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ARTICLE

Scaffolding for Optimal Challenge in K–12 Problem-Based Learning

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Abstract

Establishing optimal challenge enhances intrinsic motivation, interest, and the probability of success in the learning activity. In K–12 problem-based learning (PBL), students may struggle to address associated tasks that are beyond their current ability levels. This paper suggested learner-centered scaffolding systems (LSS) to improve K–12 students' perception of optimal challenge by addressing their learning issues in PBL. LSS enhances students' experience in autonomy and competence by providing multiple types of scaffolding in accordance with students' different needs and difficulties in PBL. Students can control the nature and frequency of scaffolding by themselves according to their needs and ability, and it plays a role in improving their self-directed learning skills. Last, peer scaffolding between students with similar abilities satisfies students' needs for relatedness.

Keywords: optimal challenge, problem-based learning, scaffolding

Introduction

Establishing optimal challenge is the practice of balancing each individual learner's skill levels with appropriate task difficulty in order to maximize learning (Shernoff, 2013). Each student who is optimally challenged experiences high levels of intrinsic motivation, interest, and success in the learning activity because task difficulty is matched to the individual student's current ability (Renninger & Hidi, 2015). Whether or not a task is optimally challenging is also dependent, in part, on how students perceive their own mastery of the skills needed to complete the task (Durik, Hulleman, & Harackiewicz, 2015). In teacher-directed classrooms, educators are responsible for moderating task difficulty via the development of course sequence and problem selection (Sungur & Tekkaya, 2006). However, in problem-centered and/or student-centered constructivist curricula, teachers lose much of their ability to effectively set an optimal level of challenge for each student because students need to address ill-structured tasks through self-directed learning (Hmelo-Silver & Barrows, 2015).

For example, problem-based learning (PBL) is characterized by ill-structured tasks, which require self-directed learning processes, during which students are confronted with many different types of rigor brought on by deficiencies in their knowledge or skills (Dolmans & Gijbels, 2013). Much of their success will depend on whether they find the right amount of personalized support and whether or not they believe that they can overcome their deficits with that support (Smith & Cook, 2012). This has led some researchers (Kirschner, Sweller, & Clark, 2006) to label instructional approaches such as PBL as instructionally ineffective. To the contrary, other researchers (Hmelo-Silver, Duncan, & Chinn, 2007) have argued that correctly implemented PBL curricula include extensive student support in the form of scaffolding, which helps students experience success even when facing learning difficulties.

Scaffolding is defined as support from experts or more knowledgeable peers, which allows students to engage in, and gain skill through, given tasks that would otherwise be beyond the students' existing capabilities (Wood, Bruner, & Ross, 1976). The concept of scaffolding, which theoretically originated from Vygotskian sociocultural perspectives and the Zone of Proximal Development (Verenikina, 2003), can help students address challenges related to a lack of content-knowledge, transfer of knowledge, and motivation that can be experienced during PBL (Schmidt, Rotgans, & Yew, 2011; Simons & Klein, 2007).

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However, a recent synthesis of problem-centered educational models including PBL showed a large difference between learning gains of different age groups despite all groups receiving support (Kim, Belland, & Walker, 2018). One possible explanation is that PBL originated in medical schools, which serves a highly motivated and highly self-directed student population and also has a relatively homogeneous set of domain-specific knowledge and advanced problem-solving skills (Barrows, 1996). In contrast to medical students, middle and secondary students not only lack requisite knowledge and skills, but also may not be motivated by their curriculum nor experience adequate support from their teachers (Torp & Sage, 1998). PBL depends on students' perceptions both of task difficulty and their own ability to tackle the given task successfully. In this sense, although the difficulty level of PBL tasks can be optimized based on students' level, optimal challenge alone may not guarantee success if implemented in isolation. Optimal challenge in PBL is not only about moderating a task to students' current ability, but also about moderating student self-efficacy. Thus, in order to have K–12 students experience success at the same level as their older counterparts, they must receive additional scaffolding supports so as to experience optimal challenge. The purpose of this paper is to put forth a design of scaffolding system to help K–12 students overcome the specific issues they face in PBL such as a lack of domain-specific knowledge, problem-solving skills, self-direction, and collaborative skills.

The Concept of Optimal Challenge

Optimal challenge maximizes learning by balancing learner skill level and task difficulty (Soltani, Roslan, Abdullah, & Jan, 2011). If tasks do not correspond well to students' ability levels, various side effects can occur (Shernoff, 2013). For instance, when a high difficulty task is assigned to a lower-achieving student, the student can become anxious and disengaged (Willingham, 2009). Assigning a low difficulty task to a higher-achieving student leads to boredom and apathy (Rheinberg & Vollmeyer, 2003; Tozman, Magdas, MacDougall, & Vollmeyer, 2015). The importance of providing students optimal challenge is that it can keep stimulating and maintaining their intrinsic motivation toward, and the chance of success in, their learning.

The impact of optimal challenge has been demonstrated by previous studies. When the challenge of the learning task was optimally suited for each student's particular ability, students from elementary school to adults spent more time on their learning (Mandigo & Holt, 2006), improved understanding of content knowledge, and actively engaged in their learning (Durr, 2009; Harter, 1978; Liu, Li, & Santhanam, 2007) in the various subjects within diverse learning environments. In addition, when students had the authority to choose the task difficulty, most selected a difficulty level aligned with their current abilities, which in turn allowed them to successfully finish their learning tasks (Sit et al., 2010). The effectiveness of optimal challenge on students' better learning performance can be explained by self-determination theory (SDT).

Self-determination theory (SDT) emphasizes the importance of intrinsic motivation on cognitive and social development through active engagement in learning (Deci & Ryan, 2000). From the perspective of SDT, human beings practice self-determination as they proactively respond with interest to environmental challenges with their social groups (Deci & Vansteenkiste, 2004). SDT, therefore, emphasizes that optimal learning in educational contexts is achieved when extrinsic motivation is transformed into intrinsic motivation, which enables the student to better self-regulate (Niemiec & Ryan, 2009). Typically, students who are self-regulated experience a greater level of intrinsic motivation, which helps them to maintain their interest and effort (Ryan, Connell, & Grolnick, 1992).

It is important to consider the fact that though a given task may satisfy students' current abilities and needs, it may not always connect with students' intrinsic motivation. To optimally and effectively develop students' potential and enhance intrinsic motivation, Deci and Ryan (2002) highlighted three essential psychological needs: (a) need for autonomy, (b) need for competence, and (c) need for relatedness. *Autonomy* can be achieved as students control their own behavior, and *competence* can be achieved when students experience success at tasks that they perceive to be difficult. Furthermore, students experience *relatedness* when they perceive a sense of belonging to the community (Deci & Ryan, 2000). By addressing these three needs students can experience an internalization process from external regulation to internal regulation, as well as sustain their intrinsic motivation toward the learning activities (Deci, Koestner, & Ryan, 1999; Deci & Ryan, 2000, 2010).

However, not all learning environments have the requisite characteristics to foster autonomy, competence, and relatedness in students. Learning curricula that are more teacher-centered will impede the development of the potential intrinsic motivation, whereas curricula that are more social, problem-centered and student directed such as problem-based learning provide students space in which they can develop greater self-determination. In addition, scaffolding can play a pivotal role in maintaining and enhancing students' perception of optimal challenge in that it can help students (a) increase the expectation for success, (b) realize the value of tasks, (c) reflect their learning process, and (d) perceive belongingness (Belland, Kim, & Hannafin, 2013).

Problem-Based Learning

Problem-based learning is a learner-centered and problem-centered instructional model, in which students engage in authentic and ill-structured problems (Savery, 2015). Students acquire new knowledge by identification of knowledge gaps between their current level of knowledge and the level of knowledge it would take them to address the given problem (Barrows, 1996). Barrows and Myers (1993) defined PBL as a multistep approach, in which small groups composed of five students work with one tutor who is assigned exclusively to a single group. After students are presented with a problem, students discuss the problem, generate hypotheses, and develop learning goals. Next, they collect needed information and through discussions with their small group evaluate the usefulness of their collected information and resources to determine whether more information is required to confidently make a supported claim. This process is repeated until the group arrives at a refined problem solution.

Theoretically, ill-structured problems in PBL are a possible way to strike a balance between task difficulty and individual ability in that they have multiple potential solution paths (Jonassen, 2000). Students must be able to devise a solution path according to their abilities, and sometimes choose one path out of many in order to solve a problem. In addition, the design of PBL fosters student self-determination by satisfying the aforementioned psychological needs of autonomy, competence, and relatedness (Müller & Louw, 2004).

