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The 3C3R Model: A Conceptual Framework for Designing Problems in PBL

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Abstract

Well-designed problems are crucial for the success of problem-based learning (PBL). Previous discussions about designing problems for PBL have been rather general and inadequate in guiding educators and practitioners to design effective PBL problems. This paper introduces the 3C3R PBL problem design model as a conceptual framework for systematically designing optimal PBL problems. The 3C3R model comprises two classes of components: core components and processing components. Core components—including content, context, and connection—support content and conceptual learning, while processing components—consisting of researching, reasoning, and reflecting—concern students' cognitive processes and problem-solving skills. This paper discusses the model in terms of its theoretical basis, component functions, and the techniques used in designing PBL problems.

Keywords: Problem-based learning, Instructional Design, Problem design, Problem solving process

Introduction

Problem-based learning (PBL) has been successfully implemented in the medical field, higher education, and K–12 settings over the past fifty years. The outcomes of PBL implementation have shown that it is an effective instructional pedagogy that inherently engages students in active, meaningful learning, resulting in deeper understanding and longer retention (Gallagher & Stepien, 1996; Hung, Bailey, & Jonassen, 2003; Norman & Schmidt, 1992). In examining the research on PBL, a majority of studies have focused on various implementation and learning outcome issues, such as the roles of tutors (Margetson, 1991; Wilkerson, & Hundert, 1991), students' perceptions (Caplow, Donaldson, Kardash, & Hosokawa, 1997; Woods, 1996), group size (Lohman & Finkelstein, 2000), group processing skills (Achilles & Hoover, 1996; Mayo, Donnelly, Nash, & Schwartz, 1993), and the rate of board exam passage (Albanese & Mitchell, 1993; Norman & Schmidt, 1992; Vernon

55–77

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& Blake, 1993). However, the issues surrounding the design of problems seem to have received little attention. A few researchers (Barrows, 1986; Duch, 2001; Lambros, 2004; Lee, 1999; Weiss, 2003) have discussed the design of PBL problems. Yet, the discussions are rather general and, therefore, inadequate in providing educators and practitioners with the conceptual framework needed to design effective PBL problems. Drummond-Young and Mohide (2001) proposed an eight-step PBL problem development process specifically designed for nursing education, which unfortunately rendered the process too domain-specific to be used in a wider range of contexts.

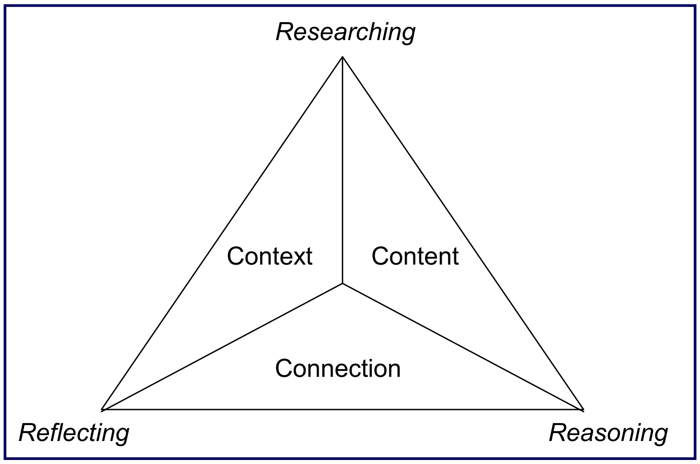
Duch (2001) contended that the problem itself is key to the success of PBL. To investigate the effectiveness of PBL problems, Dolmans, Gijselaers, Schmidt, and van der Meer (1993) analyzed the correspondence between the instructors' intended objectives and the student-generated learning issues based on their interpretations of the PBL problems. They found that only 64% of intended content was identified in the student-generated learning issues. Hence, without assurance of the quality of problem or intended aims being met, the effects of PBL are unpredictable and questionable. In addition, there has been a call from educators for a systematic way to design problems in PBL. Angeli (2002) interviewed ten middle school and high school teachers who implemented PBL within their curricula. One comment that consistently appeared in all ten teachers' interviews was that the generation or selection of problems was the most challenging task in designing a PBL curriculum. To address this challenge, I propose the 3C3R PBL problem design model as a conceptual framework for designing more effective, precise, and reliable PBL problems.

