian university. Chi's (1997) verbal analysis method was used to analyse verbal qualitative data. The results indicate that a different set of knowledge domains underpinned James's decisions in each different episode of his planning sessions giving his TPACK a dynamic and context-sensitive nature. We suggest observations of teachers when making actual planning decisions as one of the preferred methods to understand the nature of their TPACK. The study introduces a new approach in understanding how this teacher's TPACK looks when he drew on various domains of knowledge, by visually presenting the combinations made among knowledge domains.

Introduction

Instructional planning refers to creating, arranging and organising instructional events to enable students to learn effectively (Burden & Byrd, 2003). Instructional planning is considered a key aspect of a teacher's routine work, both in order to provide their students with the most useful and meaningful learning experiences and to lead to effective teaching (Straessle, 2014). Biggs (2014) states that instructional planning is a complex task that requires teachers to have a deep understanding of domains, such as learning goals, students' characteristics, content to be taught and strategies to teach this content

Various frameworks of teachers' knowledge have emphasised that teachers need to have a strong knowledge base that performs a fundamental role in their pedagogical decisions (Pitts, Vanessa, & Mariano, 2013). Technological pedagogical and content knowledge (TPACK) is one of the frameworks of teacher knowledge that have received significant attention from researchers (Mishra & Koehler, 2006). In this framework, content, pedagogy and technology intersect with each other, forming complex relationships rather than being considered as three separate bodies of knowledge. Mishra and Koehler (2006) believe that TPACK is the basis for effective teaching with technology that underpins a teacher's overall pedagogical decisions.

TPACK has been extensively investigated through self-assessment and confidence surveys (Schmidt, Baran, Thompson, Mishra, & Koehler, 2009), interviews (Harris, Grandgenett, & Hofer, 2012) and the use of mixed methods (Sancar-Tokmak, 2015). In teacher knowledge research, observations are considered a direct method for understanding the natural processes of teachers' planning and teaching (Calderhead, 1984). Despite this importance, real-life observations have not been significantly employed by many TPACK studies (Tai & Crawford, 2014). The main purpose of our study was to use real-life think-aloud observations to understand the TPACK of a university lecturer, referred to as James. In referring to understanding TPACK, we mean which TPACK domains underpinned James's planning decisions and how he made combinations among the knowledge domains.

The study aimed to investigate two main research questions:

(1) Which knowledge domains from the TPACK framework were drawn upon by the university lecturer for his planning decisions?
(2) When making decisions to use ICT, how did he combine the TPACK framework knowledge domains?

In order to answer these research questions, we conducted extensive observations of a single case of a university lecturer, who is a teacher educator, when he was planning his course. The course was offered to pre-service teachers – now more commonly referred to as initial teacher education (ITE) students by the Australian Institute for Teaching and School Leadership (AITSL) – in an Australian university to train them how to integrate technology in secondary school education. Since we observed James when planning a real course, we refer to these observations as real-life planning observations. We refer to this paper as methodological in nature as we report how observations helped us identify the way James combined TPACK domains in his real-life planning decisions. We aim to present findings from our ongoing investigations of other participants using the same method in our future work.

The paper is organised into four sections. The Review of relevant literature section provides a summary of a detailed analysis that we conducted to find how TPACK has been conceptually defined and empirically investigated. We then discuss why we felt the need to investigate TPACK in real-life planning settings. In the Methodology section, the extensive observations with James are discussed, as well as how his use of TPACK was analysed. In the Findings section, key findings related to each research question are presented in detail, as well as how observations helped us view James's TPACK in the context of real-life planning. In the Discussion section, elaboration on the findings are provided, implications are identified, and conclusions are drawn from how using real-life planning observations helped us contribute to existing TPACK literature. In the light of the findings, future recommendations are made for our ongoing research on real-life observations as well as for TPACK researchers.

Review of relevant literature

Shulman's (1986) introduction of the pedagogical content knowledge (PCK) framework led to an evident rise to overall discussion on teachers' knowledge during that period. PCK is defined as an understanding of how to teach a topic of the content using a particular teaching method. Inclusion of technology in the domains of content and pedagogy led to the inception of TPACK (Mishra & Koehler, 2006). TPACK consists of seven domains: TPACK, PCK, TK, CK, PK, TCK, and TPK (Figure 1), which are formed through the interaction of content, pedagogy and technology. Mishra and Koehler (2006) state that TPACK is a form of knowledge that is different from the knowledge of a technology expert and also from the general pedagogical knowledge of a teacher. Rather, it is knowledge that helps teachers to understand how to teach a particular topic using a particular type of technology.

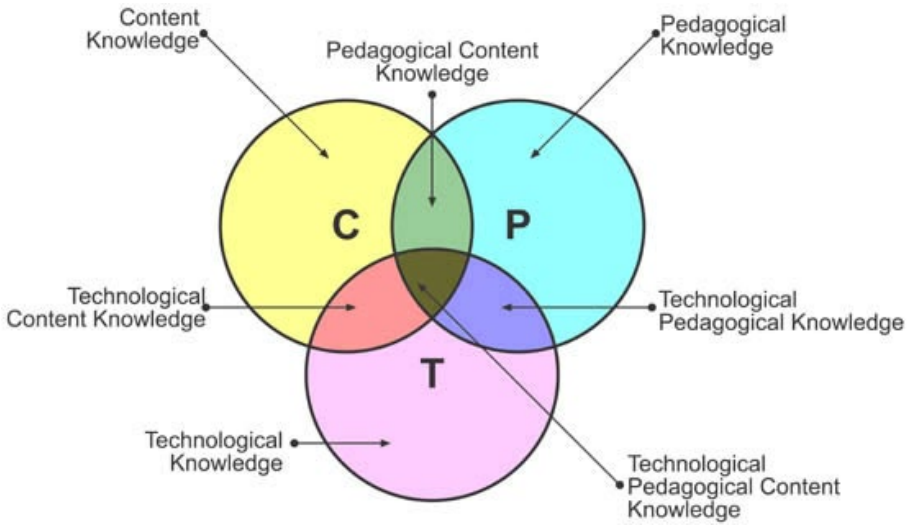

Figure 1. Koehler and Mishra's TPACK framework ((2006, p. 1025)