PBL enhances students' *autonomy*, in that students need to take the initiative in learning (Chirkov & Ryan, 2001). This happens in PBL as the teacher's role is relabeled as one of a facilitating tutor, which minimizes a teacher's control over the learning process and allows students to experience a greater level of autonomy. This new teacher-student relationship requires students to assume greater responsibility over their learning than in teacher-led instruction (Mills, Treagust, & others, 2003; Reeve, Jang, Hardre, & Omura, 2002). Group collaboration is also an essential feature of PBL that fosters r*elatedness* (Hmelo-Silver & Barrows, 2015). If the quality of teacher-student and student-student relationships in PBL collaboration is positive, then students will feel safe and their need for relatedness will be satisfied (Ferrer-Caja & Weiss, 2000). Additionally, PBL can also enhance *competence* as students experience success in tackling the rigor of ill-structured problems on their own (Chirkov & Ryan, 2001). As students satisfy their psychological needs for autonomy, competence, and relatedness in PBL, they will experience internalization of their motivation (Deci & Ryan, 2000).

Furthermore, when intrinsically motivated, students will want to engage with tasks for longer periods and will experience pleasure while doing so (Pelletier et al., 1995). For this to be achieved the given tasks in PBL should be optimally challenging, but this may prove to be difficult, especially in younger grade levels where students work in groups that have a much greater level of proficiency disparity (Cela, Sicilia, & Sánchez-Alonso, 2015; Kaufman, Felder, & Fuller, 1999). Originally PBL was designed for medical students, but the model has been revised for use among various age ranges, subjects, and educational institutions, including business, educational psychology, K–12 (e.g., science, engineering, technology, and mathematics), and higher education (e.g., undergraduate disciplines and vocational education) (Delisle, 1997; Hmelo-Silver, 2004; Torp & Sage, 1998).

Meta-analyses by Gijbels, Dochy, Bossche, and Segers (2005) and Leary, Walker, and Shelton (2012) have shown that PBL improved understanding of content knowledge and self-directed learning. Nevertheless, some scholars questioned the effectiveness of PBL on K–12 students who do not have much experience in self-directed learning and reflective thinking (e.g., Koh, Khoo, Wong, & Koh, 2008). For example, it might be difficult for younger students to be deeply immersed in a certain activity in PBL that simultaneously requires them to improve their content knowledge and problem-solving skills in addition to their self-regulation and intrinsic motivation (Salam et al., 2009).

To address this issue, scaffolding can be utilized to enhance students' engagement and to build their higher-order skills in complex learning contexts (Belland, 2014). However, it is not clear how scaffolding can affect students' perception of, and engagement through, optimal challenge in PBL by enhancing their intrinsic motivation toward learning due to a lack of studies.

Students' Challenges in PBL and Scaffolding Design for Addressing Their Challenges

PBL requires students' diverse skills such as effective problem-solving skills, self-directed learning skills, and interpersonal skills, as well as flexible knowledge (Gallagher, Sher, Stepien, & Workman, 1995). Thus, it is possible for students to experience several types of difficulties during PBL because of students' different levels of background knowledge, learning skills, and motivation. Although this challenge exists in myriad forms of differentiated learning settings, the greater agency over learning PBL affords students increases the importance of a cohesive group dynamic. There is less of a singular, linear progression for the task as well as less teacher involvement to redirect the learning if a group is struggling. If students experience any difficulties in PBL, their immersion in learning is hindered, and their recognition of optimal

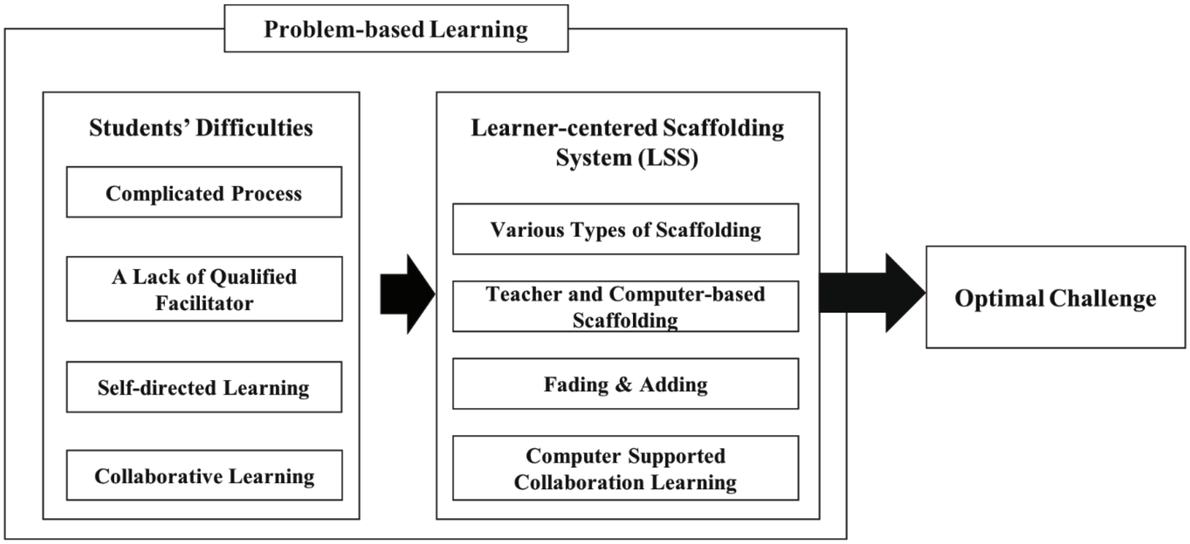

Figure 1. Students' challenges in PBL and scaffolding design for addressing their challenges.

challenge worsens due to a lack of intrinsic motivation by the reduction of autonomy, competence, and relatedness (Wijnia, Loyens, Derous, & Schmidt, 2015).

As seen in Figure 1, this paper suggests using a learner-centered scaffolding system (LSS) to address several learning difficulties in PBL (i.e., complicated learning process, self-directed learning, collaborative learning, and a lack of qualified facilitators). LSS includes several characteristics of scaffolding (i.e., various types, sources, fading/adding function, and computer-supported collaboration learning and can enhance students' intrinsic motivation through the satisfaction of three psychological needs (i.e., autonomy, competence, and relatedness), leading to students' perception of optimal challenge.

Complicated Learning Process in PBL

Students' difficulties. Students in PBL face ill-structured problems that are intertwined with their real lives (Hmelo-Silver, 2004). Students solve real-life problems that they can experience, and they actively engage in learning activities to generate various reasonable solutions by connecting new information to their existing knowledge (Jonassen & Hung, 2008). When students try to solve these types of problems by themselves, they can perceive the given tasks as personally meaningful, which can improve their intrinsic motivation (Loyens, Magda, & Rikers, 2008). However, one issue is the complicated and unfamiliar problem-solving process in PBL (Savery, 2015).

The process of PBL consists of four major steps: (a) defining problems, (b) determining information for addressing the problems, (c) finding, evaluating, and utilizing information as evidence for their solutions, and (d) generating an argument in support of the solution (Belland, Glazewski, & Richardson, 2011). Each step is intimately connected to the another, and if students cannot accomplish the task from a certain step, it will be increasingly difficult to successfully complete subsequent steps. Furthermore, at each step students have to deploy different abilities and skills. For example, students need domain and structural knowledge to understand and define the problems in the first step of PBL (Barrows, 1994). Additionally, they must use high levels of metacognition as they consider where and when domain knowledge can be utilized as they devise their own strategies for problem solving (Hmelo-Silver & Barrows, 2015).

This means that K–12 students, who quickly solve well-structured problems with information provided by teachers, could have difficulty adjusting to the ill-structured problems of PBL which require advanced problem-solving skills. Students who have previously experienced success in teacher-led classrooms may experience much more difficulty solving PBL problems as they confront deficits in their content knowledge, problem-solving skills, self-determination, and motivation. For all these reasons, students with larger deficits may need a greater level of support to experience success.

Suggested scaffolding. The original definition of scaffolding focused on developing students' problem-solving skills by providing just-in-time support (Wood et al., 1976). But recently, the role of scaffolding has been expanded into enhancing content knowledge and other skills such as self-determined learning and argumentation skills (Belland, 2010; Kek & Huijser, 2011; Leary et al., 2012). Moreover, to promote the perception of optimal challenge, scaffolding should also play a role in enhancing motivation, including self-efficacy (Belland et al., 2013; Bixler, 2007; Tuckman, 2007). Students motivation and confidence can be enhanced or weakened for a variety of reasons, and various types of scaffolding should be provided to students according to their current situation (Belland et al., 2013). For example, scaffolding that arouses interest can be used to enhance motivation among students who often exhibit low interest in academic tasks. On the other hand, for students who have a difficulty in solving problems, scaffolding to enhance content knowledge understanding is needed (Hannafin, Land, & Oliver, 1999). In this sense, scaffolding can be divided into four types—conceptual, metacognitive, strategic, and motivation scaffolds (Collins, Brown, & Newman, 1989; Hannafin et al., 1999; Tuckman & Schouwenburg, 2004) (see Table 1).

