Title	Spiral model of collaborative lesson design: A model to develop TPACK and TEL design competency in pre-service teachers
Authors	Jesmine S.H. Tan and Wenli Chen

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Spiral Model of Collaborative Lesson Design: A model to develop TPACK and TEL design competency in pre-service teachers

Jesmine S.H. Tan, Wenli Chen
jesmine.tan@nie.edu.sg, wenli.chen@nie.edu.sg
National Institute of Education, Nanyang Technological University Singapore

Abstract: Designing Technology-Enhanced Learning (TEL) lessons for 21st century learning has become an integral part of teacher education. However, developing pre-service teachers to design quality TEL lessons can be challenging as they need to keep up with the rapid proliferation of ICT tools. Besides, the competency to align technology with the relevant pedagogy and content knowledge can be overwhelming. Hence, this study presents a framework Spiral Model of Collaborative Lesson Design to scaffold pre-service teachers in designing TEL lessons. An exploratory study was conducted to examine this model. Informed by the Script Theory of Guidance, this model liberated on the five phases of the Spiral model of collaborative knowledge improvement collaborative script to engage participants in a collaborative lesson design session. Results showed that pre-service teachers' TPACK and their TEL design competency had improved. The proposed model will contribute significantly to the professional development of pre-service teacher education.

Introduction

The influx of technology worldwide has propelled the need for teachers to be fully comfortable with using digital tools to engage learners in this digital age (Bogusevschi, Maddi & Muntean, 2019; Demirkan, 2019). Given the COVID-19 pandemic, education worldwide has evolved to depend highly on technology to deliver education. Preparing pre-service teachers with the competency for TEL design is inarguably relevant in teachers' education. In essence, pre-service teachers ought to know how to use technology as a tool to integrate it with their fields and combine it with the most suitable pedagogical approach (Demirkan, 2019). However, preparing pre-service teachers to design effective technology-integrated lessons is an ongoing challenge (Baran & Uygun, 2016). Most scholars working with technology for effective teaching agree that traditional technology training methods for teachers such as workshops and courses are ill-suited to produce a deep understanding of technology in helping them become intelligent users of technology for pedagogy (Koehler, Mishra & Yahya, 2007). In fact, designing TEL lessons for 21st century learning is not easy as they need to keep up with the rapid proliferation of ICT tools inevitable (Koh, Chai, Benjamin & Hong, 2015). Besides understanding the technology affordances, integrating the components of technology, pedagogy and content are critical for effective lesson delivery. Known as TPACK (Technological, Pedagogical, and Content Knowledge), this framework had been acknowledged as a dependable guide to scaffold and help build teachers' TEL design competency (Chai, Koh, Tsai & Tan, 2011). Therefore, developing teachers to be TPACK competency is important to help them blend well into the future classrooms.

Despite leveraging a dependable framework to serve as a guide to TEL design, this process is generally messy and complex (Koehler & Mishra, 2005). Every potential solution developed has its competing solutions, and deciding between the possibilities is not easy (Mishra & Koehler, 2003). Therefore, Mishra and Koehler (2003) stipulated that design should best be learned through the active process of creating and doing rather than being taught by lectures and demonstrations. Hence, this study attempted to develop pre-service teachers' TPACK and their competency by involving them in a collaborative lesson design process. This approach could offer them the opportunities to explore and play within the relatively consequence-free zone of a classroom (Mishra & Koehler, 2003). Given the benefits of computer-supported collaborative learning (CSCL), the Collaborative Lesson Design was reckoned as a reliable approach to help pre-service teachers make better connections among content, pedagogy, and technology (So & Kim, 2009). To enable an effective collaborative learning process, the collaborative lesson design is supported via a collaboration script named the Spiral Model of Collaborative Knowledge Improvement (SMCKI) (Chen, Tan & Pi, 2021) to structure the collaborative process. By combining the strengths of the CSCL and the collaboration script SMCKI, we derive the Spiral Model of Collaborative Lesson Design (SMCLD) model to scaffold pre-service teachers in developing their TPACK and building their competency to design TEL using the TPACK framework as the design principle. Hence, we present an exploratory case study to understand better the developmental process of the pre-service teachers' TPACK and their TEL design competency. The following research question was crafted for this study:

Does the SMCLD help to develop pre-service teachers' TPACK and their competency in TEL design?