Being one of the significant frameworks of teachers' knowledge, TPACK has been extensively investigated. The main focus of our review of TPACK studies was to find out which methods were used to investigate this construct. Before presenting our analysis of empirical investigations, we start with a

discussion of how TPACK was conceptually defined. This will help us identify how TPACK in empirical studies was operationally defined and investigated. Mishra and Koehler (2006) discussed a number of times that TPACK is an integration of content, pedagogy and technology; however, they initially elaborated this amalgam through conceptual analyses of the construct. Most TPACK researchers then followed these conceptual definitions to define TPACK further. One of our major findings through the review of the literature is the notion that, despite being widely investigated, the interactions among TPACK domains are still not fully understood (Cox, 2008). Cox (2008) conducted a detailed conceptual analysis of TPACK domains and found 89 definitions of this construct. The findings also reveal that the boundaries between technology-related domains such as TCK, TPK and TPCK were not clear. Cox (2008) argued that Mishra and Koehler somewhat boldly proposed TCK and TPK within their framework, neither of which is backed by empirical evidence nor fully explored. She stated that, without empirical evidence, the existence of TCK and TPK cannot be guaranteed. Cox and Graham (2009) stated that, even after a wide range of investigations, explanations of TPACK itself and other knowledge domains are still not clear enough for researchers to agree on what is, and is not, an example of each construct. Likewise, Chai, Koh, and Tsai (2013) conducted a review of 80 TPACK studies and suggested that knowledge domains within the framework need to be further understood to develop TPACK into an actionable framework.

There may be multiple reasons why interactions among TPACK domains still remain fuzzy. Some researchers believe that the problem lies in TPACK's conceptual explanation, as Mishra and Koehler (2006) did not elaborate TPACK enough to fully understand this construct (Angeli & Valanides, 2009). Whereas another group of researchers believes that methodology employed in previous TPACK studies does not help in understanding how the knowledge domains interact with one another in underpinning teachers' planning and teaching decisions (Markauskaite, Bachfischer, Goodyear, & Kali, 2011). Therefore, a review was conducted which examined empirical studies to identify how these conceptual definitions were adopted by researchers to investigate which methods were used for investigations and how these methods can be improved to understand the fuzzy boundaries among TPACK domains. This commenced with a review of the methodology of TPACK research starting from the early years of its inception. The number of TPACK studies in higher education context has started to increase since 2011, but, between 2006 and 2011, most TPACK studies were conducted in school settings. Although James is an experienced university lecturer and our focus is mainly to review the methods used to investigate TPACK, the review of research conducted in school settings still holds relevance for higher education contexts. We have divided the review of methodologies into two main groups: survey-based investigations and real-life observations.

Survey-based investigations

The most commonly used method to investigate teachers' knowledge and confidence of TPACK domains was self-reporting and assessment surveys on a Likert scale ranging from *strongly agree* to *strongly disagree* (Abbitt, 2011; Jang & Tsai, 2012; Koh, Chai, Hong, & Tsai, 2015; Schmidt et al., 2009). Teachers were required to assess their own knowledge in single domains such as content, pedagogy and technology or in their combinations such as PCK, TPK, TCK and TPCK. The questions included in these surveys were 'I have sufficient knowledge about mathematics (CK)', 'I can adapt my teaching style to different learners (PK)", and "I frequently play around with the technology (TK)'. The importance of surveys cannot be denied when it comes to finding out whether a teacher is confident in his/her TCK, TPK or TPCK.

However, some questions are hard to answer through the use of self-reporting surveys in particular. First, from the use of surveys, it appears that researchers assumed TPACK domains to be unique constructs that can be learnt and developed over time in specific subject areas such as science or mathematics (Chen & Jang, 2013). That said, how content integrates with technology to form TCK is hard to identify using just self-reporting surveys. However, it might be desirable to complement self-report data with additional data collection processes such as observations, document analysis and microteaching. Second, despite evidence of the existence of other knowledge domains in the literature, such as knowledge of learner characteristics, educational ends and values, and knowledge of contexts, most investigations were based on just seven TPACK domains (Mishra & Koehler, 2007; Shulman, 1986, 1987). Some researchers even confined their research to only a few domains within the TPACK framework. For example, Graham et al. (2009) investigated teachers' confidence on the TPACK framework through a pre-post questionnaire in

just four TPACK domains involving technology integration such as TK, TPK, TCK and TPACK. Koh, Chai, and Tsai's (2010) study explored only technology, pedagogy, content and TPCK, eliminating the other domains. Third, surveys restrict respondents to providing answers only to the given questions, which eliminates the possibility of finding out how teachers draw on these knowledge domains in actual planning and teaching settings.

All three of these issues have their own significance and need further investigations. However, in this paper, we focus on addressing the third issue, that is, using real-life planning observations to understand how James combined TPACK domains. By real life, we mean the observations from a real course that was planned and taught by James in routine settings, unlike those situations where planning settings are deliberately created by researchers.

The need to investigate TPACK in real-life planning and teaching settings

Real-life planning observations have not been very common in TPACK studies. However, since 2011, particularly in higher education, observations of teachers in real-life planning and teaching have been used to investigate and understand university lecturers' TPACK (Alsofyani, Aris, & Eynon, 2013; Bibi, Markauskaite, & Ashe, 2012; Markauskaite et al., 2011). In this section, we summarise how using real-life observations helped the researchers view teachers' TPACK from various angles.

From the review of the literature, it was determined that using observations helps researchers look beyond seven TPACK domains. For example, when researchers observed teachers making their design decisions, new knowledge domains were found that came about through the interaction of TPACK domains with other domains (Goodyear & Markauskaite, 2009; Markauskaite et al., 2011). For example, Markauskaite et al. (2011) found four new knowledge domains:

- *technological curriculum knowledge*, which refers to teachers' knowledge and understanding of what digital resources are available to be integrated in a curriculum area
- *technological learner characteristics knowledge (TLCK)*, which refers to teachers' knowledge of which technological resources the students have, which particular resources they need and how to provide them
- *technological educational contexts knowledge (TECK)*, which shows teachers' knowledge of which technology should be used for teaching at a particular level, such as primary, secondary, higher education or teacher education
- *technological educational ends knowledge (TEEK)*, which reflects teachers' knowledge and understanding of ICT-related educational purposes, outcomes and values.