Conceptual scaffolding provides hints and prompts about the content (Hannafin et al., 1999), and it helps to structure and problematize tasks (Reiser, 2004). Conceptual scaffolding often incorporates such strategies as concept mapping and other visualization strategies. It helps students feel that the given problem is worth attempting by providing the reason the given problem is important to their life and by linking the problematic situation with their own experience. It,

Table 1. Examples of Various Types of Scaffolding

Type of scaffolding	Examples	References
Conceptual scaffolding	"If you are trying to calculate the weight and the gravitational acceleration along an axis, here is a general formula that always works: Let ɵV be the angle as you move counterclockwise from the horizontal . . ."	(Vanlehn et al., 2005, p. 155)
Metacognitive scaffolding	"Did you write your goal statement as planned?", "How are you going to choose the country?"	(Molenaar, Boxtel, & Sleegers, 2011, p. 801)
	"Why did you feel feature x was important in coming to a diagnosis?", "What feature(s) do you think is the most crucial in coming to the diagnosis of this case?"	(Roll, Aleven, McLaren, & Koedinger, 2007, p. 28)
Strategic scaffolding	"Draw a model for the structural formula of C_5 H_8 you suggested", "Write the structural formula of propylene glycol—a product of a reaction between propane, $KMNO_4$, and water."	(Kaberman & Dori, 2009, p. 606)
Motivational scaffolding	"You're feeling less overwhelmed now that you've found it's not hard at all?" "Very nice. And I think that's a difficult thing for lots of students to achieve in their writing."	(Mackiewicz & Thompson, 2014)

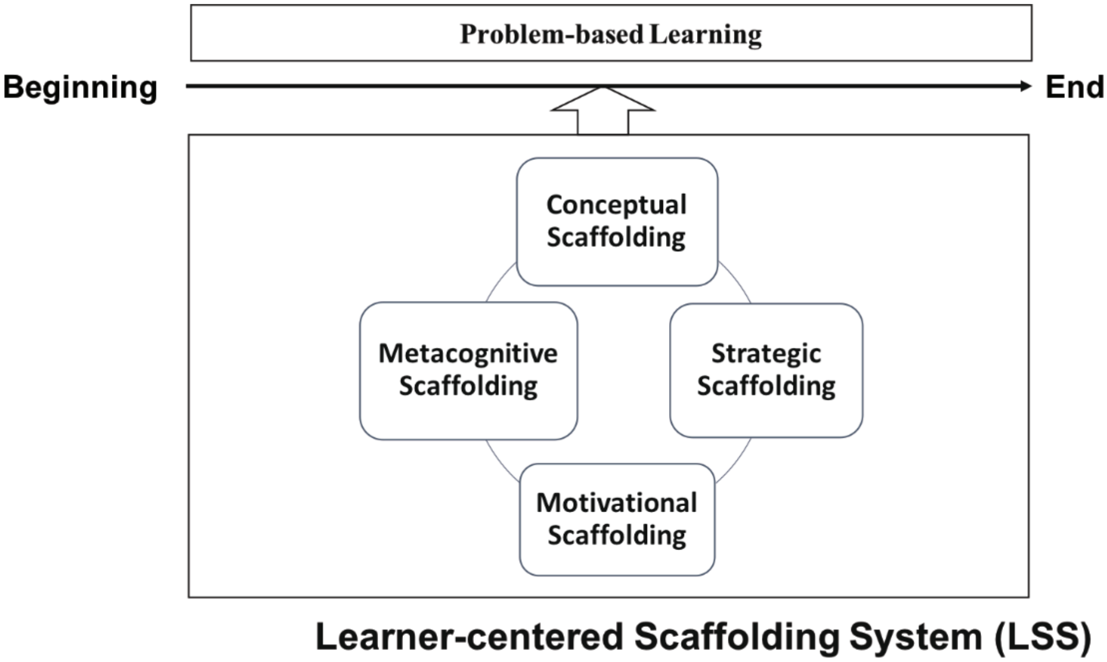

Figure 2. Four types of scaffolding in LSS.

in turn, enhances students' intrinsic motivation and makes it for students to easily adjust to authentic problems in PBL.

Metacognitive scaffolding invites students to reflect on their learning process and encourages students to consider possible problem solutions (Hannafin et al., 1999; Oliver & Hannafin, 2000). In PBL, students' recognition of what they already know, and should know, is important to establish their learning plan and strategy. In this sense, metacognitive scaffolding provides students the chance to define the problem based on their prior experience and knowledge.

Strategic scaffolding focuses on processes to solve problems and provides guidance about problem-solving strategies such as providing the information of resources utilized in solving the problems (Hannafin et al., 1999). The key to success in PBL depends on students determining the more effective information for evidence of their own solution and generating reasonable solutions based on evidence. Strategic scaffolding in PBL can be a systematic procedure of PBL, which helps students' problem-solving process.

Motivational scaffolding plays a role in enhancing students' interest, confidence, and collaboration (Rebolledo-Mendez, Boulay, & Luckin, 2006; Tuckman & Schouwenburg, 2004). There is a lack of research utilizing motivational scaffolding in PBL, but students' motivation is an important factor in the enhancement of students' perception of optimal challenge in PBL (Belland, 2014). Certainly, as students accomplish their tasks using supports from conceptual, metacognitive, and strategic scaffolding, their motivation can improve. However, it is clear that motivational scaffolding is required to directly improve students' ability to persist confidently as they face the difficulties proceeding from their learning.

In PBL, students often struggle due to a lack of content-knowledge, metacognition, learning strategy, and interest in PBL. Unless appropriate and just-in-time supports for addressing these various difficulties are provided, students may not perceive an optimal challenge. This LSS can provide different types of scaffolding according to students' current learning difficulties and needs regardless of PBL steps. For example, as seen in Figure 2, when ill-structured/authentic tasks are given at the beginning of a lesson, students can struggle to understand and define the given problems due to a lack of content knowledge. At this moment, conceptual scaffolding among various types of scaffolding can be intensively provided to help students structure their content knowledge (Barrows & Tamblyn, 1980; Belland, 2008; Hmelo-Silver, 2004). On the other hand, in the case of students who lack passion and interest in learning from the beginning, motivational scaffolding can play a role in enhancing students' willingness to complete the given task through motivational supports such as "expectancy for success" and "the value of the completed task" (Koenig, 2008; Lin & Lehman, 1999). This enables students to enhance their "competence" that is required for self-determination learning skills, leading to the perception of optimal challenge.

Lack of a Qualified Facilitator

Students' difficulties. Lack of a qualified facilitator also causes K–12 students' learning difficulties in PBL. The role of PBL facilitators (a) helps students recognize the problematic situation by themselves, (b) stimulates students' advanced thinking processes and knowledge integration skills, (c) informs the learning process, and (d) induces the evaluation of group members' opinions and work through active interaction (Dolmans et al., 2002; Johnston & Tinning, 2001). These scaffolds from facilitators can improve students' autonomy, competence, and relatedness for enhancing their intrinsic motivation, which ultimately results in students' perception of optimal challenge (Belland et al., 2013). However, in the context of K–12 PBL, teachers have a great deal of difficulty performing the role of facilitator for the following reasons.

First, K–12 teachers often lack mastery of the skills required to effectively fulfill the role of facilitator due to a lack of professional training in PBL (Johnston & Tinning, 2001). Second, according to a meta-analysis to investigate the effectiveness of scaffolding in the context of K–12 PBL (Kim et al., 2018), more than 92% of empirical research conducted PBL in K–12 classrooms where the number of students was more than 25. These issues make it difficult for teachers as facilitators to provide suitable scaffolding to address each student's current needs, which occur during PBL. If teachers do not respond quickly and effectively to students' difficulties, students can lose sight of the learning goals and how to achieve them. Furthermore, in PBL that requires students' advanced problem-solving skills and self-directed learning, students could be put off learning itself by a lack of qualified facilitators. Therefore, students need additional sources of scaffolding beyond what a teacher is able to provide.

Suggested scaffolding. The source of scaffolding indicates what type of scaffolding can be delivered to students (Belland, 2014). Typically, scaffolding can be provided by teachers, computer systems, and peers. Teacher scaffolding consists of one to one support for student learning, often in the form of probing questions, prompts to action, or illustrations that help students organize their thinking (Belland et al., 2013; Zhang, 2013). Computer-based scaffolding is often categorized as hard scaffolds (Saye & Brush, 2002), which are designed to address predictable difficulties presented by the embedded systems within a certain software. Intelligent tutoring systems can provide more individualized and just-in-time supports by addressing the issues of the existing computer-based scaffolding such as an inherent lack of immediate adaptability to student needs. However, intelligent tutoring systems often are ill-equipped to differentiate between students' deep and shallow learning (Koedinger & Aleven, 2007).

Collaboration with peers who have better knowledge and ability can be an effective scaffolding source to improve students' higher order skills and motivation (Bruner, 1986; Gillies, 2008; Oh & Jonassen, 2007; Vygotsky, 1986). However, in the case of peer scaffolding, it may be unreasonable to expect peers who have a similar level of knowledge and ability to provide sophisticated scaffolding of all types to each other. That is, peer scaffolding might not be suitable as the main delivery method for metacognitive and strategic scaffolding, which may be beyond the ability of a peer to explain or correctly apply. In this sense, both teacher and computer-based scaffolding are preferred to effectively deliver the diverse types of scaffolding. Peer-scaffolding is handled as an effective means for collaborative learning in the next section.