3C3R PBL Problem Design Model

Problems, in general, are at the heart of PBL. They function as a content and knowledge organizer, learning environment contextualizer, thinking/reasoning stimulator, and learning motivator. Unquestionably, the design of problems plays a key role in determining the success of PBL courses and curricula (Lee, 1999; Trafton & Midgett, 2001). The 3C3R PBL problem design model is a systematic method specifically designed to guide instructional designers and educators to design effective PBL problems for all levels of learners, thereby strengthening the characteristics of PBL and alleviating implementation issues revealed in previous research on PBL.

The 3C3R model consists of two classes of components: core components and processing components (see Figure 1). Core components include content, context, and connection, and are used to support content/concept learning; processing components, composed of researching, reasoning, and reflecting, concern the learners' cognitive processes of learning and problem-solving skills.

Figure 1
3C3R PBL Problem Design Model



Core Components of the 3C3R Model

The core components of the 3C3R model—content, context, and connection—are primarily concerned with the issues of appropriateness and sufficiency of content knowledge, knowledge contextualization, and knowledge integration.

Content

In reviewing PBL research of the past several decades, Hung, Bailey, and Jonassen (2003) identified a number of dilemmas related to implementing PBL. Among these dilemmas, they found that educators and students were most concerned with the issues of depth versus breadth and factual knowledge versus higher-order thinking skills. These issues arose from PBL students' slightly less than desirable performances on content tests compared to traditional students (Albanese & Mitchell, 1993; Friedman et al., 1992; Levesque, 1999; Vernon & Blake, 1993), as well as teachers' (Angeli, 2002) and students' (Dods, 1997; Lieux, 2001; Schultz-Ross & Kline, 1999) concerns with respect to sufficient content coverage in a PBL curriculum. Although some studies indicated that sufficient breadth of content acquisition was not sacrificed for depth of content learning (Gallagher & Stepien, 1996), others suggested that more balance was necessary (Dods, 1997). This problem may have resulted from, as Hoffman and Ritchie (1997) conjectured, the limited timeframe constraint in PBL courses, causing time spent on factual knowledge acquisition to be traded for the development of problem-solving and reasoning skills, or ineffective PBL problem design, requiring students to acquire and process excessive amounts of information indirectly related to the intended content area (for example, a PBL problem on "global warming" intended to address basic knowledge and concepts of earth atmosphere inherently involves many more concepts than "basic" Earth atmosphere).

It is a misperception that PBL trades content sufficiency for problem-solving skills development. On the contrary, PBL values content knowledge acquisition. According to Malopinsky, Kirkley, Stein, and Duffy (2000), PBL is designed to help students simultaneously develop problem-solving skills while constructing a domain knowledge base. Students acquire the domain knowledge by going through the processes of solving problems that, in part, require them to engage in knowledge acquisition activities. Since the acquisition of domain knowledge is the premise for reasoning and seeking solutions to the problem, both elements are equally critical in PBL. Thus, when designing PBL problems, several aspects of the content component must be taken into consideration.

Aligning with curricular standards. Although the advantages of promoting students' problem-solving and self-directed learning skills may, to some extent, justify PBL students' lower performance on basic knowledge acquisition or standardized tests, Hoffman and Ritchie (1997) argued that some measures should be taken to ensure students' domain/content knowledge proficiency. Such proficiency is necessary for students to obtain competitive scores on standardized tests that are used prevailingly to validate students' achievements (Lambros, 2004). Thus, rather than seeing curricular standards as the limits for what PBL problems should or can cover, instructional designers and teachers should use these standards to identify the major concepts and areas of the topic or subject, and then design PBL problems accordingly. To achieve this, PBL researchers (Drummond-Young & Mohide, 2001; Duch, 2001; Uyeda, Madden, Brigham, Luft, & Washburne, 2002) agreed that the first step in designing PBL problems was to set goals and objectives in accordance with the course or curricular standards. Learning goals and objectives help practitioners determine the appropriate scope of the problem for achieving the curricular standards (Trafton & Midgett, 2001), as well as balancing the breadth and depth of content afforded by PBL problems.