However, there are few studies that extended the TPACK framework, and further empirical research is needed to explore new knowledge domains.

Observations of teachers were also used to identify the nature of TPACK. For example, some researchers used observations to explore how teachers' knowledge of and confidence in the TPACK domains develops over time (Jang, 2010; Niess, vanZee, & Gillow-Wiles, 2010). Study of the development of TPACK knowledge and teachers' confidence shows that the researchers assumed TPACK to be a pre-developed unique body of knowledge viewing it as transformative (Angeli & Valanides, 2015; Jang & Tsai, 2012; Yeh, Hsu, Wu, Hwang, & Lin, 2014). This aspect is similar to what we observed in self-reporting survey studies. On the other hand, some researchers used observations and found the evidence suggesting TPACK is integrative, not existing as a unique, pre-transformed body of knowledge; rather, as a combination of content, pedagogical and technological knowledge formed during a planning or teaching act (Kadijevich, 2012; Markauskaite et al., 2011). For example, in a given situation, when a teacher combines technological knowledge with learner characteristics knowledge, a new domain TLCK is formed, which does not come under the category of pre-developed knowledge (Markauskaite, et al., 2011). The reason that these researchers viewed TPACK as transformative in one situation and integrative in another may be due to the context in which these teachers were observed. Koehler, Mishra, and Yahya (2007) claimed that developing TPACK is a multigenerational process, involving the development of deeper understandings of the complex web of relationships between content, pedagogy and technology and the contexts in which they function. Although context was not given enough significance in understanding TPACK in the first 5–6 years since its inception, since 2011 researchers

started focusing on the context of teachers' TPACK when investigating this construct (Ashe & Bibi, 2011; Bibi et al., 2012; Phillips, Koehler, & Rosenberg, 2016; Rosenberg & Koehler, 2015). We believe that using real-life planning observations would help researchers to understand how combinations among different TPACK domains take place in various contexts.

Overall, we found that in survey-based investigations teachers' TPACK was restricted to the conceptual definitions provided by the originators of the framework. We concur with Cox's (2008) challenge of the existence and use of TCK and TPK in teachers' pedagogical actions. We believe that not only TCK and TPK but also other knowledge domains in TPACK framework are broadly defined. For instance, pedagogical knowledge includes the broader areas of planning, instruction and assessment altogether (Shulman, 1986). In most survey-based TPACK studies, a teacher's pedagogical knowledge has been rated as effective or ineffective through single statements such as 'I feel confident about my pedagogical knowledge' without investigating which areas of pedagogy a teacher meant (Schmidt et al., 2009). There is a need to further know whether or not when a teacher feels confident in pedagogical knowledge, he/she means planning, teaching, assessment or any other pedagogical aspect.

In observation-based studies, the researchers moved beyond what TPACK was originally defined by looking at new knowledge domains as well as the nature of TPACK (transformative and integrative) in different contexts. Researchers emphasised investigating teachers' knowledge of TPACK domains in real-life settings gives access to the natural processes of their planning, design and classroom teaching (Tai, 2015; Tai & Crawford, 2014). It also helps differentiate the fuzzy boundaries between knowledge domains by observing teachers in practice (Cox & Graham, 2009; Koehler et al., 2007). Therefore, we aim to use real-life planning situations to look more closely into the complex relationships among TPACK domains.

Methodology

Research approach and design

We adopted a qualitative research approach involving a case study methodology to investigate the research questions (Yin, 2013). We extensively studied a university lecturer, with the pseudonym James, using think-aloud observations in real-life planning settings. Since we aim to explore the nature of TPACK, there are a number of reasons for studying a single case at this stage. First, diSessa, Elby, and Hammer (2003) emphasised involving a small number of samples particularly when investigating the nature of human knowledge and knowing to make a detailed analysis. Second, this study is part of our continued investigation on the use of think-aloud observations with a larger cohort of university lecturers when making real-life planning decisions. Third, with a growing interest in studying the context of teachers' TPACK (see Review of relevant literature section), we believe studying an individual teacher's TPACK in detail is worthwhile in understanding how each teacher combines TPACK domains in various contexts. Therefore, at this stage, we have undertaken a fine-grained analysis of James's case so that we can start understanding the nature of TPACK in detail and how we can draw on this methodology in future work in understanding the TPACK of a larger cohort.

Data collection

James is an experienced university lecturer with specialisations in the teaching of English and multiliteracy and designing and developing digital media for teaching in schools. He was observed during the planning of a course, *Designing Digital Media for Teaching in Schools*, offered to ITE students. James told us that he teaches this course through a blended model (see Figure 2). James informed us that as per the policy of his university, blended teaching refers to the use educational technologies for planning, teaching, communication, assessment and evaluation purposes along with face-to-face instruction. The main platform James used for teaching and communication purposes was his institution's central learning management system (LMS). The other tools he used for planning, teaching, assessment and evaluation were integrated within the LMS. James used to meet with his students for a two-hour face-to-face tutorial once a week. Online student surveys were also centrally administered through another system by the university but not through the central LMS.

The first author collected data through participant observation (Silverman, 2001). Considering the nature of this investigation, we decided to use a think-aloud method to gain close access to James's decision-making at the time of planning his course. Think-aloud is a unique source for collecting data on cognitive processes allowing the researchers to observe people's natural thoughts (Cotton & Gresty, 2006). All ethics requirements for the collection and analysis of the data were met. To ensure that James's routine planning was not disturbed, the first author observed James in his office where he usually planned. James's overall planning of his courses consisted of six sessions. Each planning session continued for 60 minutes. The sessions were recorded on both video and audio and the researcher gathered all field notes and made memos, comments and judgments during the process of observation.