Scaffolding provided by teachers, as opposed to computers, might fit well when respect for authority is part of the student's culture, epistemic belief system, or gender preference (Pata, Lehtinen, & Sarapuu, 2006; Van de Pol, Volman, & Beishuizen, 2010). In addition, teachers can exactly diagnose students' current needs and learning status, thereby providing more effective scaffolding to students. However, one teacher cannot provide immediate feedback to every student when classrooms contain 20–30 students (Wu, 2010). Computer-based scaffolding, therefore, can play a role in supporting teacher-based scaffolding through generic or context-specific supports (Wu, 2010).

Computer-based scaffolding can provide immediate feedback based on students' performance (Belland, 2014). Intelligent tutoring systems (ITS) use artificial intelligence technology to recognize students' different ability levels, and provide immediate feedback based on students' current understanding (Anderson, Corbett, Koedinger, & Pelletier, 1995; Fletcher, 2003; Ma, Adesope, Nesbit, & Liu, 2014; Plano, 2004). But ITS can elicit surface approaches to learning in that students often try to receive as much help including hints as possible to solve the problem faster, disregarding their learning progress (Koedinger & Aleven, 2007). There is no method to control for students' unconditional requests for scaffolding within ITS because current computer systems are unable to judge whether the requested scaffolding is absolutely essential for learning. Thus, it cannot help but provide undifferentiated and simple help (Jonassen & Reeves, 1996). This means that computer-based scaffolding cannot completely replace teacher scaffolding in PBL.

If teacher scaffolding with just-in-time and elaborated supports and computer-based scaffolding with immediate supports can be well combined, scaffolding can be delivered to students more efficiently and effectively. For example, as seen in Figure 3, in LSS, computer-based scaffolding can recognize the steps that students are performing and present various types of scaffolds (i.e., conceptual, metacognitive, strategic, and motivational) to students that correspond to their learning process. If computer-based scaffolding does not fully address students' current learning issues, teachers then can provide individualized and sophisticated supports.

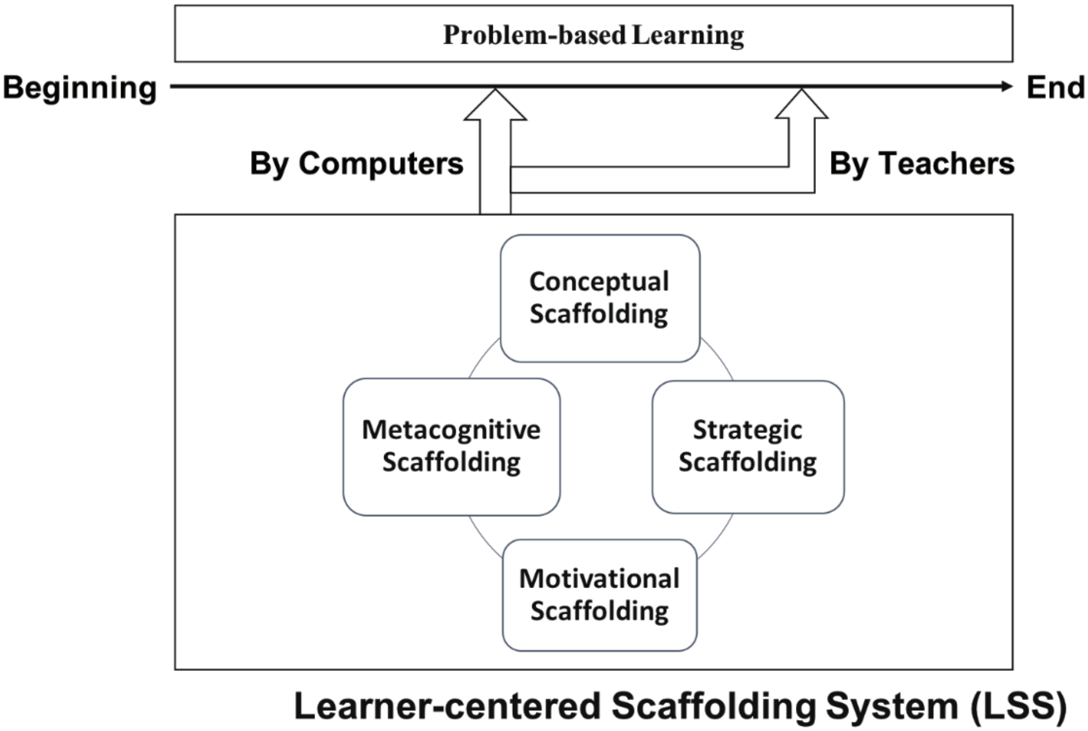

Figure 3. The sources of scaffolding in LSS.

In this case, teachers can greatly reduce their burden as a scaffolding provider because they only handle students who need more advanced supports.

Multiple sources of scaffolding (e.g., teacher-provided and computer tools) have been provided in the existing empirical research (Kajamies, Vauras, & Kinnunen, 2010). This research provided generic supports from computer systems and the more specific individualized supports from teachers as needed. The results showed that students who got teacher- and computer-based scaffolding as needed showed better problem-solving skills than those who received the teacher's help or computer-based supports alone.

Self-Directed Learning in Problem-Based Learning

Students' challenges. One of the characteristics of problem-based learning is that learning is done through self-direction (Hmelo & Lin, 2000; Loyens et al., 2008). Knowledge acquisition is always the product of self-directed learning with authentic problems according to the constructivist perspective (Leask & Younie, 2001). Thus, if learning is an active and constructive process, the role of learners should establish the learning goal and strategies in knowledge construction activities. Learners' self-directedness becomes the precondition for learning but is also a requirement to encourage transfer. Self-direction allows learners to participate more actively in the learning process and take responsibility for their learning (Rieber, 1991). Specifically in PBL, self-directed learning can boost metacognitive skills and intrinsic motivation to further encourage the learners' efforts in understanding the given problematic situation, the organization of information, generation of multiple solutions, and self-evaluation (Loyens et al., 2008). Therefore, if learners are given control over their learning, they will be able to improve self-directed learning skills to take a lead and reflect on their learning and performance. This, in turn, leads to students' perception of optimal challenge due to the improved autonomy and confidence of their learning.

However, it might be difficult to expect that K–12 students will easily adjust to self-directed learning in PBL. When K–12 students, who are familiar with the learning objectives and plan decided by teachers, first attempt to self-direct learning in PBL, they experience a lot of difficulties (Loyens et al., 2008). This can reduce students' confidence in accomplishing the tasks and motivation. It makes it difficult for students to proceed in their learning with the recognition of optimal challenge.

Suggested scaffolding. Three kinds of scaffolding customization (i.e., fading, adding, fading/adding supports) considering students' self-directed learning are required to maintain optimal challenge. There are three bases of scaffolding fading, adding, and fading/adding: fixed-time interval, performance, and self-selection. Fixed time interval means that fading, adding, and fading adding occurs after a predefined number of events or after a fixed time interval. The frequency and nature of scaffolding can be changed by students' current learning performance and status. Lastly, students can decide to request fading, adding, and a combination of both by mentioning or clicking buttons labeled "I don't need this help anymore" or "I need more supports."

Fading. If scaffolding worked successfully, students should eventually be able to reach the desired goal without scaffolding (Collins et al., 1989; Fretz et al., 2002; Hoffman, Wu, Krajcik, & Soloway, 2003). By effectively controlling the timing and degree of scaffolding, students can take the responsibility for their learning processes (Chang, Sung, & Chen, 2002), which can lead to self-directed learning (Loyens et al., 2008). It is very difficult, in computer-based instruction, to diagnose students' state of understanding, motivation, and metacognition (Azevedo, Cromley, & Seibert, 2004; Clarebout & Elen, 2006; Lee, Lee, Leu, & others, 2008; Ruzhitskaya, 2011). Most computer-based scaffolding that incorporates fading employs fixed fading, in which scaffolds are removed after a fixed time interval and are thus not completely adapted to student ability. Many intelligent tutoring systems and advanced learning analytics implement performance-adapted fading based on assessment of student performance (Cope & Kalantzis, 2015; VanLehn, 2008; West, 2012), but many scholars criticized the use of fading by computer systems due to inaccurate diagnosis of students' behavior, intention, and learning progress (Jackson, Krajcik, & Soloway, 1998; Jonassen & Reeves, 1996; Madaio, 2015).

In the case of fading based on teachers' judgment, teachers need to determine the timing of fading as a result of examining each student's learning process. So, teacher-controlled fading tends to be performance-adapted based on students' performance (Chin, 2007). In the case of performance-adapted fading by teachers, it might not be feasible for one teacher in the classroom to identify the degree to which each student has mastered the target content due to the number of students in the class (Wu & Pedersen, 2011). Considering optimal challenge, it is important to base fading decisions on the exact diagnosis of students' current understanding because the suitable timing of fading must maintain the balance between the difficulty of the task and students' ability. However, it is very difficult for computers and teachers to determine the timing of fading based on an ongoing diagnosis of students' current understanding due to the limitations of technology and current classroom environments. Therefore, one alternative fading method for optimal challenge should be considered.

