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Designing Synergistic Scaffolds for Knowledge Integration in a STEAM-DBL Context: Practitioners' Perspectives

LEE YEE LING[1] and CHIN HAI LENG[2]

[1,2] Department of Curriculum and Technology, Faculty of Education, University of Malaya,

Corresponding email:
lee.eling0204@gmail.com; chin@um.edu.my

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Abstract

Students need multiple forms of scaffoldings to learn integrate knowledge in a complex and dynamic design-based STEAM (science, technology, engineering, arts and mathematics) learning environment. Synergistic scaffolds have been found to be effective to support student learning but a review of literature revealed that there are still significant implementation issues to support students' STEAM knowledge integration in this context. This study aimed to (1) identify the challenges facing lower secondary school students when they learn to integrate knowledge and (2) explore the design features of synergistic scaffolds, including question prompts and facilitator's scaffolding strategies, to support students' STEAM knowledge integration in a DBL-STEAM context. Data was collected from semi-structured interviews with ten practitioners from different disciplines using a purposive sampling method. The finding showed that students might face a number of challenges related to domain knowledge, motivation and language in this context. The presentation, language, type and difficulty level of question prompts needed to be taken into consideration during the design process. The practitioners suggested different types of scaffoldings such as cognitive and strategic scaffoldings to support student learning. The findings will be used to design and develop a DBL-STEAM module in the next step of a broader design-based research.

BACKGROUND OF THE STUDY

STEAM is defined as an educational curriculum which integrates science, technology, engineering, arts and mathematics (English, Hudson, & Dawes, 2013). STEAM education is transdisciplinary in nature, adopting knowledge and curriculum from more than one subject to investigate a central theme, issue, problem, topic or experience (Yakman, 2008). STEAM education acknowledges that learning and task completion is interdependent, built on knowledge and expertise across all school subjects (Yakman, 2008). Rafols and Meyer (2010) advocate that knowledge integration is the key process to promote interdisciplinary curriculum. Liao (2016) further elaborates that STEAM is a platform to make connections between knowledge and skills from various disciplines explicit. One of the promising approaches to promote knowledge integration in an interdisciplinary educational context is introducing design activities (Berland, Steingut, & Ko, 2014; English et al., 2013), and more specifically, design-based learning (DBL) into integrated curriculum. The integral part of DBL is to help learners gain and apply integrated knowledge from various disciplines by constructing artefacts or solving real life problems through an iterative cycle of engineering design process (English et al., 2013; Puente, Eijck, & Jochems, 2013).

Knowledge integration studies found that students seldom compare, contrast and make meaningful connections between similar tasks in different contexts (Liu, Lee, Hofstetter, & Linn, 2008) as well as link their design to the targeted concepts (Leonard, 2006). Students face a lot of challenges and difficulties in knowledge integration due to their inabilities in making judgement, problem-analysing and reasoning which involves design activities (Puntambekar & Kolodner, 2005). Their designs were modified by trial and error without proposing adequate principles and concepts affecting the performances of their solutions (Puntambekar & Kolodner, 2005). In response to these challenges, many researchers agree that students need clearer scaffolding structures to help them engage in knowledge integration (Bell, Davis, & Linn, 1995; Bell & Linn, 2000). Scaffoldings refer to the temporary supports given to learners while they acquire conceptual understanding and skills to progressively move towards independent learning (Maybin, Mercer, & Stierer, 1992).

SYNERGISTIC SCAFFOLDS

In a complex learning environment with multiple zones of proximal development (ZPD) like the context of DBL, one type of scaffolding may not be sufficient to support students' learning (Puntambekar & Kolodner, 2005). Students need different types of explicit guidance and tools to support their understanding and skills as they work through the design process (Puntambekar & Kolodner, 2005). Two broad categories of scaffoldings are fixed and adaptive scaffolds or hard and soft scaffolds (Saye & Brush, 2002). Fixed or hard scaffolds are static supports which are planned in advance to the implementation of lessons based on students' difficulties to solve a task (Azevedo, Cromley, Winters, Moos, & Greene, 2005; Saye & Brush, 2002). Compared to hard scaffolds, soft or adaptive scaffolds are more dynamic, adaptive and situational, which means teachers have to conduct on-going diagnosis on students' emerging performances and provide adequate supports based on their progress (Azevedo et al., 2005; Saye & Brush, 2002). Distributed scaffoldings (Puntambekar & Kolodner, 2005) and more specifically, synergistic scaffoldings (Tabak, 2004) where different scaffoldings align and complement each other may be essential to support the development of students' knowledge and skills as shown in Figure 1. Tabak (2004) posits that synergistic scaffoldings are various supports that complement each other, augmenting and interacting seamlessly to assist students in achieving a learning goal. The main feature of synergistic scaffolds is "scaffolds are not only directed toward the same need, they are enmeshed, intertwined, and complete each other" (pg. 319).