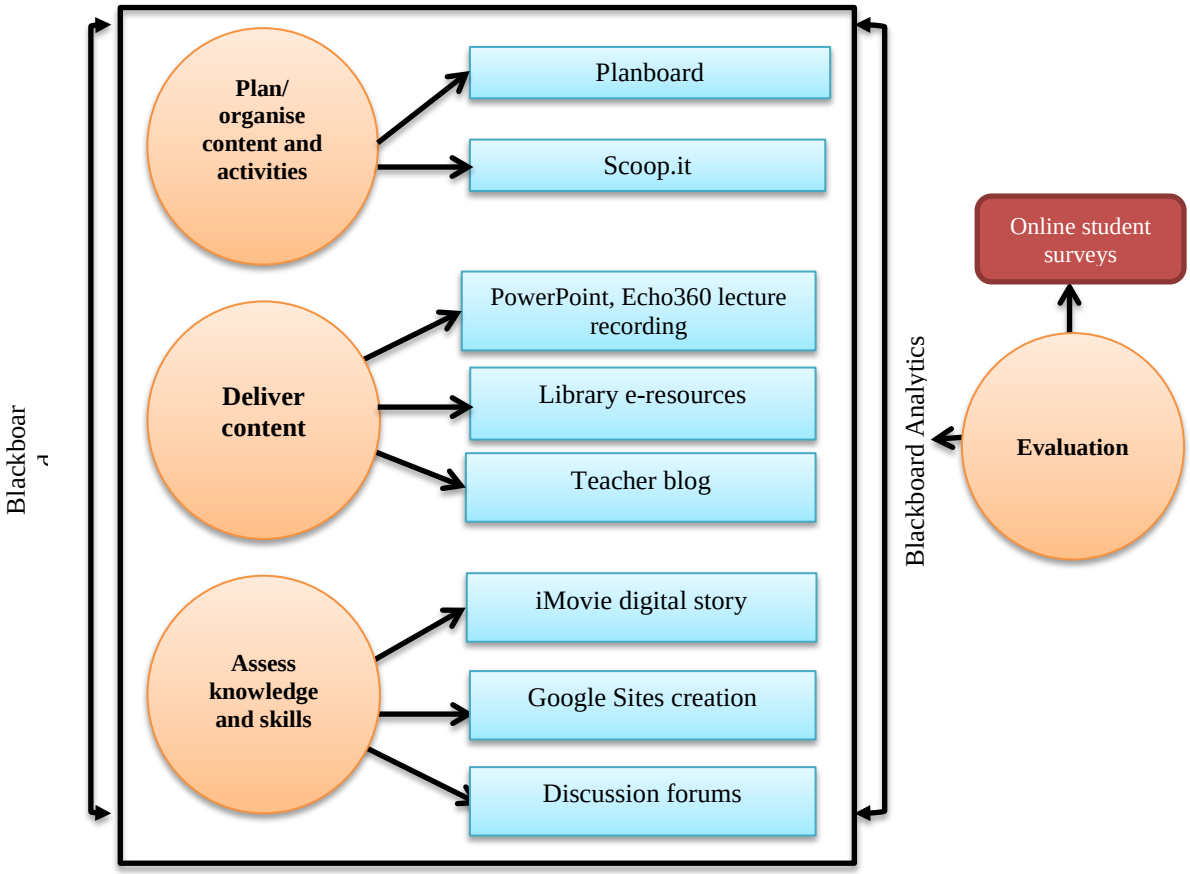

Figure 2. Model of James's blended teaching course

Data analysis

Chi's (1997) method of analysing verbal data was used to analyse the data obtained through James's think-aloud observations. Chi defined verbal data analysis as a methodology for quantifying qualitative data, which is gathered through verbal explanations, observations and gestures. The analysis process of this study comprised the following steps:

Step 1: Transcribing the recordings of James's think-aloud sessions verbatim. Afterwards, the transcripts were read in detail and initial note-taking was done to get an understanding of the data.

Step 2: James's think-aloud sessions were based on three main episodes, depending on the tasks he performed during the sessions: content selection, review of teaching methods and assessment design.

Step 3: The next step was the creation of the coding scheme to identify the knowledge domains James drew on. The creation of the coding scheme involved two rounds. Initially, we created a coding scheme based on the seven TPACK domains (Mishra & Koehler, 2006). Although we stated that TPACK's

conceptual definitions are still not well understood, we used these definitions as initial guidelines to see whether TPACK exists in the same form as it was defined by the authors. We agree that findings from one participant may not be sufficient to claim how TPACK exists in real-life planning data; however, it provides a starting point to initiate investigations to explore the context of individual teachers' TPACK. We applied this coding scheme on three planning episodes of James's sessions. During this process, we found some other domains of knowledge identified by Markauskaite et al. (2011) that were not included in the TPACK framework but strongly intertwined with James's TPACK domains. We revised our coding scheme, by including these new knowledge domains, to extend it beyond the seven TPACK domains (see Appendix).

Step 4: In order to check reliability, the coding scheme was given to another researcher who has been investigating TPACK for several years to code the transcripts. The transcripts included 687 utterances. Both the coders agreed on 682 utterances. Cohen's kappa was applied to measure the reliability. The calculated kappa measure was .81, which indicates high reliability.

Step 5: After the coding scheme was considered reliable, the transcripts from all planning sessions were read again to check the accuracy of the application of the coding scheme on the planning episodes. In the next step, the results were interpreted and reported.

Findings

This section presents the findings obtained from James's planning sessions in order to address both research questions.

The knowledge domains drawn upon by James in his planning decisions

In this section, we elaborate on the findings, addressing our first research question of exploring which knowledge domains from the TPACK framework were drawn upon by James when planning his course. The data from the planning sessions revealed that James drew upon six TPACK domains (CK, PK, TK, TPK, PCK and TPACK) and two knowledge domains (TECK, TLCK) introduced by Markauskaite et al. (2011). We could not find evidence of one knowledge domain, TCK, from the TPACK framework in James's planning data. Table 1 presents the frequency of the knowledge domains found in James's planning data.