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Literature Review

Integrating technology in education has increasingly become an important concern globally (Agyei & Voogt, 2012). The need to develop pre-service teachers' competency in designing TEL lessons is pertinent. Towards this goal, TPACK is used as the theoretical framework to analyze, evaluate refine their acquired expertise (Chai, Koh, Tsai & Tan, 2011). However, despite the inclusion of TPACK into the many pre-service courses, having mere knowledge acquisition does not necessarily equip them to become creative or innovative in their thinking about using technology for pedagogical purposes (Koehler et al., 2011).

Past studies have shown that the collaborative design of TEL supports teachers in becoming TPACK competent (Papanikolaou, Makri & Roussos, 2017). This approach was deemed a promising strategy for developing teachers' learning (Voogt et al., 2013). Specifically, when pre-service teachers come together, they can share expertise and work collaboratively to improve their skills (Bos & Engel, 2016). Divergent thinking is achieved when the design processes are operated collaboratively (Brown & Wyatt, 2010). Hence, by engaging pre-service teachers in collaborative lesson design, we can be assured that the lesson design will not be a simple cut and paste or transportation of information but rather through providing opportunities to question, manipulate, reformulate, and interact to foster thinking competency (Cañabate et al., 2019). In a nutshell, collaborative lesson design could enable pre-service teachers to intimately connect the relationship among content, pedagogy, and technology in a collaborative way (So & Kim, 2009). Besides, when participants are engaged in social metacognition activities such as agreements, disagreements, and questioning, these interactions can influence the paths of the subsequent discussions, stimulating the generation of correct new ideas (Chen, Chiu & Wang, 2012).

Learning by design is one collaborative learning approach that focuses on having teachers work in groups as designers and producers of educational technology (Mishra & Koehler, 2003). This approach fit the current context as it is an environment that is created for participants to confront educational technology naturally (Koehler & Mishra, 2005). When the participants participate in the collaborative lesson design process, they get to build something sensitive to their subject matter instead of learning the technology in general. Therefore, every act of the TEL design process weaved together components of technology, content, and pedagogy (Koehler & Mishra, 2005). This approach differs from a traditional workshop or technology class where teachers are trained to be a consumer of tools with the hope that they can apply them to their practice. Past research studies have advocated that pre-service teachers' pedagogical beliefs affect how they integrate technology into their lesson design (Voogt et al., 2013). Therefore, by engaging pre-service teachers in learning by design, they can learn in ways that tie their content knowledge to the pedagogy and technology for its intended educational use (Mishra & Koehler, 2003). This process helped better develop their pedagogical beliefs.

Despite the benefits of collaborative lesson design, survey findings reported that pre-service teachers generally do not prefer to collaborate during their learning process (Ruys, Van Keer & Aelterman, 2010). Such attitude would indubitably lead to ineffective collaborative learning with challenges like freeriding, which are still common in higher education (Arashpour, Lamborn & Farzanehfar, 2019). In view of that, providing a collaboration script to scaffold the CSCL activities whilst working in the Web-based collaborative board was deemed feasible to prevent hampering the effectiveness of collaborative learning (Hämäläinen & Häkkinen, 2010). Given that the context of this study was set within an authentic classroom, the concept of Rapid Collaborative Knowledge Improvement (RCKI) was drawn in to support the collaborative learning lesson. Initially proposed by Looi, Chen and Patton (2010), RCKI dictates an environment where knowledge improvement is situated within a short period of a class session. Specifically, RCKI "seeks to harness the collective intelligence of the group to learn faster, envision new possibilities, and to reveal latent knowledge in a dynamic live setting, characterized by rapid cycles of knowledge building activities in a face-to-face setting" (Looi, Chen & Patton, 2010, p. 26). In this study, we leveraged the collaboration script SMCKI to regulate collaborative learning in an RCKI environment. The SMCKI script entails five phases. By respecting and encouraging cognitive diversity, the first phase encourages the creation of diverse ideas. The subsequent phases tap on this idea diversity to seek synergy of ideas and a phase of convergence and consensus-seeking that leads to knowledge convergence and advancement. Phase five Individual achievement refers to an individual reflection and consolidation process, where each participant reflects and recollect their learnings across the collaborative phases for individual knowledge improvement. This model fitted the intended objective of the two basic types of learning outcomes in this study. The objectives fitted the crux of examining the CSCL processes and outcomes at the group level and individual level (Kollar, Wecker & Fischer, 2018). The following describes the model proposed for this study.