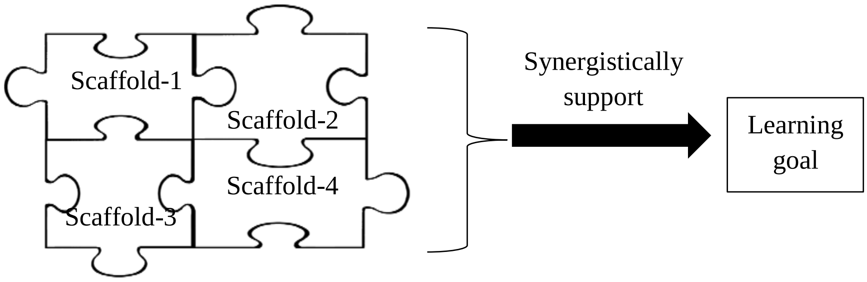

Figure 1. Conceptual model of synergistic scaffolds. Modified and adapted from Tabak (2004).

Kim (2017) suggest that different types of scaffoldings which included cognitive, metacognitive, motivational and strategic scaffoldings could be integrated into fixed and adaptive scaffolds to support student learning. Cognitive scaffoldings are used for focusing students' attention to the crucial aspect of task (Mackiewicz

& Thompson, 2014). Strategic scaffolding can offer strategies to students to help them solve the task (Belland, 2017). Metacognitive scaffolding aim to encourage students to reflect on their knowledge and monitor their own progress (Belland, 2017; Kim, 2017). Motivational scaffoldings are for enhancing students' interest and confidence (Belland, Kim, & Hannafin, 2013). Researchers also suggest scaffolding students' language so that they can use precise academic terms (Smit, 2013). Language support for supporting students to use correct academic terms to justify their design solutions. Social scaffolding needs to be provided to students to help them work with each other (Baxter & Williams, 2010). In this study, fixed scaffolds referred to question prompts while adaptive scaffolds meant the facilitator's scaffolding strategies.

I. *Supporting students' knowledge integration with question prompts*

Previous research has shown that written fixed scaffolds – question prompts could promote student learning. E. A. Davis and Linn (2000) examined the roles of two types of prompts, activity and self-monitoring prompts in promoting students' reflection in a context of Knowledge Integration Environment (KIE) software. They found that self-monitoring prompts that encouraged planning and reflection were more effective in encouraging knowledge integration than activity prompts that guided completion of specific aspects of the activity.

In a different study, E. A. Davis (2003) investigated the use of generic and specific prompts in supporting students' development of science concepts. Generic or domain general prompts are general supports which help students to understand a general framework or strategies to solve a problem despite the differences in context and knowledge area. Students receive hints about the tasks and domain specific knowledge which could help to solve a problem through the use of content specific or directed prompts. E. A. Davis (2003) concluded that generic prompts were more effective in supporting students learning as the students were required to "stop-and-think" and were given higher autonomy on their own learning.

Linn, Clark, and Slotta (2003) suggest that different types of prompts which can be used to support students' knowledge integration. Overarching prompts can help students connect their opinions and the whole project. Critiquing prompts support students to make comparisons and critique an outcome. Interpreting prompts help students analyse and interpret data to answer research questions. Explaining prompts support students to make justification of decisions using evidences. Besides, metacognitive prompts help students evaluate and reflect on their progress in the design activities (Linn et al., 2003; Puntambekar & Kolodner, 2005). Predicting prompts help students use their prior knowledge to make predictions (Linn et al., 2003).

Puntambekar and Kolodner (2005) developed a combination of different types of specific prompts including metacognitive prompts that guided students' evaluation of their work at the end of each phase of the DBL cycle. They found that students who received the metacognitive prompts acquired greater understanding of scientific reasoning at the second DBL cycle. In addition, Kim (2017) suggest that conceptual, strategic and motivational prompts need to be integrated into fixed scaffolds to support students' higher thinking skills in STEM education. In a more recent research, Fang, Hsu, and Hsu (2016) investigated the effects of using generic and context-specific prompts in three different scaffolded conditions on students' inquiry practices when they solved a socio-scientific issue. Consistent with the previous research which showed that fading is essential to enhance the affordances of prompts (McNeil & Krajcik, 2009), their research found that students exhibited significant gains in conceptual understanding on socio-scientific issues and scientific inquiry in all three conditions – explicit, implicit and fading, regardless the types of prompts used. This study suggests that fading helps students transfer their inquiry ability to a new learning context (Fang et al., 2016).

II. *Studies on facilitator's scaffolding strategies to support students' learning in design-based learning*

Barron et al. (1998) highlighted the importance of teachers' scaffolding to support students' conceptual understanding when they engaged in project-based learning. The researchers suggested using contrasting cases as scaffolds to help students differentiate distinctive features of each project and notice significance information which they might miss if they only investigate a project. Barron et al. (1998) concluded that problem-based learning which focused on stimulating students' ideas and motivation, acknowledging the existence of multiple solutions as well as prompting students to reflect on their design solutions could enhance student learning. Bhat and Kolodner (2009) supported Barron et al.'s (1998) view that self-reflection on their design tasks could enhance students' content knowledge and skills.