Scope of problems. The second element of the content component is ensuring proper scope of PBL problems. This includes breadth and depth of the problem scope. First, designing the breadth of the problem can be accomplished by conducting task analyses on both the learning goals and the candidate PBL problem to reveal the degree of correspondence between the two. Based on this information, the designers can adjust the breadth of the PBL problem as needed to better facilitate the students' learning in the extent of the content area and intellectual skills required to achieve the learning goal. According to Jonassen, Tessmer, and Hannum (1999), depending upon the nature of the learning tasks, a number of task analysis methods can be used to analyze what specific concepts, tasks, procedural skills, or cognitive skills need to be covered within the instruction. Among the various task analysis methods, a learning hierarchy analysis (Gagné, 1962) would be useful for analyzing the instructional content and tasks because curricular standards (or learning goals) are often general and context-independent. The specifications of major concepts, information, or cognitive skills resulting from the content/task analysis on the learning goal can then function as pointers to help instructional designers select candidate PBL problems. PARI (Precursor-Action-Results-Interpretation) (Hall, Gott, & Pokorny,

1995) is a suitable method for performing the analysis on candidate PBL problems, since it is designed to map out the detailed knowledge base and cognitive reasoning processes required in solving problems.

To design PBL problems with appropriate depth, complexity and ill-structuredness are the two key parameters (Koschmann, Myers, Feltovich, & Barrows, 1994; Weiss, 2003). If a problem only requires basic information to solve it, the learners are likely to study the topic only at the surface level. Once a problem can be easily solved, the needs, as well as the motivation for the learners to go deeper into the topic, no longer exist. Also, Trafton and Midgett (2001) suggested that the complexity of the problems should largely contribute to enriching the subject area, rather than developing general problem-solving skills. Furthermore, the ill-structuredness of problems helps to deepen the learners' understanding of the topic. This is because the nature of multiple reasoning paths and multiple solutions (Jonassen, 1997; Kitchner, 1983) inherent in ill-structured problems provides chances for the learners to explore other alternatives to solve the problems and, in turn, understand the domain in more depth.

Context

The second core component in the 3C3R model is context. Cognitivists such as Godden and Baddeley (1975) suggested that when content is learned in the same or similar context in which it will be applied, the knowledge and skills will be recalled and retained more easily. Moreover, to structure their knowledge for more effective use, students' knowledge base should be organized around problems (Gallagher, 1997) and in a form ready to use in clinical contexts (Barrows, 1986). To become an effective problem solver in a specific field, the learner needs to acquire not only sufficient domain knowledge, but also specific situational/contextual knowledge that is implicit yet still crucial to effective problem solving. As Torp and Sage (1998) suggested, the contextual information of the problems helps learners link the knowledge constructed and skills acquired to related situations in real life. Lack of situational/contextual knowledge may account for students' difficulties in transferring knowledge to real-life situations because, as Prawat (1989) argued, this particular type of knowledge helps learners become more aware of how the domain knowledge can be used. Many researchers agree that the problems being used in PBL should be as authentic as possible (Barrows, 1994; Duch, 2001; Hmelo & Ferrari, 1997; Koschmann et al., 1994). The authenticity of a problem is largely determined by the contextual information in which the problem is situated. The uniqueness of every given real-life context imposes different constraints and ways of thinking, and sometimes different cultural practices, which a problem solver will naturally take into account. For example, a civil engineer will automatically take much more extreme measures in considering the effect of possible earthquakes when designing a building structure in California than when designing a building in Kansas. The ability to detect and consider explicit as well as implicit information is one of the keys to effective and successful problem solving. In considering the context component of PBL problems, contextual validity, degree of contextualization, and students' motivation are three important design elements.

Contextual validity. According to Hays and Gupta (2003), PBL problems should be evaluated in terms of whether the context in which the problems are situated is valid for its intended instructional goal. For example, a PBL problem within the context of a hospital emergency room would be contextually invalid for training students to be paramedics who generally perform their tasks at an accident site or in an ambulance. Therefore, the contextual validity in PBL problems should be evaluated by examining their clinical/practical relevance to the learners' future professional settings (Dolmans & Snellen-Balendong, 1997; Hays & Gupta, 2003), and this relevance needs to be addressed explicitly in the problem (Yeung, Au-Yeung, Chiu, Mok, & Lai, 2003).