Theoretical Framework

According to the Script Theory of Guidance, there are two main factors to a collaboration script, namely the internal and external script (Fischer et al., 2013). While an internal script is dynamically configured by the learner during the CSCL process, it is not manipulatable and hence will not be considered in this study. The SMCKI

script is premised upon the concept of external collaboration scripts where representations serve to guide CSCL practices by facilitating the participants. Informed by the SMCKI script, the proposed Spiral Model of Collaborative Lesson Design (SMCLD) integrates the components of SMCKI into the CSCL collaborative lesson design environment, undergirded by the RCKI to support a live classroom setting. Table 1 list the external script components, their definitions and how it defines the SMCLD.

Table 1
Alignment between Script Theory of Guidance and SMCLD

Script Theory of Guidance component	Component Definition	SMCLD model
Play scaffold	Prompts that provide general task definitions such as the main goal of the collaboration	The process of collaboration undergirds by the five-phases SMCKI script
Scene scaffold	The sequence of activities the individuals engage in during the CSCL process	The procedures in which the participants engage in each phase of the SMCLD
Role scaffold	Roles assigned to the participants at each scene scaffold	The roles assigned to each when they are engaged in the collaborative phases
Scriptlet scaffold	Prompts given to participants to help them engage during each scene scaffold	Prompts such as sentence starters, questions to guide the participants during each SMCLD phase.

Figure 1
Spiral Model of Collaborative Lesson Design

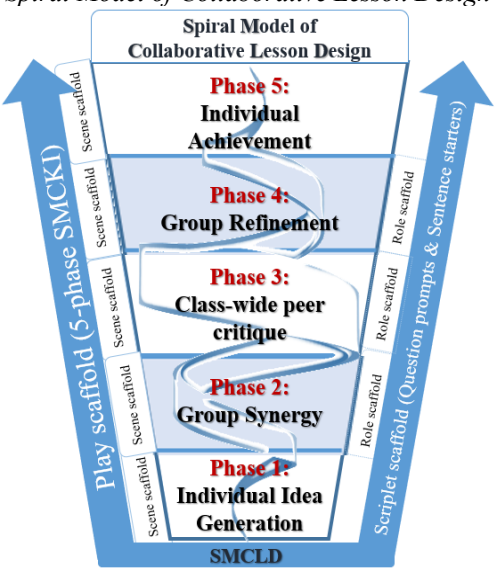


Figure 1 shows the embedment of the five phases of SMCKI (play scaffold) from phase one to phase five within the SMCLD. The participants will be engaged in the activities as stipulated with the specific phase (scene scaffold) within each phase. For example, each participant will contribute their individual ideas during phase one in preparation for phase two synergy. During phase two, the group members will scrutinize each group member's ideas to rise above a group idea that represents the best quality within the group. In phase three, each group will visit the group ideas of other groups and provide constructive feedback. These feedback comments will be reviewed during phase four, where refinements will be made in response to the feedback. Finally, phase five allows every participant to recollect their learning across the collaborative learning phase. This phase can take the form of a reflection or rise above an individual product that surpasses the phase one version.

During the collaborative learning phases, the role distribution (role scaffold) ensured positive interdependence among group members. During phase two, each participant could be assigned to critique the ideas of another group member. In addition, role assignments such as timekeeping could also help to manage the logistics within the group. In phase three, different group members can be assigned to view specific segments of the different groups. At the same time, the assignment of different members to view different groups can also promote a wider range of knowledge sharing and knowledge contribution. At phase four, different members can be assigned to view different segments of peer comments before group discussion and refinement. During the entire collaborative lesson design, question prompts or sentence starters (scriptlet scaffold) can guide the

participants with the collaborative work. This scriptlet scaffold may be considered as a micro script (Kollar et al., 2018). According to Dillenbourg and Jermann (2007), micro-script scaffolds tend to directly influence the interactions of group members by giving more specific instructions. In this study, these scaffolds are the design guidelines that are specific to the TEL design task.