Hmelo, Holton, and Kolodner (2000) found that a teacher adopted various scaffolding strategies to help elementary school students learn about human respiratory system through constructing a lung model. The teacher diagnosed students' ongoing performance to decide adequate supports to help them move forward. The teacher clarified terms and rephrased the student's explanation into more precise terminology to scaffold the students' language. This research found that there were some missed opportunities in the teacher's scaffolding strategies which included less-structured activities and lacking of explicit efforts to help students debug and explain their models. Hmelo et al. (2000) suggested a few strategies to enhance student' knowledge and systematic thinking:

(a) introduce scientific terminology explicitly to help students develop early causal mechanism; (b) conduct reflective discussions and whole class discussions more seamlessly to promote idea-sharing and self-reflection; (c) motivate students by planning self-directed and problem-solving tasks; (d) plan and structure activities based on time constraint and available resources; (e) provide dynamic and timely feedback; and (f) connect new design task to students' prior knowledge.

Puntambekar and Kolodner (2005) explicated that teachers' roles during design activities which included (a) planning whole class discussions and small group discussion at appropriate intervals for idea articulation, (b) planning the sequences and structures of activities, (c) preparing appropriate learning sources, (d) chunking complex tasks into more manageable pieces, (e) providing suggestion to help student focus on important knowledge, (f) highlighting learning issues, and (g) eliciting information to make connections between design stages more explicit. Slough and Milam (2013) further suggested that different forms of scaffoldings such as modeling, sequencing complex tasks, highlighting critical features and prompting allowed students to make their thinking visible for diagnosis. Morgan, Moon, and Barroso (2013) echoed the suggestions for scaffoldings by Malim (2013) and added that teachers' scaffolding should include problematising students' designs to help them revise their own conceptual understandings on a subject area.

Cunningham and Lachapelle (2016) further elaborated that scaffolding should model and make the design process explicit to students so that they can see the connections between each design stage. Cunningham and Lachapelle (2016) argued that students should be viewed as having no familiarity with materials, tasks or terminology so that teacher can plan more exploratory activities to them. The researchers highlight the need to plan dynamic and calibrated activities to students with different learning needs. Similar to other research, a variety of scaffolding strategies such as modeling for making domain knowledge and ways of thinking explicit, providing hints and explanations as well as generating activity structure and prompts to reduce cognitive load could be adopted to engage students in design tasks (Cunningham & Lachapelle, 2016).

WHY A STUDY ON SYNERGISTIC SCAFFOLDS?

There are several factors for making synergistic scaffolds the central research feature of this study. First issue is related to knowledge integration process in the context of DBL. Typical classrooms focus on adding new knowledge into students' mental models but neglect the importance of helping students to connect and integrate ideas (Chiu & Linn, 2011). They possess fragmented knowledge piece and tend to isolate knowledge from different subject areas (Chiu & Linn, 2011). Research on using synergistic scaffolds to support interdisciplinary knowledge integration in the context of DBL is scarce. Puntambekar and Kolodner (2005) who used distributed scaffolds to help students learn and reason science knowledge from design activities did not explicitly discuss the process and skills they attempted to scaffold. It is in this area of research, scaffolding knowledge integration for interdisciplinary curriculum, and particularly in the context of DBL-STEAM, that requires further inquiry.

Second, there is also a literature gap in using the notion of synergistic scaffolds for knowledge integration to guide instructional design in the DBL context. Most studies on distributed scaffolding focused on explaining the characteristics and strategies of scaffolding as well as the effectiveness of these strategies (van de Pol, Volman, & Beishuizen, 2010) on student's learning. It is necessary to understand synergies between various scaffolds to bridge the gaps between the theories anchored instructions and classroom practices (Wang & Hannafin, 2005), as well as generate and elaborate design principles for designing effective instructional materials and activities (Edelson, 2002; Li & Lim, 2008).

Third, prompts are common hard scaffolding tools used to drive students towards specific learning goals. The existing research only focused on using question prompts to scaffold students' scientific understanding and reasoning in a single domain-specific context, but not in a transdisciplinary DBL learning environment (E. A. Davis & Linn, 2000; Linn, 2000; Linn et al., 2003; Puntambekar & Kolodner, 2005). Besides, the process of generating question prompts is not discussed in detailed. As a result of these combined issues, a research is needed to understand the design features of synergistic scaffolds.

RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

The purposes of this study are to identify the challenges students face in knowledge integration, and understand the design features of fixed scaffolds, which are the question prompts, as well as the potential adaptive scaffolds which can complement the question prompts to support lower secondary school students in integrating knowledge from different STEAM subjects. The two research questions that guide this research are:

1) What are the challenges students face in STEAM knowledge integration in a designed-based learning context?