Degree of contextualization. Over-contextualized PBL problems may overwhelm the learners with unnecessary information or considerations, while under-contextualized problems may cause the students to fail to consider issues that are implicit but critical in that particular setting. Thus, the appropriate degree of contextualization in designing PBL problems will depend upon the learners' projected future settings. For instance, medical school students studying about cells have a very specific and certain projected future context in which they will apply their knowledge, while the range of projected future contexts for high school students learning the same topic is broad and general.

Motivation issues. Biggs (1989) argued that students would attempt to maximize their understanding of a topic when they were motivated intrinsically, such as when satisfying a curiosity or interest about a topic, or when an immediate threat was posed. Barrows (1994) also maintained the importance of the authentic context of PBL problems in motivating students to learn. Thus, the relevance and proximity of the context influences the degree to which the learners take ownership of the problems, which determines how actively the learners engage in the problem-solving process. For example, problems involving illegal immigrants in Farmingville, New York, will be less intrinsically motivational for students in Tucson, Arizona, even though Tucson residents face similar problems. In short, proximity to the learners' needs for future professional development or immediate everyday life is a strategic design issue for the context component in the 3C3R model.

Connection

The third core component of the 3C3R model is connection. Gallagher (1997) suggested that PBL students are expected to organize their knowledge base around problems. If students possess knowledge that is "packaged" as a collection of cases or problems, they can effectively retrieve relevant knowledge when they are solving the same or similar problems in real-life settings (Gentner, Loewenstein, & Thompson, 2003). However, there is a pitfall if the problem cases are all independent of each other in the students' knowledge bases.

Hung (2003) and Lieux (2001) both described how very few college students actively and willingly integrate the knowledge learned. Given that students are not intrinsically apt to integrate what they have learned, if the concepts and information within the domain are not explicitly interconnected, students' "packaged" knowledge could become "compartmental" knowledge according to the cognitive flexibility theory (see Spiro, Coulson, Feltovich, & Anderson, 1988). To solve ill-structured problems effectively, the problem solvers not only have to possess a rich repertoire of necessary knowledge (Battig, 1979), they also must interlink these diverse sources and knowledge into an effective knowledge base network and be able to cross-reference related concepts (Jacobson & Spiro, 1994; Spiro et al., 1988). Kitchner (1983) deemed this cross-referencing ability as a critical element for devising viable solutions to ill-structured problems.

The connection component functions to interweave (1) the concepts and information within the conceptual framework, and (2) content into contexts. PBL curricula typically consist of a series of problems that encompass different portions of the curricula, instead of one extremely complex problem covering the entire curriculum. Thus, the design of the connections among the PBL problems is crucial to guide students to integrate what they have learned into a cognitively flexible and conceptually sound knowledge base. The connection component can also help learners understand how the concepts or variables may manifest themselves differently in different contexts. Several approaches can be used to incorporate a connection component in PBL problem design.

Prerequisite approach. Based on the interviews of the teachers who implemented PBL, Angeli (2002) concluded that PBL problems should be sequenced from simple to complex. Thus, the prerequisite approach can establish the PBL problem's connection component in a conceptually logical order from simple/basic to complex/advanced. The problems at the more complex level should build upon the prerequisite concepts and information that appear in the preceding problems. This approach helps students see the interconnected relationships among different levels of concepts by engaging them in problem-solving activities in a sequential manner. When the structural relationships among the concepts to be learned are sequential or hierarchical, this approach is an appropriate instructional design choice to help students logically connect the related concepts and information and structure their knowledge base.

Overlapping approach. Another approach is overlapping concepts among problems. Hierarchical relationships do not always exist among the concepts in a domain, such as subjects in humanities. To help students establish an integrated conceptual framework, the concepts should be grouped into a set of problems. Yet, each concept should not appear exclusively in one problem. Rather, the concepts should appear in several problems so that the learners can study each concept in relation to other concepts. By understanding multiple sets of concepts involved in multiple problems, the learners link these sub-networks into a larger and more complete network.

Multi-facets approach. Savery and Duffy (1996) suggested that guiding learners to test ideas in different contexts would broaden their conceptions about a topic. The multi-facets approach helps students enrich their conceptual understanding and repertoire for solving problems in their professional domain by helping them realize the dynamic nature of concepts. The characteristics or nature of the variables or concepts could change from one context to another or over time. Incorporating the same concept in multiple problems with different contexts helps learners understand the multi-faceted effect of variables. As Hoffman and Ritchie (1997) suggested, learning concepts in only one type of problem may hinder the students' ability to transfer and deal with complex, real-world problems. The overlapping approach helps students link related concepts within a particular domain or context, while the multi-facets approach takes it to the next level and enables students to integrate their conceptual networks more fully by interlinking concepts among different domains and contexts. In sum, the function of the three core components of the 3C3R model—content, context, and connection—is to establish the foundation of a PBL problem that will sufficiently and precisely afford intended learning goals and objectives, contextualize domain knowledge, and guide students to form integrated conceptual frameworks.