Methodology

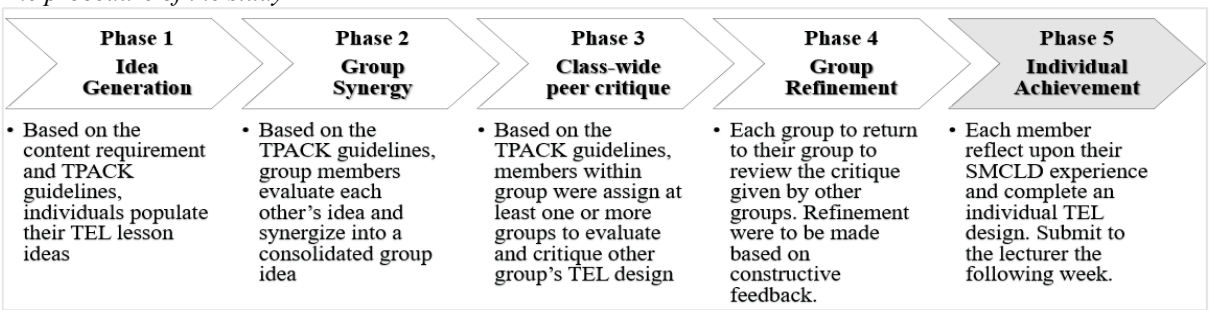
Research participants and context

An exploratory study was employed in this study. Convenience sampling was applied to gain initial primary data to validate the SMCLD framework for TEL design. Forty pre-service Chinese language teachers participated in this study. They were enrolled in a course titled "The use of ICT in Character and Citizenship Education and Chinese Language Learning" during their one-year Postgraduate Diploma in Education programme with the National Institute of Education, Nanyang Technological University Singapore. Of the 40 participants, 98% are female, 2% male; 25% are between 20 – 25 years of age, 48% between 26 – 30 years old, and the rest are above 30 years old. All participants had at least a bachelor's degree, with 10% having a Master degree or PhD degree. The lecturer, who is the first author of the paper, has three years of experience in teacher education at the time of the intervention. The 40 participants were divided into ten small groups of four members in each group. Chapman et al. (2006) reported that self-selected groups might simulate "real-world" workgroups more closely than randomly assigned groups. Evidence had suggested that self-selected groups led to better group dynamics and yielded better group collaborative work results (as cited in Chapman et al., 2006, p. 560). Hence, the groups were self-formed by the participants.

The course was carried out in twelve face-to-face (F2F) lessons. The task was to collaboratively design a TEL lesson for Chinese language teaching and learning targeting at primary schools in Singapore. To ascertain the validity of the SMCLD framework, an exploratory study was conducted. As part of the participants' course work, they were taught Content knowledge (CK) about their subject mastery. Prior to the collaborative lesson design lesson, each group selected a reading text within the primary school syllabus of the Singapore national curriculum TEL design task. The first four phases of the SMCLD took place within a class session of one hour. Phase five was taken out-of-class, allowing the individual participants to complete an individual TEL design based on their learnings across the first four phases. The final phase five work was handed to the lecturer one week later.

Figure 2

The procedure of the study



The TPACK coding scheme

The TPACK coding scheme was derived referencing the TEL lesson assessment rubric TPACK for meaningful learning with ICT (Koh, 2013) to evaluate the TEL lesson ideas. Figure 3 shows the codes and their scale dimension. Apart from analyzing the data on the lesson ideas generated, it is also important to examine if an idea refinement (phase four) is improved based on the comments from the inter-group critique (phase three). The statistical discourse analysis was adopted to harvest this information to analyze the cognitive and social metacognitive (Chiu, 2013) aspects of each comment given to each group. According to Chiu (2013), social metacognitive components can aid or hinder students' ideas and explanations. By coding inter-group data under this domain, we can better understand how the peer comments contributed to idea improvement at phase four. Based on the explanatory variables suggested by Chiu (2013), Chiu and Fujita (2014), the peer critique coding scheme was derived (Table 2). This coding scheme aimed to establish how informal cognition (opinions, anecdotes, elaborations) or social metacognition, in the form of questions and different opinions at phase three facilitated formal cognition (new information and theoretical explanations) at phase four (Chiu & Fujita, 2014). The unit of analysis for SMCLD-TPACK and SMCLD-SDA is illustrated in Table 3.