Table 1
Frequency of the knowledge domains found in James's six planning sessions

No.	TPACK domains	Frequency
1	CK	31
2	PK(a)	39
3	PK(b)	18
4	TK	59
5	PCK(a)	21
6	PCK(b)	19
7	PCK(c)	33
8	TPK(a)	103
9	TPK(b)	44
10	TPK(c)	23
11	TCK	00
12	TPCK(a)	21
13	TPCK(b)	17
14	TECK	14
15	TLCK	38
Total		480

Overall, TPK(a) remained dominant throughout the entire planning of James's course. Table 2 shows this knowledge domain was referred to 103 times. The second most used knowledge domain was TK with an overall frequency of 59, and the third most used knowledge domain was TPK(b) with 44 references. We

now elaborate on whether the knowledge domains we found in James's planning data reflect the conceptual definitions provided by the authors (see Appendix).

CK

References to CK indicated James's understanding of what content is (such as fractions, algebra, and Pompeii and Herculaneum), why it is important to include a topic of the content in the course and from where it can be obtained. For example, "digital literacy is a significant concept for them to know and to understand, it is the requirement of a modern classroom too, so I'm going to focus more this time on it [digital literacy]" shows James's reasoning of including digital literacy as a topic in his course. Similarly, statements such as "fractions is a difficult topic" and "Pompeii and Herculaneum is based on real facts" showed James's judgment of these topics.

PK

In teacher knowledge research, PK is considered an overall knowledge of pedagogy, which is a broad area of knowledge. In this study we did a fine-grained analysis of James's pedagogical knowledge in order to find out which specific forms of pedagogical knowledge underpinned James's planning decisions. The data reveals that during the planning of his course, James drew on PK in two ways. We refer to them as PK(a) and PK(b).

PK(a). This involved James's knowledge of timetabling such as setting dates and schedules for lectures and tutorials and making decisions about time management to suit various requirements of the course and learners. The reference to this knowledge was identified through statements such as "the first week is more going to be lecture focused to build their knowledge of the concepts and from week two onwards, I'll focus more towards tutorials and classroom activities", indicating how in the beginning of the semester James wanted to use lectures and as the semester continued he would start focusing more on practical activities and tutorials.

PK(b). Another form of PK found in this study showed James's understanding of teaching methods and strategies (such as lecture, inquiry and discussion), knowledge of how to teach and knowledge of various episodes of teaching (such as gaining attention, recalling previous knowledge, delivering classroom activities and review). For example:

> The task I'll give them involves these steps: pick up a topic, write at least 3 instructional objectives, then show it to your work partner and look at their [instructional] objectives, then provide [your partner] feedback and get their feedback, implement their feedback [on your instructional objectives], pick up one objective to show it to the entire class and explain its characteristics.

This statement shows how James planned to do the activity of creating instructional objectives in the classroom. James also mentioned how much time he would allocate to this activity. These statements show how James would teach in classroom.

TK

TK showed James's understanding of features, characteristics and affordances of a particular technological tool (such as iPads, PowerPoint, interactive whiteboard, YouTube, WordPress and Google Sites).

> Google Sites is free, it's flexible, but they'll need a Gmail account for that, so they've to sign up for Gmail, even if they don't do so [use it for Google Site] this account will still remain active and can help them use many other programs as well, such as YouTube and Blogger.

The above statement is specifically about Gmail and its uses for services such as Google sites and other tools supported by Google. James also extensively referred to other tools several times during his planning indicating his knowledge of these tools.

PCK

The fine-grained analysis of this broad knowledge base reveals that James used PCK in three forms that are referred as PCK(a), PCK(b) and PCK(c).

PCK(a). This knowledge was identified from James's statements such as:

> Week 1 is going to be general introduction of fractions but in week 2, I'll be building on the concepts I taught them in previous week … they need to know general before they could go into specifics of the topic.

This indicates James's knowledge of planning and organising content in weekly schedules by giving the topics a logical sequence in relation to the other topics of the content, and how much time and emphasis each topic of the content needs.

PCK(b). This form of PCK shows James's knowledge of teaching a particular topic of the content using a particular teaching method or approach. This knowledge was identified from James's statements such as "I am going to teach them design skills through peer collaboration" and "Demonstration is one of the best methods to show how blood is supplied to the heart".

PCK(c). This involved knowledge of assessing students' content knowledge through questioning techniques, assignments, projects, quizzes, rubrics and any other assessment methods. Statements such as "this [design skills] rubric is really very helpful in understanding how much knowledge they've already gained of creating digital stories".

TPK

We identified that James drew on TPK in three forms when planning.

TPK(a). This knowledge indicates James's understanding of planning and designing blended learning tools such as creating instructional blogs and websites. The statement 'Although the university has provided us with LMS [Blackboard] and we can use it for planning purposes but I mostly rely on Planboard because it is more user-friendly than Blackboard' shows James's use of blended learning tools in his teaching.

TPK(b). This form refers to James's use of different technological tools and resources for teaching. For example:

> I'm going to run a LMS for students but I'll have to provide links within it to Scoop.it site where I've organised all the content and other digital resources, and also to Planboard that contains all my lesson plans, but I've yet to actually build the site by integrating these links into it so you know to make it more sort of a proper instructional site.

Statements like the one above show James's knowledge of teaching with technology (such as online discussions, peer reviews, online tutorials, recording and distributing lectures online).

TPK(c). The results reveal that James extensively referred to using different kinds of technology to assess students' knowledge and skills, such as using online discussion forums for collaboration and creation of digital storytelling projects and the creation of Google sites to assess students' design skills. For example:

> They'll have to have online discussions so I'm going set up a discussion forum for them and there's going be a moderator from among the students who could monitor the discussions throughout.

On another occasion James said:

> Turnitin is a software that helps assess when students have written reports so perhaps I'll ask them to submit their project reports via Turnitin but I'm not sure yet; however, iMovie … I'm going to use it to assess their design skills.

He also referred to using technology (Blackboard assignments) for students' submission of their work.

TPCK

The analysis of the data reveals that TPCK was referred to by James in two different forms.

TPCK(a). It shows James's knowledge of using technology to manage and organise the content. Statements such as 'Scoop.it is an online tool that I've been using to curate the content according to the topics that I'm going to teach in this course' indicate how James makes use of technology to keep the content organised.