Processing Components of the 3C3R Model

PBL is considered an instructional approach that engages students in problem-solving activities (Knowlton, 2003). However, Schwartz, Brophy, Lin, and Bransford (1999) warned that engagement does not guarantee desired learning outcomes. In studying sixth-grade students who participated in a rocket project, Petrosino (1998) found that simply engaging in hands-on activities did not yield satisfactory learning outcomes. Barron et al. (1998) speculated that these inadequate learning outcomes might be due to a lack of facilitation in directing the learning process, such as providing a driving question.

To ensure that the desired learning outcomes do occur in the course of PBL processes, another class of components in the 3C3R model—processing components—is designed to facilitate mindful and meaningful engagement in PBL. The processing components, which include researching, reasoning, and reflecting, are the dynamic elements, in relation to the static core components in the 3C3R model. The functions of these dynamic components are twofold. First, the main function of the processing components is to serve as an activator, that is, to guide the learners to take advantage of the design of the core components. Second, processing components function as a calibration system to (1) guide students' learning toward the intended learning goal(s), (2) adjust the level of cognitive processing required during the course of PBL in accordance with the cognitive readiness of the learners, and (3) alleviate the issue of students' initial unfamiliarity and/or discomfort with PBL (Dabbagh, Jonassen, Yueh, & Samouilova, 2000; Fiddler & Knoll, 1995; Hoffman & Ritchie, 1997; Jost, Harvard, & Smith, 1997; Schultz-Ross & Kline, 1999). Hence, the general purpose of the 3Rs is to facilitate meaningful engagement in scientific inquiry and problem-solving processes and to cultivate effective and efficient learners and problem solvers.

Researching

The first stage of the problem-solving process is understanding the problem (Bransford & Stein, 1984; Polya, 1957), also termed problem space construction (Newell & Simon, 1972). The main task in this stage is researching necessary information within the domain as preparation for the next stage of the problem-solving process. Learners may deviate from the intended content area if they are not directed properly because ill-structured problems are naturally open to interpretation. Therefore, goal specification and context specification are two design issues in crafting an effective researching component of a PBL problem that can direct learners toward intended content and contextual knowledge. Also, the researching component should be supported by the context component and reflected in the contextual information of the problem.

Goal specification. As Barron et al. (1998) pointed out, learners' awareness of the goal state of the problem, that is, the end point of the problem space, significantly directs their learning. The goal state of PBL problems should be explicitly stipulated in order to direct the learners toward the content information specified by the content component. Without a clear, specific goal state for the problem, learners are unlikely to engage in systematic researching processes. In Petrosino's (1998) study mentioned earlier, sixth-grade students worked on the same problem: launching a rocket. Some students received very specific goals in the problem, such as constructing rockets, launching and measuring their rockets (stated in the Request for Design Plans), and reporting their results according to the standards set by a national organization and the teacher. These students showed more systematic research and data collection processes and a better understanding of the topic than other classes of students who were simply asked to build and launch rockets and perform random testing on launching rockets. Thus, defining specific goals in the problems can focus the students' efforts within the domain knowledge, and therefore greatly alleviate the concerns regarding content acquisition in PBL.

Context specification. In most professions, the domain knowledge is highly context-specific. Some concepts or principles may be the common foundation for several fields or professions, yet their applications could be drastically different from one profession to another. For example, Flesher (1993) studied the impact of three different contexts—design, production, and repair—on the performance of electronic troubleshooters. He found that context determined the troubleshooters' initial frame of reference, which in turn influenced their researching and processing of the information related to the problem-solving tasks. Also, the nature of the profession influences the problem solvers' primary concerns, which partially help to shape the unique culture that implicitly dictates the professionals' practices. Martin and Beach (1992) observed this phenomenon when they studied the differences in thinking patterns of technical personnel. They found that engineers' primary concerns were economic issues, as opposed to personnel officers, whose primary concerns were practical matters. Thus, it is important to situate the learning within the conventional researching processes practiced by the professionals in the particular field.