Figure 3

Rubric for assessing TPACK for meaningful learning with ICT

Dimension	0	1	2	3	4
Active	Students passively receive subject matter from media or ICT all the time	There is sporadic use of ICT tools by students to work with subject matter	Students are using ICT to work with subject matter half the time	There is substantial use of ICT by students to work with subject matter.	Almost all lesson time involves students using ICT to work with subject matter.
Constructive	ICT tools used for transmission of subject matter rather than meaning-making.	ICT tools used to support reproduction of subject matter or convergent knowledge expression by students.	ICT used to support some degrees of divergent knowledge expression by students with respect to the subject matter.	ICT tools used by students to synthesize information in order to construct verbal, written, visual, conceptual or product-oriented expressions of the subject matter.	ICT tools used by students to articulate their personal reflections of subject matter in the form of verbal, written, visual, conceptual or product-oriented expressions.
Authentic	No representations of real-world phenomenon or problems related to the subject matter are presented with ICT tools.	ICT tools used to present examples of real-world phenomena related to the subject matter of students.	ICT tools support students to investigate real-world phenomena or problems related to the subject matter.	A problem associated with a real-world phenomenon related to the subject matter is used to anchor the activity and students investigate the real-world phenomenon with ICT tools in order to propose solutions.	Students represent their personal experiences of the real-world phenomenon/ problem related to the subject matter with ICT tools
Intentional	Students do not use ICT tools to support them in diagnosing, strategizing about or improving their learning gaps of the subject matter.	Students' learning gaps of the subject matter are being diagnosed by teachers or peers.	Students self-diagnose their learning gaps of the subject matter by using ICT tools/resources.	Students use ICT tools/resources to self-diagnose their learning gaps of the subject matter. Thereafter, they are to fix these learning gaps.	Students continually use ICT-based tools/resources to self-diagnose and fix their learning gaps of the subject matter.
Cooperative	No cooperative activity over ICT platforms/tools or ICT tools/platforms are used to share information and resources related to the subject matter but no online discussion occurs.	Students work together either around the computer or through the computer in activities requiring convergent knowledge expressions of the subject matter.	Students work together either around the computer or through the computer in activities requiring some degree of divergent knowledge expression of the subject matter.	Students work together either around the computer or through the computer in activities requiring a large degree of divergent knowledge expression of the subject matter.	Students work together either around the computer or through the computer in activities requiring primarily divergent knowledge expression of the subject matter.

Table 2

Peer critique coding scheme

Code	Definition	Scale 3	Scale 2	Scale 1
Cognitive	Refers to knowledge acquisition, building shared understanding, constructing meaning (Molenaar & Chiu, 2014)	Opinion with Elaboration and Anecdotal evidence	Opinion with Elaboration	Opinion only
Social metacognition	Defined as group members' monitoring and control of one another's knowledge, emotions, and actions (Chiu & Kuo, 2009)	Different opinion (include suggestions)	Ask for explanation (include clarification)	Ask about use

Table 3

Coding scheme and unit of analysis

SMCLD Phase	Phase 1 & 5	Phase 2 & 4	Phase 3
Coding scheme	TPACK	TPACK	Peer critique
Unit of Analysis	Individual lesson ideas	Group lesson ideas	Individual comments

Data Analysis

To answer the research question, content analysis was conducted on the TEL artefacts based on the TPACK coding scheme. To understand the type of knowledge shared by the participants leading to TEL improvement, the peer comments were counted and coded according to the peer comment coding scheme.