In PBL, students have ownership of their learning (Wood, 2015) and take responsibility for their learning process and strategy (Hoffman & Ritchie, 1997). This indicates that PBL requires self-directed learners who can exercise control over their learning by autonomously selecting learning materials and the strength or frequency of supports (Loyens et al., 2008; McLoughlin & Lee, 2010). In this sense, self-selected fading can be one method of fading for optimal challenge. Certainly, it is possible that students misjudge their understanding of learning, and make poor instructional decisions (Aleven & Koedinger, 2002; Hadwin & Winne, 2001); however, self-confidence and motivation may be enhanced through the use of self-selected fading because in this way, students can control their own learning (Ryan & Deci, 2000).

Students can maintain a state of optimal challenge through self-selecting fading and conduct learning efficiently by eliminating unnecessary scaffolding. Considering the goal of fading for optimal challenge is to help students reach the final learning goal using their own learning strategies, self-selected fading is a good method to improve students' confidence in their ability to successfully accomplish tasks. This claim has been proven by a Bayesian meta-analysis on the effectiveness of computer-based scaffolding in PBL in which self-selected scaffolding customization was the best choice to directly improve students' learning performance, rather than the change of scaffolding by performance-adapted and fixed-time interval (Kim et al., 2018). Therefore, if the limitation of self-selected fading mentioned above (i.e., students' insufficient ability to diagnose their learning process and to figure out whether scaffolding is still needed or not) can be overcome, self-selected fading can be helpful for students to maintain the perception of optimal challenge in PBL.

The possible solution to overcome the aforementioned limitations is that teachers and computers can play a role in supporting self-selected fading. In other words, students can fade scaffolding by themselves, but when their decision of fading is problematic, computers and teachers can invite students to reflect on their decisions. For example, as seen in Figure 4 (see next page), in LSS, computer systems can recognize students' current learning progress based on their learning stage, performance, and time. Currently, research has demonstrated the possibility of automatic evaluation of students' learning status and progress through learning analytics techniques and machine learning algorithms (Kim, Belland, & Kim, 2017; Martin & Ndoye, 2016; Park & Jo, 2015). If computers judge that students' decision for fading is not effectively timed, students will be provided reflective questions such as "Are you certain that you do not need help anymore?" In this case, computers play a supportive role in helping students' judgment about the decision of fading and such questions can raise the likelihood that self-selected fading proceeds at the right time. In addition, it is possible for students to ignore computers' messages about their fading to finish the tasks as soon as possible. In this case, teachers can identify whether students stop receiving scaffolding with an exact understanding of content knowledge after a fixed time interval. So, in this

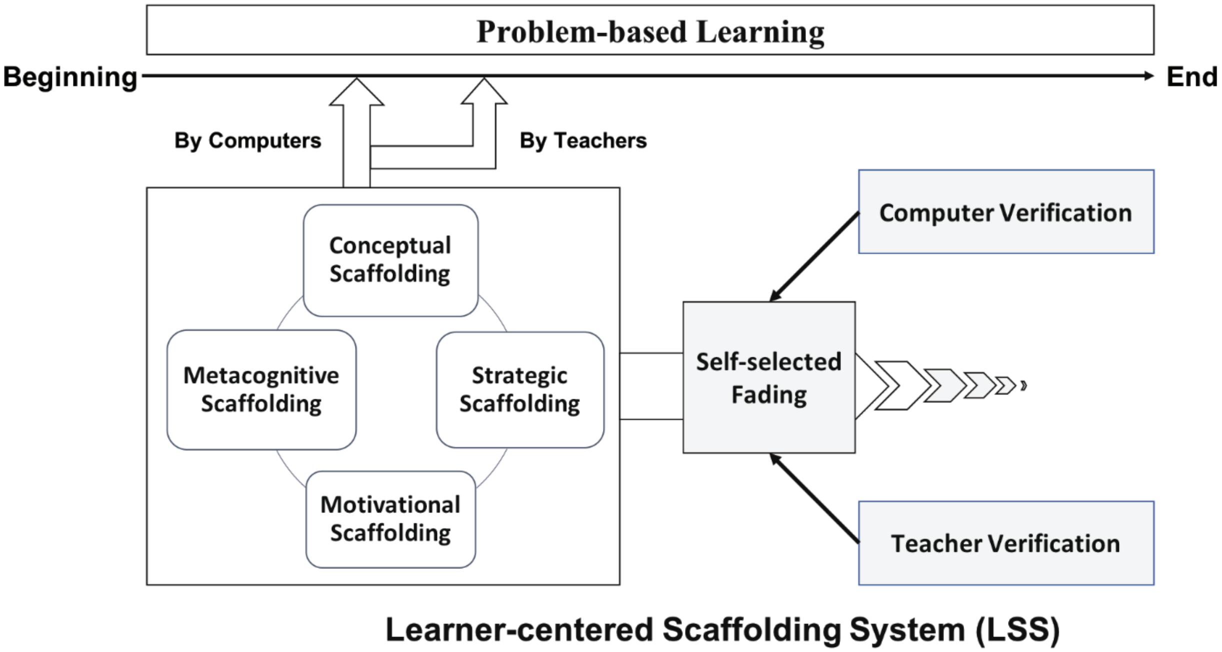

Figure 4. Fading systems to improve self-directed learning in LSS.

instance, teachers can effectively control students' self-selected fading by providing questioning and prompts.

Adding supports. Studies of problem-based learning in which scaffolding is added by intelligent tutoring systems are not numerous (Belland, Walker, Kim, & Lefler, 2017). In intelligent tutoring systems, adding is typically initiated by students pushing a hint button to request more support (Girault & d'Ham, 2014; Rouinfar et al., 2014). In addition, as supports are added, the characteristics of scaffolding can be changed from generic to context-specific to help students solve a specific learning issue at the step or process during which they experience the challenge (Koedinger & Aleven, 2007).

In intelligent tutoring systems, scaffolding can be added repeatedly until the correct answer is finally given (Koedinger & Aleven, 2007). However, in PBL, there is no one right answer because the problems are ill-structured. Therefore, even though students keep asking for more scaffolds, scaffolding will just keep providing more specific guidance to solve the problem, not the right answer. This means that unlike fading, students are unlikely to make poor decisions about adding supports because they can easily recognize that scaffolding never tells the right answer by trial and error, and if they want to finish learning quickly, they tended not to request more scaffolding. So, in the case of adding support during PBL, guidance by computers and teachers concerning students' decisions like fading might not be required.

The strategy for adding supports in this paper is as follows (see Figure 5, next page). First, when the initial scaffolding with various sources and types cannot satisfy students' needs in learning in LSS, pushing an embedded button such as "more help" provides immediate, more specific scaffolding from the computer systems. Such added support systems have been utilized in empirical research, and the positive effects on students' learning performance have been demonstrated (Kajamies et al., 2010; Mendicino, Razzaq, & Heffernan, 2009). Second, although the supports from computer systems are continuously added by students' requests, if students are not satisfied by this help, they can directly ask teachers for other help. In this case as well, students would push the button "ask teachers," and then teachers can easily identify who wants more scaffolding through the network between students and teachers' computers. After teachers diagnose students' current learning status, they can add the suitable types and sources of scaffolding with more specific supports rather than the initial scaffolding. Teachers do not need to take care of all students; rather, the teacher can focus on students who request more help. Therefore, this might be possible in a classroom situation in which teachers are in charge of scaffolding customization for all students.

Considering the above-mentioned roles of fading and adding supports, it is possible to design a singular scaffolding system that uses a combination of fading and adding scaffolding. Figure 6 suggests the fading and adding scaffolding system as combining the above-suggested fading and adding scaffolding designs.

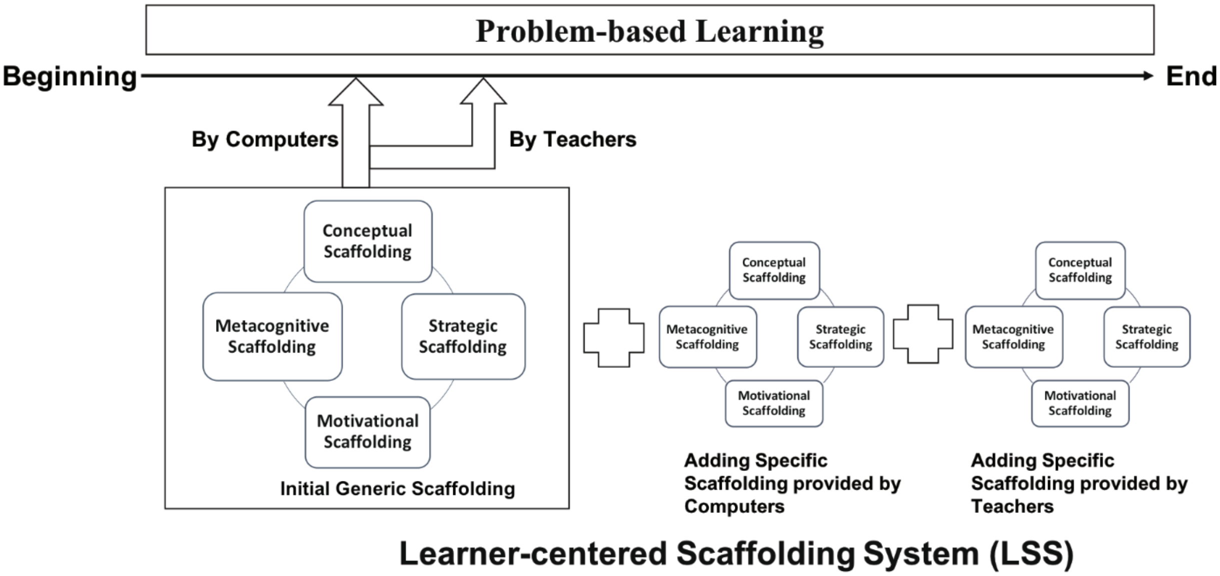

Figure 5. Adding systems to improve self-directed learning in LSS.