Reasoning

Reasoning is the processing component that promotes application of knowledge acquired from researching related information and the development of the learners' problem-solving skills. By being required to analyze information and generate and test hypotheses and solutions to the problems, the learners put their knowledge into practice instead of only memorizing it. During this process, problem solvers engage in the cognitive activities that enable them to solve the problem. This includes analyzing the nature of all the variables and the interrelationships among them; linking newly acquired knowledge with existing knowledge and restructuring their domain knowledge base; reasoning causally to understand the intercausal relationships among the variables and the underlying mechanisms; and reasoning logically to generate and test hypotheses as well as identify possible solutions and/or eliminate implausible solutions. By engaging in these cognitive activities, the problem solvers process the somewhat raw knowledge into meaningful, applicable, and conceptually integrated knowledge. In essence, the reasoning process enables problem solvers to deepen and expand their conceptual understanding. Researching and reasoning processes occur simultaneously and reiteratively, and they complement each other in enabling an effective and efficient problem-solving process. Thus, these two processing components should be considered simultaneously.

Undoubtedly, the researching and reasoning components are critical to PBL problem design in activating the effects of the core components and directing learners to construct knowledge and develop problem-solving skills. The cognitive activities involved in the researching and reasoning processes are higher-order thinking skills. Most learners do not naturally possess these cognitive capabilities; rather, they develop these cognitive skills with sufficient training over their academic careers. Therefore, it is crucial to calibrate the levels of researching and reasoning processes required for solving the problem with the learners' levels of cognitive readiness as well as their self-directed learning skills (or comfort level with PBL). To determine appropriate levels of researching and reasoning components in the problems, Barrows's (1986) PBL taxonomy provides a useful reference for designing processing components in PBL problems. Barrows (1986) classified PBL into six categories using two variables with three levels each. The two variables include the degrees of self-directedness and problem structuredness. He further defined the three levels of the variable of self-directedness as teacher-directed, student-directed, and partially student- and teacher-directed. The three levels of the variable of problem structuredness were defined as complete case, partial problem simulation, and full problem simulation (free inquiry).

Using Barrows's idea of differentiating various levels of problem structuredness and degrees of self-directedness, the researching and reasoning components in PBL problems can be adjusted to fit the cognitive readiness of the learners. If less information is included in a PBL problem, the learners with higher cognitive capabilities will have to do more research on necessary and critical information (researching component) and make logical connections among this critical information (reasoning component); the learners with lower cognitive capabilities should be given PBL problems with more complete information. For example, in the Appendix, the learners with higher cognitive abilities (example A) have to find (researching) information about the large cone of depression in the water table that occurred in the path of underground water flow. They also have to make a logical link (reasoning) between this critical information (the most viable causes based on the available data to date) and the problem, which is the decrease of the water level in the San Pedro River. For learners with lower cognitive ability (example B), this piece of critical information can be included in the problem to help them reason through the potential cause.

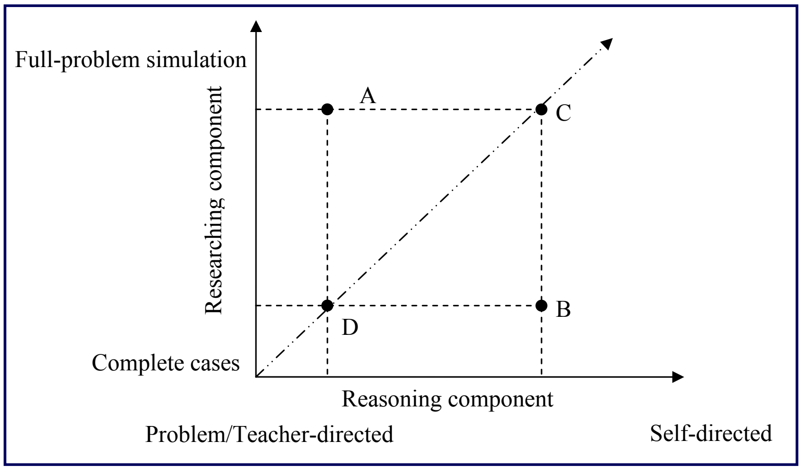
In determining what levels of researching and reasoning components should be included in PBL problems, students' researching and reasoning abilities could be roughly categorized as high, medium, or low. Full-problem simulation—free-inquiry types of problems—should be used only for learners who possess high researching and high reasoning abilities. These types of problems should be highly ill-structured and contain relatively little information about the concepts or knowledge needed for solving the problems. The learners will have to research and integrate the information and reason through the logic of the problem independently. Conversely, PBL problems for learners who have lower levels of researching and reasoning abilities should lean toward more case-based types of problems. That is, more key information should be given in the problem to scaffold the learners' researching and reasoning processes (see Figure 2). The calibration of researching and reasoning components can also be used to adjust the PBL problem to fit the learners' familiarity and comfort level with PBL.