Results

Figure 4 illustrates an incremented improvement of TEL design measured by TPACK score over phases one, two, four and five for all the ten groups. These results suggested that the SMCLD could help pre-service teachers improve their TPACK and competency. Further analysis was conducted on the ten groups by sorting their TPACK scores at phase four, which is the final phase of the F2F session during class. Two trends were surfaced with TPACK between the scale 2 to 3 as trend one and scale 3 to 4 for trend two. Coincidently, there are five groups within each trend. Figure 5 shows the two different outcomes of how participants appropriate SMCLD in their collaborative lesson design over the TEL design phases. Trend one TPACK score is lower than trend two across phases one, two, four and five. However, the incremental improvement of TPACK score for trend one is shown by the mean difference score from phase one to two (MD = 0.2), from phase two to four (MD = 0.3), and from phase four to five (MD = 0.8) suggests that when individuals have a lower TPACK capacity, the collaborative learning phases could help them build up their individual capacity exponentially. The greater improvement from phase two to phase four could be when ideas are exhausted at the group level. The class-wide peer critique provided multiple perspectives, which elevated knowledge that brought about greater improvement at phase four compared to phase two. For trend two, the higher mean difference from phase one to two (MD = 0.6) than phase

two to four (*MD* = 0.3) suggests that the higher individuals' prior knowledge aids with the knowledge co-construction at the group level during phase two. The same mean difference between the groups in trends one and two suggest that the knowledge shared during class-wide peer critique is evenly distributed among the groups, resulting in the same degree of improvement.

Figure 4
TPACK competency improvement

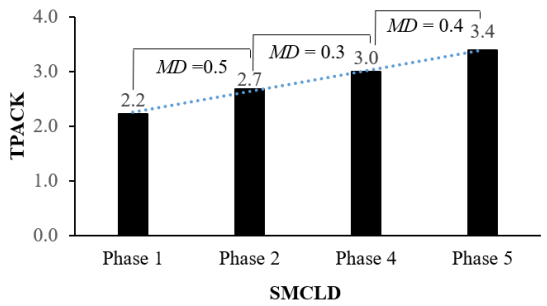


Figure 5
TPACK Improvement Trend

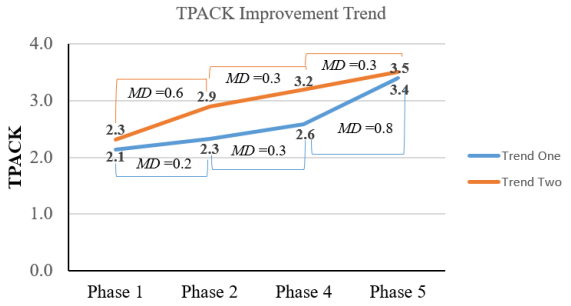


Figure 6 shows the number of comments received during the class-wide inter-group peer critique phase. Comments received by groups in trend two is higher than in trend one. Figure 7 shows the type of comments generated. For both cognitive and social metacognitive comments, trend two groups received a higher count compared to trend one. Since the degree of improvement is the same for both trends, this result suggests that the number of comments has no influence over the degree of improvement. The quality of improvement is relative to the phase two quality. x