2) How can synergistic scaffolds be designed to support students' STEAM knowledge integration in the aforementioned context from the following aspect?
   a) design features of question prompts
   b) facilitator's scaffolding strategies

METHODOLOGY

This research was a design-based research (DBR) which involved an iterative process of designing, developing, implementing, evaluating, refining and reflecting over two implementations (Barab & Squire, 2004; Design-Based Research Collective, 2003; McKenney & Reeves, 2012b; Reeves, 2000). This paper reports the first step of the design research approach, which was the problem analysis during the first implementation of the cycle. At the beginning of a DBR, researchers usually collaborate with practitioners to identify problems, research goals and research questions in a learning ecology (Amiel & Reeves, 2008). Both researchers and practitioners provide different field of expertise and experiences to the research (Amiel & Reeves, 2008).

From the perspective of DBR, practitioners' opinions and expertise are essential further identify and clarify the learning gaps informed by the existing literature in a natural setting (McKenney & Reeves, 2012a). It is crucial to understand stakeholders' opinions to gain insightful views on the problem; as well as the opportunities or challenges which must be considered when designing a solution (McKenney & Reeves, 2012a). While the literature provides an insight into these issues at the conceptual level, the interviews with the practitioners contextualize these issues at the practice level. The findings of the interviews would be discussed along with the existing literature.

I. *Participants*

This current research involved ten in-service practitioners who were teaching one of the STEAM subjects at the time the interviews were conducted. A purposive sampling was adopted to select the practitioners as to gain insight views into the central issue (Creswell, 2008b) of scaffolding knowledge integration. The practitioners were selected based on their expertise and experiences in teaching. All of them have been teachers for at least 5 years, with an average of 17 years of teaching experiences. This research involved the practitioners from both national and private secondary schools. Thus, a diversity of teaching experiences in term of educational system and school context could be represented in this study. The profiles of the practitioners are shown in Table 1.

TABLE 1

PROFILES OF PRACTITIONERS

practitioners	Gender	Types of school	Field of expertise	Years of service
T1	Female	National	Mathematics	32
T2	Female	National	Arts (Music)	22
T3	Female	National	Science	20
T4	Female	National	Design and Technology	20
T5	Male	National	Science	18
T6	Female	National	Arts (Visual art)	18
T7	Female	Private	Arts (Geo)	13
T8	Female	National	Mathematics	11
T9	Male	Private	Arts (Visual art)	5
T10	Female	Private	ICT	5

III. *Data collection and analysis*

Semi-structured interviews were conducted with the practitioners. A semi-structured interview combines a pre-determined set of less and more structured questions with the opportunity for a researcher to explore particular themes or responses further (Merriam, 2009a). The researcher conducted a pilot interview with a practitioner to make sure that the questions were appropriate and could provide useful data to answered the research questions (Merriam, 2009a). Each interview took between 30-45 minutes. Each interview was recorded and transcribed. The researcher checked the transcriptions and interpretations of the data with the practitioners through the process of member checking. The member checking process included sending the transcribed verbatim documents and a summary of merging themes and interpretations of the interviews to the practitioners via email. The member check process allowed the practitioners to review and provide feedbacks to the findings, as well as confirm the credibility of the research (Merriam, 2009b).

The data analysis started with coding the data. Coding is the process of dividing transcription into segments of information and assigning a code to the segments (Creswell, 2008a). Codes are labels used to explain a segment of text (Creswell, 2008a). After coding, similar codes were grouped together, while redundant codes were eliminated. The codes were collapsed into themes till the stage of saturation, where no new theme emerged (Merriam, 2009c). Each theme consisted of a few sub-themes which emerged during the interview process. Significant statements and excerpts which directly pertained the practitioners' opinions for synergistic scaffolds were extracted and presented to exemplify each sub-theme.

FINDINGS AND DISCUSSIONS

The results of the interviews were presented in the following section to answer the two research questions.

I. *Challenges students face in knowledge integration*

The DBR process started with analysing the challenges which students might face in knowledge integration in a DBL-STEAM context. The problems could be discussed from three aspects: (1) cognitive; (2) motivation; and (3) language.

First Challenge: Cognitive factor

Most of the research on knowledge integration discuss students' problems from the cognitive aspects. Cognitive factors are closely related to students' thinking and mental process in mind which involve knowledge acquisition and understanding (von Glasersfeld, 1989).

Lack of ability to link concepts. Compartmentation of school system (M. Davis, 1999) provide less chance for students to connect knowledge from different disciplines to solve a real-life issue, which results in their inability to link congruent concepts across various subjects (Chiu & Linn, 2011). Students also seldom compare, contrast and make connections between concepts, or link concepts with their design task (Leonard, 2006). T1 explained that the students were not able to make connections between concepts. Her view was in line with the findings of previous research which found that students seldom compare, contrast and make meaningful connections between similar tasks in different contexts (Liu et al., 2008) as well as link their design to the targeted concepts (Leonard, 2006). T1 and T9 said that:

> *Few students are able to integrate knowledge. They are not able to link concepts from one subject to another subject. They have problems even in linking concepts within a same subject. Another thing (problem of KI) is the exam-oriented school system, which is very subject specific, does not encourage students to apply and connect concepts across different subjects. Not so much exposure to tell the students what you learn can actually be applied to other fields and how you apply it. (T1)*
>
> *Our education system now is compartmentalized. For examples, after art class, students learn history, and continue with other subjects. There is no effort to bring these subjects together. (T6)*