TPCK(b). James's knowledge of teaching a particular topic of the content using a particular technology is referred to as TPCK(b). This knowledge indicates how James planned to deliver the content using technology. For example, 'Wordle tool helps to summarise the entire content or long chunks of content into a nice and visually appealing graphic, so I'll create a Wordle and add into my blog' and 'There are a number of tools available for screen capture, like ScreenFlow and Camtasia but I use Echo360 recordings with PowerPoint to teach the content' reflect James's knowledge of teaching with technology.

TECK

TECK is the knowledge domain that is not included in the original seven TPACK domains; however, Markauskaite et al. (2011) indicated the existence of this knowledge domain. We also found evidence of this knowledge domain through James's references to the use of technology in specific teaching and learning contexts. These references indicate James's understanding of which technology should be used for teaching at a particular level of education (primary school, secondary school and teacher education). For example, 'integration of technology in a university setting is far more different from schools and so is in pre-service teaching context'. This indicates that James's knowledge of teaching contexts underpinned his choices of technology integration.

TLCK

Markauskaite et al. (2011) also found TLCK when their design teams were involved in making design decisions to teach in e-learning environments. The existence of this knowledge in our study shows James's understanding of what type of technological resources students already have, which resources need to be provided to them if they do not have them and how the access of students to these technological resources can be assured. This knowledge was identified in James's statements such as:

> I need to check how many students have the laptops, because I might not get the labs to run my tutorials this time, and if the students don't have laptops how I can provide them. And also to check whether these [laptops] have got the [required] software so that each and every student has the resources required to perform the tasks.

James's references to students' technological requirements indicates that knowledge of students' requirements also underpins teachers' ways of technology integration in teaching, along with knowledge of content and pedagogy.

Interactions among knowledge domains

We now address our second research question: how James combined knowledge domains from TPACK framework when making decisions to use information and communications technology (ICT). The results reveal that James's combination of knowledge domains was dynamic and varied from one episode to another in each planning session. We have chosen one planning session to illustrate these dynamic

combinations. In order to present the findings, we have visualised James's combinations of knowledge domains in three planning episodes: content selection, review of teaching methods and assessment design (see Figure 3). Three episodes of James's planning session are given on x-axis. The frequencies in terms of how many times a knowledge domain was used appear on y-axis. All knowledge domains are colour coded with different shapes to differentiate them from each other. We now discuss the results in each episode to show how the combinations among these knowledge domains were made.

Content selection (1–21 min.): In this episode James, while thinking aloud, indicated that the main purpose in selecting the most appropriate content was to make the ITE students digitally literate. In order to achieve this, James was planning which concepts to include in his course. James made three main decisions in terms of content selection: (1) teaching ITE students how to use technology to organise online resources and copyright issues, (2) how to create digital storytelling and (3) social networking among teachers. In the content selection episode, James drew on CK, TPK(a), TPCK(b), TPK(c), TECK, TLCK, PCK(b), TK, PK(a), PCK(c), TPCK(a), TPK(b) and TPCK(a).

In the first seven minutes, James reviewed his decision about teaching his ITE students how to use technology to organise content in terms of why it is important for teachers to keep their educational resources organised and which technology can help them organise these resources.

The extract below shows James's combination among knowledge domains:

> The main concept of the course is going to be which educational resources they can organise as teachers [CK] … and I'll set up an instructional blog for them [TPKa] and then based on this I'll give them an assessment task how they use a Web 2.0 tool to organise the content so they have to set up a Scoop.it site, … I'll ask them to submit the URL of their Scoop.it site via the LMS [TPKc]. Now the point here is that the technology I'm using is different because it has to be for pre-service teachers it's more knowing how to use technology [TECK] … why I chose Scoop.it because it is nice, it's free, and the university LMS is also free for them [TK] … all I've to think is to make sure everyone gets access to Scoop.it. Okay so, [coming back to the] blog. The instructional blog will have all these steps to create a Scoop.it site, where they can share their views about each other's site [TPKa], so at the same time this blog will be for instructional purposes showing them how to set up a Scoop.it site [PCKb].

The above extract indicates how different knowledge domains underpin James's decision to use Scoop.it, the instructional blog and the LMS. James spent next two minutes deciding whether he should use iMovie or another movie editing tool such as Adobe Premier for digital storytelling. His comparison between the features of the tools indicates his use of TK. Then he reminded himself that he had to design learning tasks for the students to undertake in class, indicating his use of PK(a). The change from referring to a technology-related knowledge TK to a pedagogy-related knowledge PK(a) was abrupt. There were no obvious indicators as to what prompted James to switch from TK to PK(a).

After reminding himself about task design, James started thinking what kinds of tasks (such as peer reviews) he would use and how technology (LMS) will support his students' completion of these tasks, indicating his use of TPK(a). Occasionally, he made comparisons between different Web 2.0 tools (TK), how these tools help meet student learning requirements (TLCK), and what kind of tools are going to help him assess, what his students have learned and how he can use this tools. These references indicate his use of PCK(c).

In last four minutes of this episode (17–20 minutes), James referred to 'teaching students about copyright issues' [CK]; 'creating an interactive quiz in LMS to test students' knowledge about copyrights' [TPKc and PCKc]; 'using online lectures, recording lectures and making these recordings available to students via the LMS' [PKb]; 'how an online planning tool Planboard will be used to organise the content for teaching into different weeks' [TPCKa]; and 'promoting collaboration among students through social networks such as blogs or [a little reference to Twitter]' [TPK(a]. In this episode, overall TK was the most used knowledge domain showing James's understanding of various technologies and their features and characteristics.