Reflecting

In the model of PBL proposed by Barrows and Myers (as cited in Savery & Duffy, 1996), knowledge abstraction, summary, and self-evaluation are three main metacognitive activities designed to help learners achieve optimal learning outcomes. By reflecting on the knowledge they have constructed throughout the problem-solving process, learners have an opportunity to organize and integrate their knowledge into a more systematic conceptual framework. The cognitive activities of abstracting, summarizing (Jonassen, Hartley, & Trueman, 1986; Rinehart, Stahl, & Erickson, 1986), and organizing knowledge (Kail, 1990)

Figure 2
Interaction of researching and reasoning components in 3C3R model.

- A – high information researching, low reasoning ability students
- B – high reasoning, low information researching ability students
- C – high reasoning, high information researching ability students
- D – low reasoning, low information researching ability students



enhance learners' conceptual integration and retention of the topic under study. Through self-evaluation of their problem-solving strategies and exploring and examining alternative hypotheses and solutions that they might have missed, learners can improve their problem-solving skills and learning in these metacognitive processes (Andre, 1986; Duell, 1986). These reflection activities can extend students' learning by helping them discover information, concepts, and areas that they can explore further, as well as enhance their ability to transfer knowledge to different contexts (Koszalka, Song, & Grabowski, 2001).

The reflecting component acts as a built-in metacognitive guide in PBL problems. This component optimizes the PBL processes by ensuring the maximum effects of other components in the PBL problems. The reflecting component is also the one feature in the 3C3R model that helps the learners not only integrate what they have learned, but go beyond the intended scope of the PBL problem and develop self-directed learning skills. Traditionally, reflection is accomplished with guidance given by tutors (Gallagher, 1997). Incorporating a reflection component into PBL problems can promote learner independence and metacognitive skills and, ideally, cultivate their habits of mind to reflect on their own learning. This way, learners can elevate their learning outcomes and reach the goal of developing self-directed learning skills.

When designing the reflecting component in PBL problems, two types of reflective processes, formative and summative, could be considered. A formative reflective process should occur throughout the PBL course along with the processes of researching and reasoning. The learners should evaluate and reflect on their problem-solving and learning processes and adjust their strategies accordingly during the course of learning. The formative reflective process provides learners with opportunities to assess their own learning during the PBL course in terms of whether (1) they acquire the breadth of knowledge that the PBL problem is designed to cover; (2) the depth of their study on the topic is adequate; (3) their research methods are effective and efficient; (4) their reasoning processes are logical and effective; (5) they integrate their knowledge conceptually; and (6) their problem-solving strategies are effective. In studying the facilitation of students' reflection processes, Andrusyszyn and Davie (1997) found that interactive journal writing was effective in promoting synthesis of processes used during the students' learning. Thus, interactive journal writing can be used to help learners engage in such processes as well as to receive feedback from the instructor to guide self-assessment throughout the course. For example, a statement in a PBL problem, "you need to keep a journal and report to your supervisor on a weekly basis," can convey this formative reflective process.

Another type of reflecting component is a summative reflective process. Very often learners equate the end of learning with the end of the semester or having found a solution to a problem. Thus, the reflecting component should also encourage learners to continue learning about the topic, and cultivate within the learners the habits of experts. For this type of reflective process, the reflecting component in PBL problems could include (1) a reflection element (for example, incorporating a requirement such as "you need to provide a comprehensive final report that includes the process of how you researched the information related to this problem, the logic of how you linked the key points that led to your hypothesis and solutions, any alternative hypotheses and solutions, the reason you selected your solution, and how you would solve this problem differently if given a chance to start over" in the PBL problem), (2) follow-up problems or questions, or (3) a reflection problem (the final problem). The reflecting component in the 3C3R model makes learning a recursive, continuing, deepening, and expanding process that pushes students to go beyond the scope of the learning content and become self-directed learners. Thus, encouraging the learners' curiosity to explore the topic more deeply and elicit an awareness and evaluation of their own learning is the ultimate purpose of the reflecting component.