T5 further added that the students could not relate new knowledge to prior knowledge. Eliciting ideas which means relating new tasks to existing knowledge or experiences is crucial in knowledge integration (Chiu & Linn, 2011). Puntambekar and Kolodner (2005) found that students did not see the connections between different design stages. T5 explained that:

> *Students are quite weak in generating ideas based on existing knowledge. They have the knowledge but they don't know how to apply in real context…it is caused by rote learning which focuses on memorization. (T5)*
> *Most of the students do not have good problem-solving skills. So, they hardly see the connections between different subjects. I think they seldom link science and mathematics to arts. (T9)*

Shallow understanding on underlying concepts. Previous research documented that students pay more focus to task completion and design their artefacts on trial-and-error basis rather than developing informed knowledge and scientific explanations (Baumgartner & Reiser, 1998; Puntambekar & Kolodner, 2005). They are unable to reason their design solutions due to superficial understanding on the underlying concepts or theories from multiple subjects, which cause disconnections between their design artefacts and design principles (Baumgartner & Reiser, 1998; Puntambekar & Kolodner, 2005). They also do not use relevant concepts and empirical data to reason about their designs (e.g., (Barron et al., 1998; Hmelo et al., 2000; Puntambekar & Kolodner, 2005). During interviews, T1 expressed her thought that:

> *Some students' knowledge is surface. So, some difficult questions, they cannot use different concepts to solve (the problems). (T1)*
> *Most students gain knowledge through textbooks and rote memorization. They don't really think deeply unless teachers push them to give detailed explanation. (T5)*

Cognitive load: Multiple factors and processes involved in a complex design system and a wealth of possible design solutions to a design problem may cause cognitive load to students (Hmelo et al., 2000; Puntambekar & Kolodner, 2005). This happens when students do not have proper schemata to accommodate or assimilate new knowledge into their prior knowledge (Kirschner, Sweller, & Clark, 2006). Cognitive load results in poorer performance in learning as it overburdens novice students' working memory (Kirschner et al., 2006). During the interviews, a practitioner showed her concern over the confusion caused by interconnectedness between multiple concepts:

> *Too many subjects might confuse them (students). They do not know which aspect to focus…I mean students need to learn too many concepts. The concepts, skills and knowledge emphasized in STEM may not be the same as arts…I give you one example. Science drawing emphasize accuracy in ratio but for art drawing, colour, lines, and ratio are more important…That's why students need to understand different need of each subject. (T9)*

Challenge 2: Motivational factor

Motivation refers to students' desire and willingness to put in effort persistently until they accomplish a task (Belland et al., 2013). Motivation has impact on students' learning and engagement in classroom activities (Belland et al., 2013). Two practitioners talked about student motivation in relation to knowledge integration from the aspect of establishing task value (Belland et al., 2013). P1's explanation revealed the fact that students were passive learners because they did not initiate the learning process. P5's opinion was related to the students' perception on the attainment value of arts.

> *The first thing (problem of KI) is their acquisitiveness. Students never ask questions. When they don't ask, they do not think. They are not able to link concepts from one subject to another subject. How to encourage them (students) to ask? (T1).*

> *Art has minor role to play in term of furthering studies and subject selection… Students who do not like art grumble and do not understand why they learn art… They don't see the link between arts with STEM subjects. The main aim of Finnish education system is to help students clarifying their doubts: why do I learn this subject? So, they will appreciate the importance of a subject and are keen to learn. (T9)*

Challenge 3: Language factor

The language problem emerged from the interview data. The existing literature which discusses the impact of language barrier on knowledge integration is rare. A plausible reason might be the previous studies (e.g., (E. A. Davis, 2003; E. A. Davis & Linn, 2000) were conducted in a leaning context where all students shared a common language. However, this study was conducted in a multi-racial and multi-lingual context. The practitioners found that some students had poor mastery of Malaysia national language. The practitioners explained that:

> *When it comes to students' ability in knowledge integration, I divide the students into three groups. The high, average and low knowledge integration groups. The students in high KI group can apply what they have learned with minimum support. The average students need our (teachers') help to link concepts. The low KI group, don't talk about knowledge integration, they cannot even understand Malay language…quite difficult. (T3)*

> *Language is a problem. They (students) cannot understand Malay language. I have to explain in their mother tongue (Mandarin). (T4)*

The interviews and previous studies showed that students were expected to face some challenges in knowledge integration. Therefore, the design features of synergistic scaffolds, consisting of question prompts and facilitator's scaffolding strategies needed to be explored in-depth.

II. *Design features of fixed scaffolds – Question prompts*

The existing literature, supported with the practitioners' experiences showed that effective fixed scaffolds, or more specifically referred to question prompts in the current research, had various characteristics. Four main design features emerged from the interviews as summarised in Table 2.