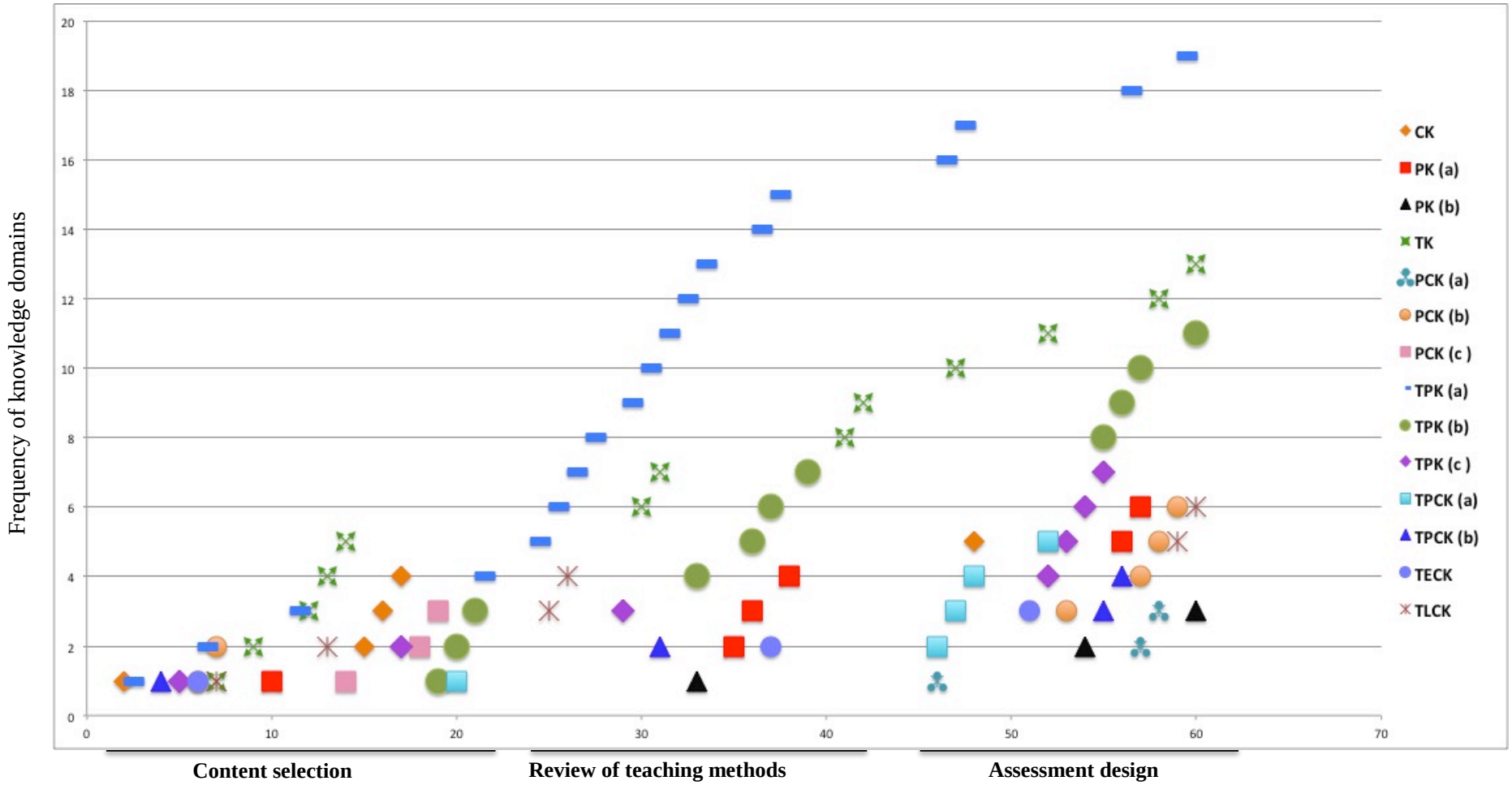

Figure 3. James's references to various knowledge domains

Review of teaching methods (24–42 min.): Between 21 and 24 minutes after remaining silent (he stopped thinking aloud and this happened for the first time so James was not reminded to think aloud. We waited until he spoke again to avoid disruptions in his natural thought processes). James started planning teaching methods. This helped us identify switching from one episode to another.
In this episode, James reviewed overall decisions about which teaching methods he would use to teach the topics of the content he selected and how. He kept switching between different knowledge domains. Since, in content selection episode, we described in detail how James drew on different TPACK domains and others, in this episode we present just an overall picture of the knowledge domains James used to avoid repetitions. As shown in Figure 2, in this episode James used TPK(a), TLCK, TPK(c), TK, TPCK(b), PK(b), TPK(b), PK(a) and TECK when making decisions about teaching methods. In this episode, TPK(a) remained the most prevalent knowledge domain as James spent most of the time in designing instructional strategies.

Assessment design (46–60 min.): In this episode, the overall knowledge domains used were PCK(a), TPCK(a), CK, TK, TPK(a), TECK, TPK(c), PCK(b), PK(b), TPCK(b), TPK(b), PK(a) and TLCK. In this last episode of planning sessions, James focused mainly on assessment design. He planned how many assessments he would have in this course and how these assessments would help his students (future teachers) achieve the Australian Professional Standards for Teachers (AITSL, 2014) and course learning outcomes. The episode started with his decision to use an iMovie project as an assessment task in which he drew on PCK(a), TPCK(a), TPK(a), TK and CK. Later, he kept switching between knowledge domains, such as TPK(a), TECK, TPK(c), PCK(b), PK(b), TPCK(b), TPK(b), PK(a) and TLCK when making decisions about assessment design.

The above findings show that, in each episode, the combinations among knowledge domains were dynamic. We illustrated in Figure 3 how the combinations among these knowledge domains would look if presented visually. Each episode shows the different sets of knowledge domains underpinning James's planning decisions.

Discussion

The results of the study generated two main findings. First, James drew on six knowledge domains from the TPACK framework (CK, PK, TK, PCK, TPK and TPACK) and two new knowledge domains (TECK and TLCK). This finding helps answer research question one: Which knowledge domains from the TPACK framework were drawn upon by the university lecturer for his planning decisions? Second, the combinations made among knowledge domains were dynamic and sensitive to each episode in which they were made. This finding helps us answer our second research question: When making decisions to use ICT, how did he combine the TPACK framework knowledge domains?

We now discuss these findings in detail. Initially, the main purpose of this study was to explore the use of the seven TPACK domains only. However, evidence of new knowledge domains such as TECK and TLCK (Markauskaite et al., 2011) in addition to the TPACK domains assisted us to claim that James's knowledge does not only involve the seven TPACK domains; rather, it goes beyond content, pedagogy and technology. These new domains were so strongly embedded in James's planning ideas that it was hard to report the results without throwing light on them. James is a single case, and we do not claim these findings to be generalisable. However, we strongly believe that investigating TPACK in real-life planning or teaching settings will open ways for researchers to look for new knowledge domains.