Figure 6
Number of peer comments

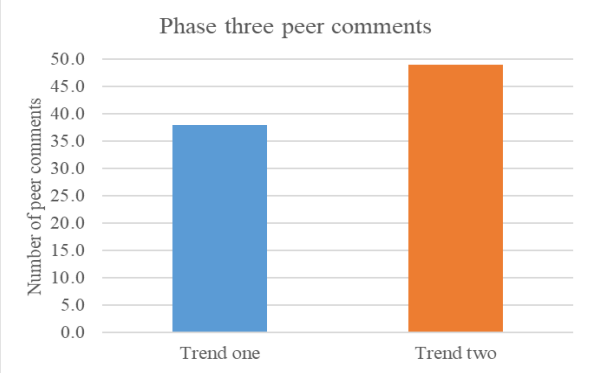


Figure 7
Peer comment by cognitive and social metacognitive

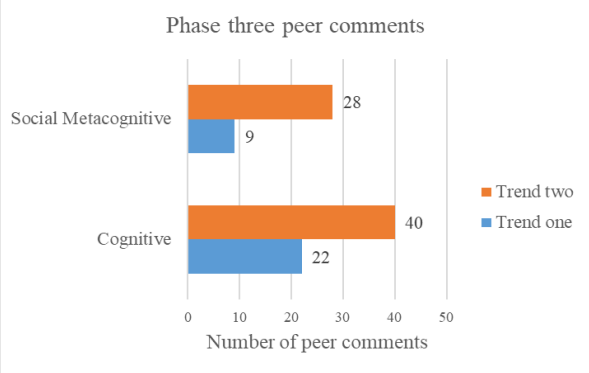


Figure 8
Depth of peer comments elaboration

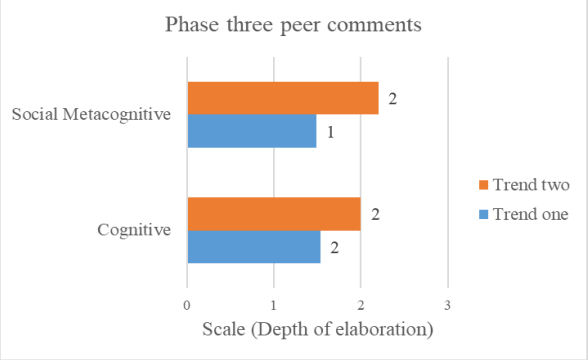


Figure 9
Participants' perception of SMCLD

Participants' perceptions of SMCLD	SD
I find the idea generation phase during the collaborative learning beneficial for me	0.7
I find the inter-group feedback phase during the collaborative learning beneficial for me	0.6
I find all phases of SMCKI helpful for fruitful collaborative learning	0.8
The design principles help with lesson design at individual idea generation	0.6
The design principles help with lesson design during synergize group phase	0.7
The design principles help with lesson design during the inter-group feedback phase	0.7
The design principles help with lesson design during the refinement group discussion	0.7
The roles (e.g. Leader, facilitator, recorder) help to facilitate group discussion	0.8

Figures 8 shows the depth of the peer comments elaboration measured by the three scales (Table 2). More in-depth elaborated comments were received by groups in trend two than in trend one, suggesting that elaborated comments could support higher quality TPACK improvement. A survey was conducted for all the participants at the end of the collaborative lesson design session. 92% of the participants agreed that the different

phases of SMCKI help to scaffold a fruitful collaboration process. In addition, the participants mostly agreed that the different scaffolds (Play, Scene, Scriptlet and Role) supported the process of collaborative lesson design.

Discussion and Conclusion

This study proposed a scripted collaborative lesson design model Spiral Model of Collaborative Lesson Design (SMCLD), to support pre-service teachers in developing their TPACK and competency by designing TEL lessons. The presented results show that the proposed SMCLD could help pre-service teachers improve their TEL design across the collaborative learning phases from one phase to the next. Results had shown that by leveraging on the scripts within SMCLD to scaffold the collaborative lesson design, pre-service teachers' competencies in designing TEL lessons had improved. This result corroborated with the recent study that participants improved in their TPACK when working in groups as peers (Njiku, Mutarutinya & Maniraho, 2021). The building and learning were deep and strong, which was at best through collective successes and mistakes (Rigelman & Ruben, 2012). This collaborative learning process helped complement each other's strengths and helped in overcoming challenges inherent in individuals' professional competencies (Njiku, Mutarutinya & Maniraho, 2021).

This study has theoretical contributions. Engaging pre-service teachers in collaborative lesson design is not new. However, providing a scripted process guided by an external script could provide new insights to leveraging the inherent capacity of each individual and group synergy to elevate the degree of improvement within a short class time duration. By providing a scripted scenario through the different scaffolds, the participants were fully engaged in the process of knowledge co-construction, enabling the full potential of collaborative learning to be activated across the SMCLD phases. The improved outcome at the group and individual level illustrated that when the participants appropriated the script according to its design, the intended outcome could be achieved. This positive result could contribute to future collaboration script design and further enhancement of existing scripts (Tchounikine, 2016). Practically, this study provides a pedagogical approach to developing pre-service teachers' TPACK and competency in an authentic learning environment.

Some limitations exist in this study. Being a small-scale study, there is no control group to ascertain that the improved results at the group and individual levels are attributed to scripted SMCLD processes. Moreover, a more in-depth qualitative analysis could be conducted to establish how the individuals' knowledge shared during phase one were uptaken during phase two group synergy; and how phase three comments helped with the improvement during phase four; and how the collaborative learning phases supported the phase five individual improvement in the TEL design.

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