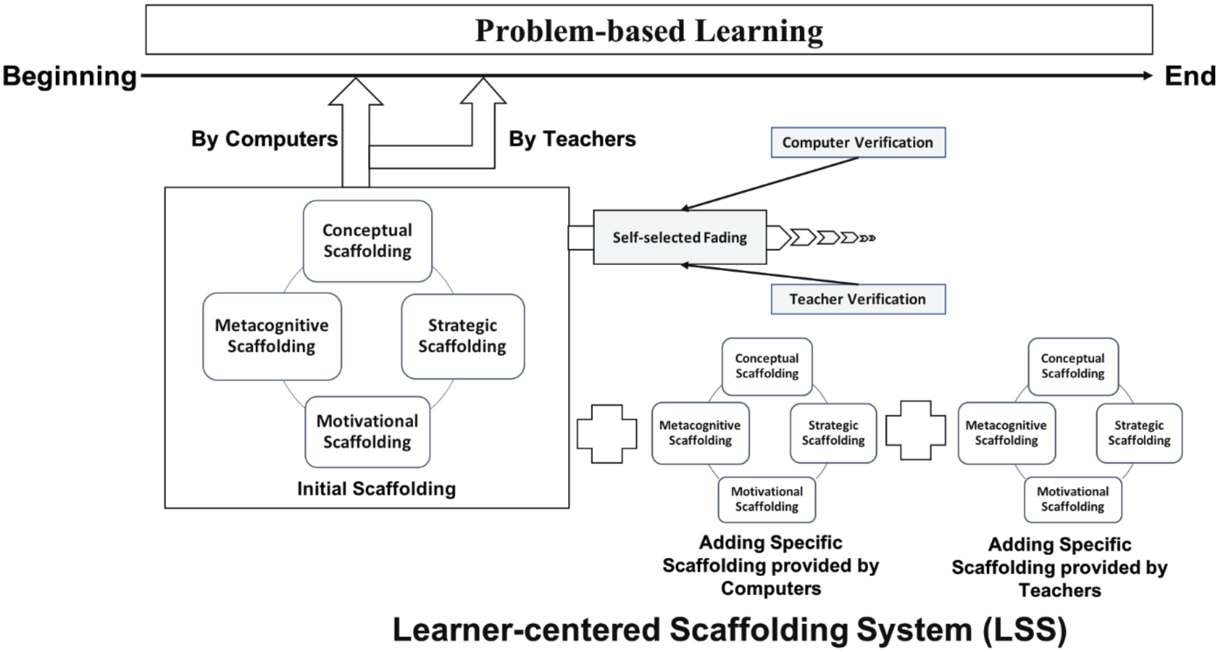

Figure 6. Fading and adding systems to improve self-directed learning in LSS.

According to a meta-analysis that synthesized the results of individual studies regarding the effectiveness of scaffolding in PBL (Kim et al., 2018), there was a significant difference in cognitive outcomes among scaffolding customization types (i.e., no fading or adding, fading, adding, and fading & adding). Scaffolding that included both adding and fading functions ($g = .59$) showed the highest effect size compared to scaffolding with no fading/adding ($g = .16$), only fading ($g = .42$), and only adding ($g = .44$).

Collaborative Learning in Problem-Based Learning

Students' challenge. In PBL, collaborative learning makes the problem-solving process more effective and efficient (Barrows, 1996). Making Fractions Visual, a PBL multimodal math group project, has students take on the role of professionals whose jobs require using fractions (Intel Teach Program, 2010). The students work collaboratively to publish newsletters, conduct presentations, and create wikis that incorporate digital mediated communication. By dividing roles between students, many diverse problem-solving methods can be created. Students can perform the tasks while watching the problem-solving execution process of other students (Belland, 2014), which can lead to students' reflection on their own problem-solving processes and strategies. Therefore, students can engage in the learning activities by collaborative learning. The collaboration results in improved student autonomy and relatedness, which are the important factors that lead to perceived optimal challenge (Benson, 1996; Du, Ge, & Xu, 2015; Fan & others, 2015).

Despite the aforementioned advantages, collaborative learning often suffers from issues caused by group composition. Groups often include one or two students who show a passive attitude to learning due to a lack of motivation, learning goals, and abilities (Kaufman et al., 1999). At first, these students make a superficial attempt to engage in the group activity, but shortly afterward, they negatively affect group members' collaboration due to disturbance and off-task behavior. In the opposite case, there might be a student who has more advanced knowledge and leadership than other group members, but this student accidentally or deliberately tends to ignore the opinions of group members who were regarded as the obstructers from the leader's perspective.

Furthermore, a progression to the next step in PBL can be delayed by other students' slow learning paces, and it, in turn, decreases the group's level of immersion in learning. This type of student prefers to learn alone due to the efficiency of learning (Cela et al., 2015). The tasks in PBL, which require active collaborative learning, might not be optimally challenging from this student's perspective. Unequal participation and a lack of discussion in the group, which consists of students with different abilities and learning paces, make it hard for students to psychologically experience optimal challenge if there are few proper supports to balance the different abilities of group members.

Suggested scaffolding. In PBL, group work is critical to complement individual students' lack of skills by allowing them to obtain more reasonable solutions and further information from peers (Hommes et al., 2014). Therefore, collaborative learning systems, which enable the exchange of information through close interaction between learners, should be established to overcome the individual differences in PBL (Savery, 2015). To address this, research related to computer-supported collaborative learning (CSCL) has been extensively carried out. Learners create learning communities in the CSCL environment and show the following cognitive growth through the experience of forming and developing knowledge within the groups (Okada, 2005). First, learners can develop the skills to pursue and construct knowledge. Second, learners can improve their communication skills through discussion among the other group members. Third, learners can experience higher-order skills such as critical thinking, reflective thinking, and creative thinking. In this regard, many studies have utilized CSCL in PBL and demonstrated the effects of CSCL on enhancing the group activities in PBL (Hmelo-Silver & Eberbach, 2012). However, students in K–12 do not naturally know how to collaborate effectively. CSCL in K–12 often incorporates collaboration scripts, which guide students in such important tasks as distributing tasks, balancing group member perspectives, responding to groupmates' articulations, and synthesizing results (Atmatzidou & Demetriadis, 2012; Erkens, Bodemer, & Hoppe, 2016; Kollar, Fischer, & Hesse, 2006). In addition, CSCL has not yet fully considered the different patterns of behavior seen in active and passive students (Kwon, Liu, & Johnson, 2014). The passive or active nature of students has a strong influence on success in CSCL. Generally, students who display a passive attitude toward their learning lack content knowledge, learning skills, and motivation (Benware & Deci, 1984; Huang & Chiu, 2015). If CSCL focuses on the development of collaboration skills without consideration of individual supports, which help the passive students actively engage in learning, it merely facilitates superficial group interaction. In this sense, the results of meta-analysis, which analyzed and synthesized the effects of CSCL from 175 articles, indicated that CSCL had a large effect (d = 0.63) on enhancing collaborative skills, but a small effect (d = 0.26) on improving students' domain-specific knowledge in the context of K–12 education (Vogel, Wecker, Kollar, & Fischer, 2016). This is due to a lack of content-related individual supports in CSCL (Kollar et al., 2014).

To address this weakness, this paper suggests advanced CSCL in which the different roles are assigned by considering the different ability levels of each student in relation to those of the rest of the students in the group. This way, each student enhances the group's motivation by purposefully conducting the learning task in accordance with each individual's specific ability. In other words, this type of CSCL can overcome the learning differences between students in the group. Moreover, this provides immediate scaffolding to students in order to move across individual learning and collaborative learning in PBL (Jeong & Hmelo-Silver, 2016).