The finding that reflect our second research question reveal how the knowledge domains were drawn upon by James when he made planning decisions. Real-life planning observations helped us find that dynamic relationships exist among the knowledge domains. In research to date, most researchers have focused on exploring the development of TPACK domains (Angeli & Valanides, 2009, 2015; Harris & Hofer, 2011), how teachers view their knowledge of and confidence in the TPACK domain (Chen & Jang, 2013), which knowledge domains teachers draw on and whether TPACK is a unique body of knowledge or an amalgam of knowledge domains (Jang & Chen, 2010; Kadijevich, 2012). This study extends the findings of TPACK

research by visually representing the combinations made among knowledge domains. It shows that in each episode different clusters or combinations of knowledge domains underpinned James's decisions to teach through technology. This finding also suggests that James's TPACK was sensitive to the context of each episode.

Here, we would extend our ideas on conceptual definitions of TPACK and their empirical existence. Prior studies on TPACK framework investigations showed that most researchers focused on seven TPACK domains (Abbitt, 2011). We believe this restriction of investigations to seven TPACK domains may be due to the use of self-reporting surveys which are constructed to question respondents on seven TPACK domains that are conceptually defined (Jang & Tsai, 2012; Schmidt et al., 2009). We found that the way that the TPACK seven domains have been conceptually defined in the literature may not necessarily exist in practice. For example, TCK, which is considered one of the significant knowledge domains from the TPACK framework, was not found in James's think-aloud data. This finding supports the claims made by Cox (2008) that Mishra and Koehler (2006) had broadly proposed some of the domains by providing conceptual definitions rather than investigating them empirically. Analysis of real-life planning data helped us differentiate the blurry boundaries between broadly defined knowledge domains such as PK and PCK (Graham, 2011). PK, in this study, was found in two forms: knowledge of settings dates and schedules and knowledge of how each activity will be performed. Conceptual definitions of pedagogy (Mishra & Koehler, 2006; Shulman, 1986) show that this knowledge is very broad. Knowledge of assessment is also considered a part of PK. In this study, we could not separate knowledge of assessment from PCK because every time James referred to assessment he meant assessing (PK) the content (CK) he had taught (PK). We do not reject or challenge these conceptual definitions. We only wanted to see this knowledge at a finer-grained level (how this knowledge exists in real-life practice). We believe that knowledge of setting dates and schedules is only one form of general pedagogical knowledge which reflects James's knowledge of time management so that each activity in the course takes place at an appropriate time, meeting various requirements of course and learners. We also believe that observing James in the teaching context may indicate various other forms of his PK.

Conclusion and limitations

We summarise here how the findings of our study can benefit future TPACK research. Studying a teacher's use of TPACK knowledge domains through the think-aloud method in a real-life planning context opened new ways to study TPACK, which have not been used much in the literature. Investigating TPACK in natural settings assisted us in exploring TPACK domains more closely through studying James's natural thought processes.

The frequency of the use of knowledge domains we identified during James's planning session indicates which knowledge domain he referred to more and which knowledge domains he did not refer to even once, such as TCK. Our findings would help teacher educators to devise teacher-training programs focusing on knowledge domains needing more attention.

We have found that TPACK knowledge domains in practice may not necessarily appear as they are conceptualised in the literature. However, we believe this finding is still subject to further investigations. We aim to present findings from our work in progress on other participants to identify TPACK in practice.

We acknowledge that there are several points we did not cover in this study and future research needs to be done in order to understand this complex framework further. For instance, we did not look for new domains of knowledge apart from the ones already identified by Markauskaite et al. (2011). We aim to find new knowledge domains to extend the TPACK framework in future work. In this study, we focused on one participant's planning data to gain deeper insights into his thought processes. The findings may not be generalisable to a larger population. Future research involving a larger sample needs to be carried out to understand teachers' use of knowledge domains and how each teacher's context contributes to the way they draw on their TPACK.

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Appendix

Coding scheme based on Shulman (1986; 1987), Mishra and Koehler (2006) and Markauskaite et. al's (2011) work

Knowledge bases	Descriptions
Content knowledge (CK)	Knowledge about the actual subject matter, knowledge of central facts, concepts, theories, and procedures within a given field; knowledge of explanatory frameworks that organise and connect ideas; and knowledge of the rules of evidence and proof. It also includes an understanding of the nature of knowledge and inquiry in different fields.
Pedagogical knowledge (PK)	Knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims; knowledge about classroom management, lesson plan development and implementation, and student evaluation; knowledge of cognitive, social, and developmental theories of learning and how they apply to students in their classrooms.
Technological knowledge (TK)	Knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video. It further requires knowledge of hardware and software programs, including how to install and uninstall programs.
Pedagogical content knowledge (PCK)	Knowledge of what teaching approaches fit the content or how a particular content could be taught using particular teaching methods, and knowing how elements of the content can be arranged for better teaching.
Technological content knowledge (TCK)	Knowledge of not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology.
Technological pedagogical knowledge (TPK)	Technological pedagogical knowledge (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies.
Technological pedagogical content knowledge (TPCK)	TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content and knowledge of what makes concepts difficult or easy to learn.
Technological educational context knowledge (TECK)	Shulman's (1986, 1987) initial work indicates the evidence of the knowledge of educational contexts, which he has defined as, 'the knowledge educational contexts ranging from the working of groups or classroom, the government and the financing of school districts, to the character of communities and cultures'. Later on, Markauskaite et al. (2011) found evidence of technological educational context knowledge in the accounts of their learning design teams. This knowledge is referred to as a combination between educational contexts knowledge and technological knowledge.
Technological learner characteristics knowledge (TLCK)	Shulman (1986, 1987) defined knowledge of learner characteristics as an understanding of students' characteristics, their backgrounds, and preconceptions that they bring to a learning situation. Technological learner characteristics knowledge is referred to when a teacher knows about what technological resources the students have and what they need more of and how to provide students with technological resources they need (Markauskaite et al., 2011).