TABLE 2

DESIGN FEATURES OF FIXED SCAFFOLDS

Design Features	Description
Presentation	Table form
	Using sentence starters
Types	Generic and directed prompts
Difficulty	Based on Bloom's Taxonomy
Language	Short and brief

First design feature: Presentation of prompts

The practitioner suggested that question prompts could be presented in two forms: using table and sentence starters.

Presentation of fixed scaffolds in the form of tables. The practitioners explained that benefits of presenting prompts in the form of tables. For examples, they said,

Questions can be prepared in form of table. It is more organized and students can understand easier. (T3)
If we prepare tables, students can fill in their ideas systematically. (T6)

Previous research has shown that fixed scaffolds presented in the form of tables help students to organize ideas and reduce cognitive load (Kannaki, Kamala, Fauziah, & Tee, 2011). Stuyf (2002) explained that tables focus students' attention on important ideas to avoid oversight of key information which need to be collected and analysed.

Using sentence starters. A sentence starter requires students to complete a sentence, which may guide them to focus on the task and the needs of questions (E. A. Davis, 2003). T3 explicated:

If they (students) cannot answer the question, we (teachers) can give them clue, like we start to say something…such as in the topic of matter, the kinetic theory. The more energy a particle has… and let students continue to complete our sentence. (T3)

Second design feature: Using different types of prompts

Prompts can be dived into two types: generic and specific prompts. Generic or domain general prompts are general supports which help students to understand a general framework or strategies to solve a problem despite the differences in context and knowledge area (E. A. Davis, 2003; McNeill & Krajcik, 2006; Tabak & Reiser, 1997). Students receive hints about the tasks and domain specific knowledge which could help to solve a problem through the use of content specific or directed prompts (E. A. Davis, 2003; McNeill & Krajcik, 2006; Tabak & Reiser, 1997). A few teachers agreed that both general and specific prompts should be used:

Teachers can provide leading questions…to guide the students to solve a problem. (T1)
It should include both direct and higher order thinking questions. Direct questions guide most students, especially the students with lower achievement to solve a problem. (T4)
More opened questions…not textbook-typed of questions with standard answers. (T9)
The tasks given could be modified to make it more relevant to local school context…the prompts could be created based on similar format as the school assessment so that they are more relevant to school syllabus. (T10)

Different types of prompts which could be used to support student's knowledge integration (Linn et al., 2003). Question prompts which support students' knowledge integration encompass overarching prompts which help students connecting their opinions and the whole project; critiquing prompts ask students to make comparisons and critique an outcome; interpreting prompts help students to analyse and interpret data to answer research questions; and explaining prompts to justify their decisions using evidences (Linn et al., 2003). To ongoingly diagnose students' performance and to provide adequate scaffolds, metacognitive question prompts require students to evaluate and reflect on their progress in the design activities (Linn et al., 2003; Puntambekar & Kolodner, 2005). The practitioners advocated the use of different types of question prompts:

The concept of integrated STEAM should be introduced properly to the students. The prompts should encourage the students to see a problem from various perspectives. (T5)
Start with the questions which can brainstorm students' ideas..followed by more specific questions. (T8)

Third design feature: Difficulty level of prompts

Researchers advocate that generating prompts based Bloom's Taxonomy promotes different level of thinking (Lemons, Lemons, & DeHaan, 2012). Lemons et al. (2012) further add that level of difficulty is important to develop students' higher thinking skills. Three practitioners explained that:

It must be well-sequenced…either guiding students to move from a topic to another, or from simpler to more difficult questions. (T1)
Questions with different level of difficulty, such as simpler multiple-choice questions and subjective questions which consists of higher order thinking questions to target different students' needs. (T4)
I still think that questions which are created based on Bloom's Taxonomy are suitable…the questions will cover different level of difficulty (T7)

Fourth design feature: Language

The practitioners emphasised the importance of providing language supports to students based on their real-life teaching experiences in the participating school. Smit and Eerde (2011) explain that the language proficiency of non-native language speakers is not as high as native speakers. Using language that is congruent with students' everyday experiences when describing tasks and content can keep students engaged in learning (Belland et al., 2013). The practitioners suggested,

Use short and simple sentence. Don't make it too lengthy. The students might get confused…their mastery of Malay language is still poor. (T6)
Use easy sentences so that students can understand the content. Academic terms such as pictorial diagram and design must be introduced with proper language because students need to use these key terms regularly. (T8)

III. *Potential facilitator's scaffolding strategies to support knowledge integration*

Educators have the responsibility to provide adequate scaffolds to support design task so that students are able to develop knowledge and skills (Baumgartner & Reiser, 1998; Puntambekar & Kolodner, 2005). During the interviews, the practitioners suggested various scaffolding strategies which could work synergistically with the question prompts to scaffold students. The facilitator's scaffolding strategies could be discussed from six main categories: cognitive, language, metacognitive, motivational, social and strategic.

Cognitive scaffoldings

The facilitator suggested various cognitive scaffolding strategies which could be used to scaffold students' STEAM knowledge integration. These strategies are presented along with some examples of excerpts from the practitioners' interviews in Table 3.