As seen in Figure 7, the above model explains collaborative learning systems in LSS, which are composed of individual and collaborative learning. At the beginning, the proper role and subtasks are assigned to each student through discussion between group members and the advice of teachers. Students proceed in their individual learning according to their learning ability and pace. The difficulties occurring during individual learning can be addressed by the previously

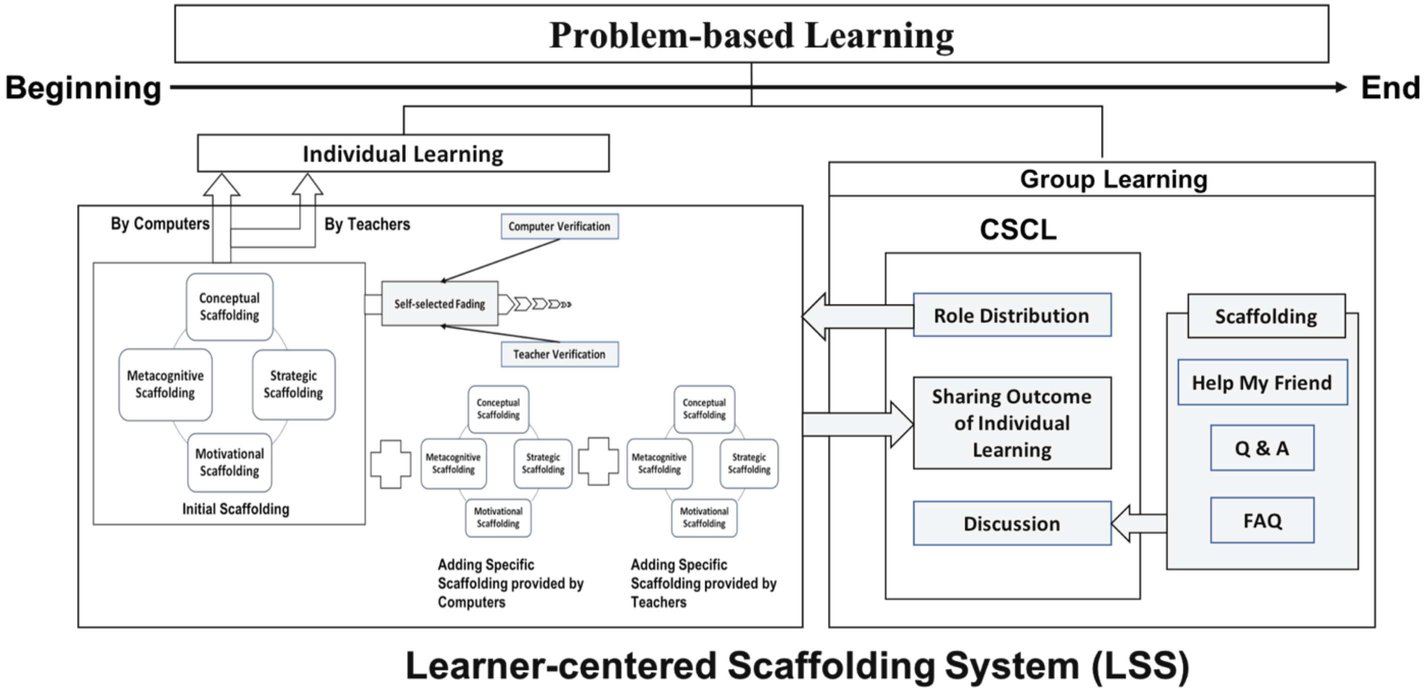

Figure 7. Collaborative learning system in LSS.

discussed types and sources of scaffolding and the fading/adding supports of scaffolding. The learning outcomes from each student's research can be uploaded into the CSCL system. Then, the students come back together to review one another's results. They come to a consensus about inconsistent evidence and claims for solutions through discussion, and their conclusion becomes the final group claim.

In addition to scaffolding in individual learning, group learning needs scaffolding to enhance group interaction, to evaluate the resources each student gathered, and to draw a consistent conclusion. "Help My Friend," "Q&A," and "FAQ" play a role in scaffolding in the suggested CSCL. The students have differences in their degree of prior knowledge as well as interests and attitudes about their current learning goals. These differences manifest themselves in the varied roles students play, such as leaders who have excellent learning skills or as assistants who help their peers.

"Help My Friend" enables peer scaffolding. A student who requires help in CSCL is connected with peers who have similar levels of individual learning and current learning pace. Figure 8 (see next page) shows how to provide peer scaffolding among students with similar ability. The gray block indicates students' current steps in PBL. The solid line means possible peer scaffolds between students who have the similar abilities (e.g., A and D, B and C, C and D). However, it is possible that peer scaffolding between similar-ability students does not work well (Vygotsky, 1986). If this is the case, supportive peer scaffolding (the dotted line) from a slightly more advanced student can be utilized.

Unlike potential connections between students who have slightly different learning levels, the network between students who have a big gap in terms of learning pace and abilities is not provided. This supports Csikszentmihalyi's (1996) claim that collaborative learning among students with similar ability improves intrinsic motivation by raising their interests, which in turn leads to students' perception of a great challenge. The reason for greater connection with students who have similar abilities and pace is that they can better understand one another's difficulties by sharing their experience in solving similar issues. One potential problem with this system is that the peer scaffolding between students who have a low level of ability might be superficial and shallow, resulting in intensifying the students' confusion. In this sense, for effective peer scaffolding to occur, it is necessary to have a guideline to explain how and when peer scaffolding should be provided. Table 2 (see next page) shows guidelines for the use of peer scaffolding to elicit the perception of optimal challenge.

"FAQ" provides immediate scaffolding that facilitates individual learning without waiting for the time period by posting the answers to the anticipated questions on the board. On the other hand, it is difficult to anticipate the questions learners want to ask. If students are not satisfied with the scaffolding provided by peers or computer systems, they can directly request additional help from teachers through a

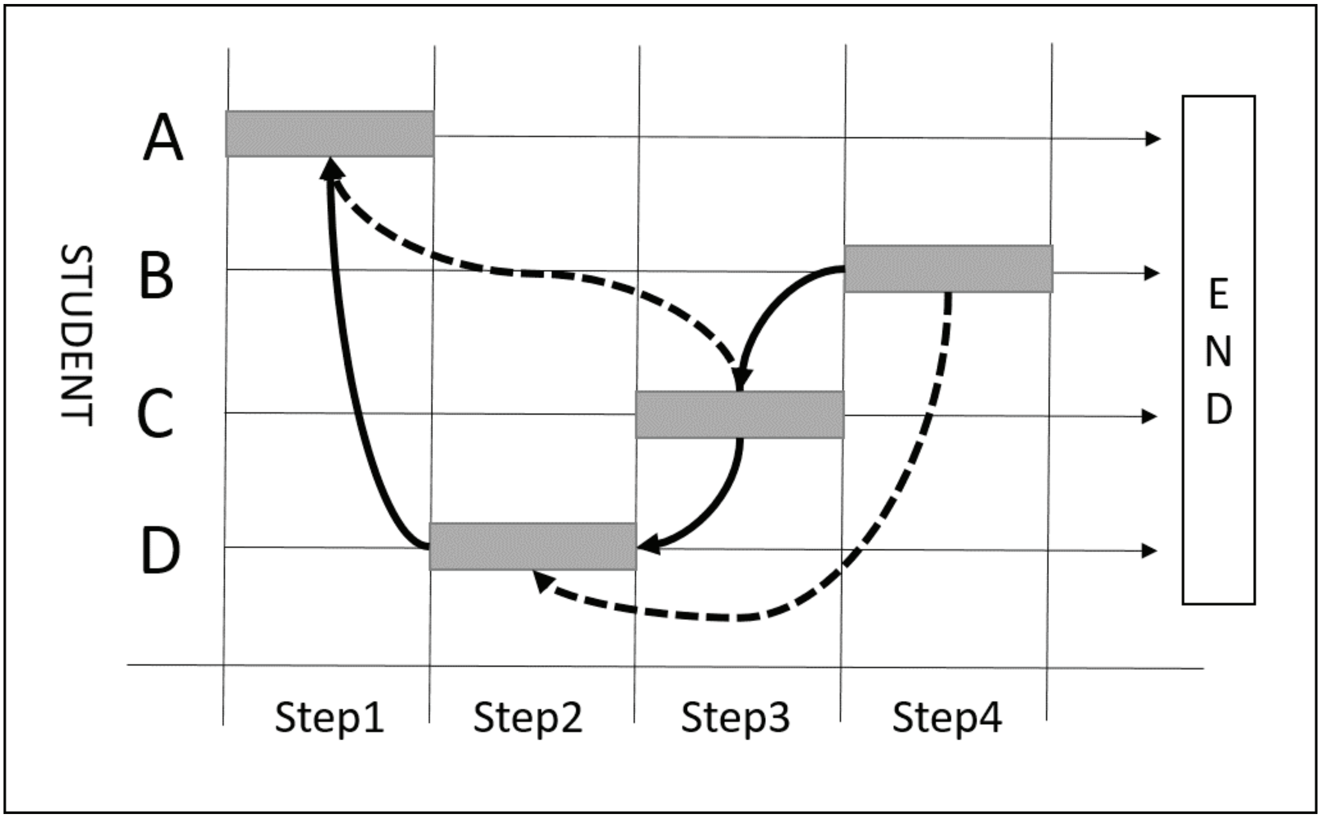

Figure 8. Peer scaffolding in CSCL.

Q&A board. Teachers who are monitoring students' learning status can provide more detailed and just-in-time supports to students independently.

Limitations

Several limitations to this approach have been identified and require further research. Little is known about the effectiveness of the combination of timing, types, sources, and customization of scaffolding. In addition, the complicated scaffolding system this paper suggests has the potential to cause cognitive overload (Mayer & Moreno, 2003). Therefore, more empirical research to address the above issues is required.

This paper suggests self-selected fading as one method of fading to enhance students' self-directed learning skills and responsibility of learning, but in the case of less confident and dependent students, self-selected fading may even be counterproductive, resulting in lack of self-control and self-determination.

Continuous monitoring of student progress may become burdensome to the scaffolding provider who is less acquainted with the many sources of scaffolding types. Making decisions about timing, type, levels, and sources of scaffolding imply a variety of options about which a teacher needs to be informed and prepared. Additionally, algorithms upon which computer-based support of student scaffolding decisions are made may be difficult to design.

Discussion

According to self-determination theory (Deci & Ryan, 2000), if students can enhance their intrinsic motivation toward their learning through the satisfaction of the following psychological needs: (a) autonomy, (b) competence, and (c) relatedness, they can perceive the given task as optimally challengeable (Mandigo & Holt, 2006). Problem-based learning provides a learning environment to experience these psychological needs, in that students take responsibility for their learning, conduct their research with peers, and experience success in independently tackling the rigor of ill-structured problems (Savery, 2015). However, the complicated problem-solving process, a lack of self-directed learning, and a lack of cooperative learning and qualified facilitators make it difficult for K–12 students to experience optimal challenge by accomplishing the given tasks in PBL (Wijnia et al., 2015).

In order to address the above-mentioned learning issues, this paper suggests learner-centered scaffolding systems (LSS), which utilize the multiple types and sources of

Table 2. Guidelines for peer scaffolding that promotes the perception of optimal challenge.

Guideline of Peer Scaffolding	The Effect of Peer Scaffolding on Perception of Optimal Challenge
1a. Describe tasks by providing narratives of peers that show the accomplishment of other students with similar problems (Belland et al., 2013). 1b. Enable students to search and access peers' evaluation about previous works (Saavedra & Kwun, 1993; Trivedi, Kar, & Patterson-McNeill, 2003).	Peer scaffolding allows students to identify the difficulty of tasks, and help them perceive tasks as manageable.
2a. Embed discussion between peers to enhance motivation (Kear, 2004; Slavin, 1987; Suh, Kim, & Kim, 2010). 2b. Enable students to improve motivation through cooperative learning including peer interaction (Slavin, 1987). 2c. Provide immediate peer feedback to students for maintaining motivation (Carrico & Riemer, 2011). 2d. Assign suitable roles according to ability (Soller, Goodman, Linton, & Gaimari, 1998).	Peer scaffolding can motivate students toward their learning, and students can be immersed in their learning
3. Embed peer-questioning to help students understand their current ability (Choi, Land, & Turgeon, 2005).	Peer scaffolding can instill self-confidence about the achievement of tasks, and it can make students successfully accomplish their tasks.
4. Enable students to experience the internalization process of learning through peers' learning (Damon, 1984).	Students can experience the internalization process through peer scaffolding, and this can lead them to self-determination as an essential factor in perceiving optimal challenge.

scaffolding, fading, and adding function, and the advanced CSCL, which considers the interaction of students' individual learning abilities. To be successful in PBL, a student needs to handle all the types of rigor brought on by deficiencies in knowledge or skills (Belland et al., 2017). Many scaffolds have been suggested and implemented to support students' difficulties in problem-centered instructional models, but their roles were limited to addressing only one or a few areas of difficulty such as domain knowledge, learning strategies, and collaborative learning.

To solve this issue, distributed scaffolding suggested by Puntambekar & Kolodner (2005) is consistent with the intended purpose of multiple types of scaffolding, in that various types of scaffolding are provided according to each student's current needs, understanding, interest, and motivation. However, the limitation of Puntambekar and Kolodner (2005)'s study is that they did not mention how scaffolding can be effectively delivered to students who have different ability levels. In this sense, LSS suggested by this paper can enhance students' perception of optimal challenge by addressing all kinds of students' difficulties in PBL and enhancing students' intrinsic motivation for learning.

As LSS supports students' diverse difficulties that occur during PBL with various types of scaffolding—conceptual, metacognitive, strategic, and motivational scaffolding—it can help students handle difficulties in many contexts. Regardless of students' levels (Hannafin et al., 1999), it can lead to improvement of students' competence in the accomplishment of tasks that is one of the psychological needs for intrinsic motivation (Deci & Ryan, 2000; Gormley, Colella, & Shell, 2012).

Moreover, the effective delivery of several types of scaffolding can be operated by the combination of teachers and computer systems in LSS. The role of computer-based scaffolding is to provide a generic and immediate response to the broad range of student needs that occur during learning, while teacher scaffolding can provide more advanced and sophisticated supports to students (Belland, 2014). In this system, teachers do not need to monitor every student's learning status, and it is possible for one teacher to effectively facilitate individualized scaffolding for 25+ students in one classroom. In this situation, several types of scaffolding can be delivered to students more efficiently and effectively by addressing students' needs immediately and in greater detail. This allows students to learn how well they performed the activities, and what they can do to improve.

A lack of students' skills regarding self-directed learning can be addressed through self-selection of the fading/adding of scaffolding (Collins et al., 1989; Van de Pol et al., 2010). Fading by self-selection can allow students to take responsibility for their learning, and it can enhance students' motivation, self-determination, and confidence (Savery, 2006). Moreover, teachers and computers support students' decisions on fading in order to prevent students from making rash or wrong decisions on scaffolding customization. Adding supports by self-selection can also improve students' self-directed learning skills by changing the nature of scaffolding from generic to context-specific according to their own decisions (Koedinger & Aleven, 2007; Koedinger & Corbett, 2006). Students' requests to add scaffolds means they have taken an initiative in learning as well as have a passion for, and expectation of, success—"autonomy," which leads to their perception of optimal challenge (Deci & Ryan, 2000).

Another important activity in PBL is collaborative learning, which allows students to arrive at more reasonable and valuable solutions by sharing their experiences, information, and learning strategies (Barrows, 1994; Hmelo-Silver, 2004). However, K–12 students have diverse learning skills, background knowledge, and motivations, so a composition of group members who have unbalanced abilities might result in a reduction of interests and confidence (Moos & Azevedo, 2009). Therefore, CSCL in LSS, as suggested in this paper, considers individual work according to each student's ability and the utilization of peer scaffolding between students with similar learning abilities and pace. Within this system, group members figure out that the whole group cannot proceed with their learning if each group member does not finish the tasks assigned them. Therefore, they participate in individual learning and collaborative learning, as well as peer scaffolding, to support students who have lower ability and work at a slower pace. This can enhance students' responsibility and autonomy for successful learning (Du et al., 2015; Miller & Hadwin, 2015). The proposed LSS design may seem too complex, but recently, some intelligent tutoring systems have partially adopted the above-suggested scaffolding (Beal, Arroyo, Cohen, Woolf, & Beal, 2010; Woo et al., 2006). The effects of scaffolding (e.g., increased intrinsic motivation, engagement, perception of optimal challenge in PBL, etc.) have practical implications including, but not limited to, increased teacher effectiveness, more effective individual supports for students with disabilities, increased incorporation of students' cultural and linguistic diversity, and increased presence of authentic assessment and achievement.

Conclusion and Implication

Learner-centered scaffolding systems (LSS) suggested in this paper can enhance students' experience of autonomy and competence by providing multiple types of scaffolding in accordance with students' different needs and difficulties in PBL. It can also effectively and efficiently deliver these scaffolds through a combination of teachers and computer systems. In addition, students can control the nature and frequency of scaffolding by themselves according to their needs and ability, which plays a role in improving their self-directed learning skills. Finally, peer scaffolding between students with similar abilities satisfies students' needs for relatedness. Students' autonomy, competence, and relatedness, which were improved by LSS, directly connected students' immersion with intrinsic motivation for their learning. Through all the supports from LSS, students can improve the perception of optimal challenge in the given tasks in PBL.

There are many positive implications when using LSS scaffolding to achieve optimal challenge. Teachers are supported in their attempt to provide help for all students and can be assured that struggling students effectively receive needed help (Tabak, 2004). Self-directed learning in PBL can be amplified when students control not only to whom they turn for help, but also the selection of the type and quantity of help they need when confronted by challenges beyond their abilities (Dahlgren & Dahlgren, 2002; Hmelo-Silver & Barrows, 2015). As a consequence, student confidence to take on the ill-structured nature of PBL will increase and student problem-solving abilities will grow (Guglielmino, 2008; Lefever-Davis & Pearman, 2015).

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