TABLE 3

COGNITIVE SCAFFOLDING STRATEGIES FOR SUPPORTING STUDENT'S KNOWLEDGE INTEGRATION

Strategies	Examples of excerpts
Modeling	I do demonstration on the spot to show them the correct techniques to do a task…like the drawing and colouring techniques. (T6)
Questioning and pushing for explanation	I ask many questions to "dig out" and challenge the students' ideas till they achieve the learning objectives. (T3)
	I ask many questions till the students get the correct answers, either in small groups or whole class discussion. (T4)
Explaining	Normally I explain the theories before I ask the students to do the practical works. I show them (students) examples of works. (T6)
Feeding back	We (teachers) check the students' works (drawings), grade their works, and tell them what is good or bad about their works…we can inform them about the evaluation criteria and give suggestions on how to improve their works. (T6).
Summarising	We (teachers) can conclude the topics discussed on that day by asking the students to narrate again what they have done and learned. From their responses, we can evaluate their understanding and get to know whether the learning objectives have been achieved. (T3).
Hinting	If the students still cannot give correct answers after several attempts, I will give them hints or clues to spark their ideas. (T3)

Linking to prior knowledge or real-life experiences	Practitioners can relate what the students are going to learn with their prior knowledge. This will initiate the students' thinking process. (T3) I will use more examples to explain a concept to students. Normally I relate the examples with their daily life issues. It is easier for them to understand a problem they are familiar with. (T8)

Cognitive scaffoldings are commonly used to help students gain conceptual understanding and focus on main design task (Belland, 2017). The cognitive scaffolding strategies mentioned by the practitioners had been documented in the existing literature. For example, modeling takes place when a particular skill or desired outcome is demonstrated by "experts" or more knowledgeable people to people with less expertise for imitation (van de Pol et al., 2010). Wood, Bruner, and Ross (1976) explain that modelling sets a desired behaviour for imitation. Questioning involves students in linguistic and cognitive processes (van de Pol et al., 2010) and encourages students to explain and justify their ideas (Hmelo-Silver & Barrows, 2006). Previous research suggest that questioning process can either facilitator- or student-initiated. Student-initiated questions are significant as these questions can help facilitators identify the students' knowledge gaps, inform facilitators that deep processing of integrated knowledge has taken place and students are attempting to make sense of data (Engin, 2010).

The practitioners explained that they linked students' existing knowledge with new tasks. Researchers suggest that a pivotal case can serve this function. (Chiu & Linn, 2011; Linn, 2000). A pivotal case is an example used to encourage students to reorganize and restructure their ideas so that they can develop a more cohesive and normative idea on new knowledge (Chiu & Linn, 2011; Linn, 2000). Pivotal cases are used as an anchorage to students' elicit prior knowledge and to link relevant concepts (Linn, 2000). Linking existing and new knowledge is crucial as this strategy can reduce students' cognitive load as they have stored relevant information in their working memory (Kirschner et al., 2006).

Scaffolding Language

Teachers may use simpler language to explain jargons, clarify terms or tasks (Hmelo-Silver & Barrows, 2006). Teachers may also paraphrase difficult sentences into simpler and easily understood sentences. These strategies were mentioned by a few practitioners. They said,

> *Use simpler sentences which are suitable with students' understandings and language level to explain the questions. (T6)*
> *Some non-native Malay language speakers have low proficiency in language. Teachers may pre-teach some academic terms or vocabulary. (T7)*

Smit (2013) suggest teachers to use diagrams or gestures to support students' verbal explanation and reformulating students' daily language using precise academic wordings. Kirschner, Sweller, Kirschner, and Zambrano (2018) explain that all words in a sentence are inter-related and thus, students especially non-native language speakers may experience high cognitive load if any change is made on a sentence without considering their language proficiency level.

Strategic Scaffoldings

The practitioners suggested chunking the questions into more manageable pieces. For instance, T4 explained,

> *Explain the tasks step-by-step so that they can understand what they have to do…some students need a longer time to "digest" and understand our explanations. (T4)*

Chunking the design tasks into more manageable tasks serve two purposes: (1) reduced students' cognitive load caused by complex interconnectedness between STEAM concepts (Reiser, 2004); (2) focused students' attention to important goals; and (3) encouraged students to more readily monitor their progress (Morgan et al., 2013). Morgan et al. (2013) elaborate that complex design tasks need a substantive implementation time as students need to link various concepts during the iterative design cycle.

Social scaffoldings

The practitioners acknowledged that creating social spaces for students to share their knowledge is essential in knowledge integration. For example, they explained,

> *Teacher can conduct group discussions to encourage students to exchange ideas. Some students are more willing to tell their ideas to their friends. (TI)*
> *Let students work in small group so that they can discuss the solution with their peers. Then we can discuss the topic as a whole group. (T10)*

Previous research found that that peer interactions could encourage students to share ideas, integrate knowledge from different agents and collaboratively develop informed concepts underlying a design activity (Hmelo-Silver, 2004; Puntambekar & Kolodner, 2005). (Morgan et al., 2013) explicate that discussions can help students make their own mental models and ideas visible and they benefit from sharing and reflecting on their peers' ideas during knowledge integration. Whole class and small group discussions need to be seamlessly integrate so that students have the opportunities to explore their ideas in small groups and disseminate their group ideas to whole class of students for deeper negotiation (Puntambekar & Kolodner, 2005; Tabak & Reiser, 1997).

CONCLUSION

The purpose of this research was to identify the challenges of knowledge integration in a DBL context as well as to gain an understanding on the design features of synergistic scaffolds which could help lower secondary school students link knowledge across the STEAM subjects. The practitioners identified three main challenges in knowledge integration from the aspects of cognitive, motivational and language factors.

A facilitator cannot provide adequate scaffoldings to all students in a classroom at the same time (Kim, 2017). Therefore, the responsibility of scaffolding needs to be distributed to other agents or tools (Kim, 2017; McNeil & Krajcik, 2009; Puntambekar & Kolodner, 2005; Ustunel & Tokel, 2018). Meanwhile, previous studies had documented that despite being well-planned and generated, question prompts might still need to work in concert with facilitator's scaffoldings to support student learning (Kannaki et al., 2011; Kim, 2017; McNeil & Krajcik, 2009; Ustunel & Tokel, 2018). The reason is facilitators can adjust and calibrate supports based on students' ongoing progress and students' needs in a specific learning context (Ustunel & Tokel, 2018).

Researchers explain that different types of scaffolds need to work as a system to help students achieve a learning goal (Belland et al., 2013; McNeil & Krajcik, 2009; Ustunel & Tokel, 2018). Consistent with the previous studies (Kim, 2017), this study suggest that various types of scaffoldings such as cognitive scaffolding, metacognitive scaffolding, motivational scaffolding, strategic scaffolding, social scaffolding and language support can be distributed between question prompts and facilitator's scaffolding strategies to support students' knowledge integration as shown in Figure 2.

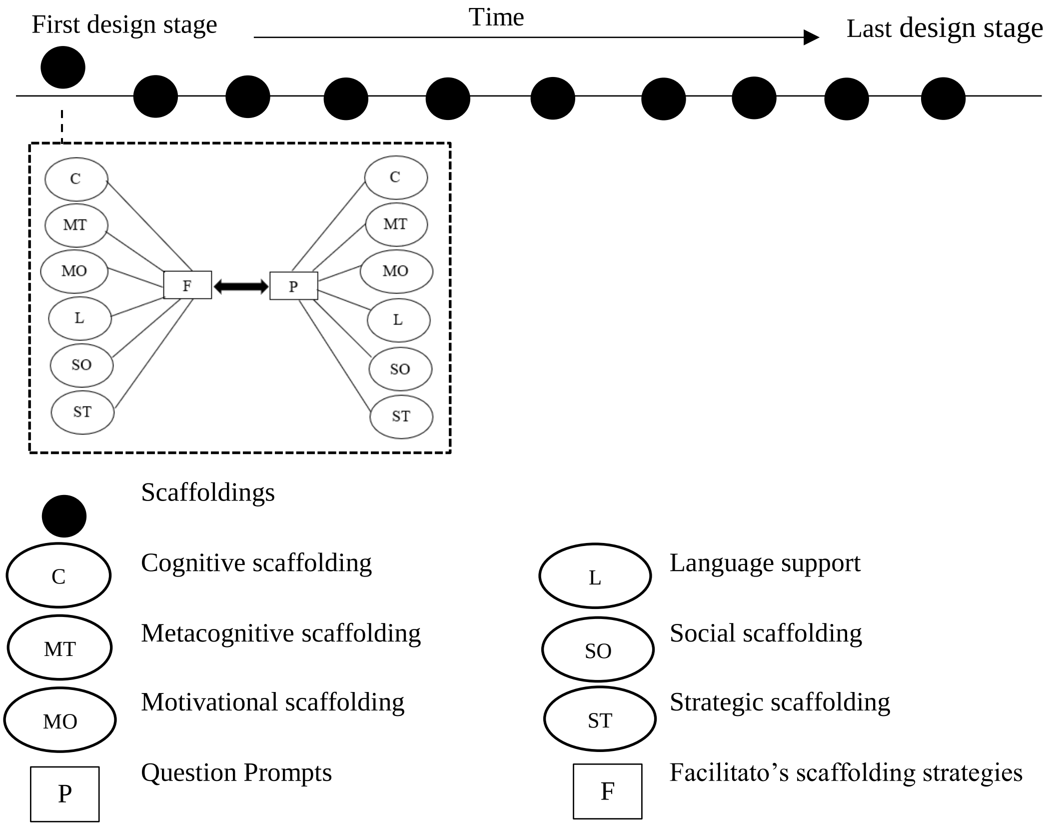

Figure 2. Design of synergistic scaffolds

There is a need to balance the role of scaffolding between fixed and scaffolds (Ustunel & Tokel, 2018). The findings of this study would be used as guidelines to design and develop the first version of synergistic scaffolds to support students' STEAM knowledge in a DBL learning context in the next solution design and development phase of DBR.

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