Conclusion

The 3C3R PBL problem design model aims to enhance problem-based learning by optimizing its key components, the problems. This model considers the issues critical to the effectiveness of problem-based learning. PBL problems that are designed using the 3C3R model may reflect more precisely, and be more in line with, curriculum standards, learning goals, learners' characteristics, and implicit clinical constraints, instead of leaving these aspects entirely to the students' or tutors' interpretations. This precision helps guide the students to achieve learning goals as designed and desired. Therefore, the 3C3R model could enable PBL to be a more reliable form of instruction.

For a PBL problem design team, the 3C3R model serves not only as a conceptual design framework but also as a common frame of reference from which the members can more systematically discuss and communicate important design issues and ideas during the PBL problem and curricular design process. For individual instructional designers and teachers, the 3C3R model provides a conceptual structure upon which they can formulate and design PBL problems more systematically and effectively. Another function of the 3C3R model is that it provides a conceptual framework for evaluating the appropriateness and effectiveness of PBL problems. The 3C3R components can serve as the conceptual dimensions and criteria for evaluating the effectiveness of PBL problems in terms of the PBL problem design issues discussed throughout this paper.

To optimize and maximize the effects of PBL, the quality of the problems is vital. Research is needed to evaluate and validate the 3C3R model in terms of its comprehensiveness and conceptual soundness in guiding instructional designers and educators to design effective PBL problems. Investigation of the impact of the core and processing components of PBL problems on students' knowledge acquisition and construction as well as their reasoning and problem-solving skills is also needed in future studies. According to Jonassen's (2000) typology of problems, the cognitive and affective requirements for solving problems change from one type of problem to another. Further studies are needed to examine whether the 3C3R model can sufficiently address these different requirements for solving different types of problems as well as the interaction between types of problems and the components of the 3C3R model.

The following are some questions to answer: How can we better match the scope of the PBL problems to intended learning goals and coverage of content? How does the degree of contextualization influence learners' researching and reasoning in problem-solving processes? How does the amount of information provided in the PBL problem affect learners' cognitive processes when researching information and reasoning through problems? How do we create a more precise calibration system to adjust the PBL problems to suit learners' learning goals and cognitive readiness? Research on these questions will help to improve the 3C3R PBL problem design model.

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Appendix

PBL Problem Example A—High School Level

The Problem (high school level): The San Pedro River stretches 140 miles from Mexico to northern Arizona and forms a green ribbon in the desert country in southeastern Arizona. The San Pedro River Watershed is the home of more than four hundred bird species (nearly half the U.S. total), which either live in or migrate through the basin, 180 species of butterflies, 87 species of mammals, and 68 species of amphibians and reptiles. The interaction of biogeography, topography, vegetation, and climate in the area makes the San Pedro River Watershed one of the most biologically diverse ecosystems in the world. The San Pedro has the highest diversity of vertebrate species in the inland U.S. and the second-highest diversity of land mammals in the world. In 1988, a 45-mile stretch of the upper river was designated by Congress as the first national Riparian National Conservation Area in recognition of its biodiversity value and to protect the health of the ecosystem.

However, the Commission for Environmental Cooperation (CEC) reported that the river's flow has steadily decreased since 1935. The hydrologists estimated that the base-flows have decreased 75% in the last 50 years. The bird watchers have reported more and more dry sections in the river during the normal season. The health of the San Pedro River is essential to the local ecosystem, which directly affects the wildlife's survival in the area.

You're a member of the investigation team for studying the cause of the San Pedro River's drying up. You will need to work closely with your team members to investigate and report what the possible causes are for the San Pedro River's drying up, and what the impacts to the area are if the San Pedro River dries up, and what needs to be done to save the San Pedro River.

PBL Problem Example B—Elementary School Level

The Problem (for fourth grade): The San Pedro River stretches 140 miles from Mexico to northern Arizona and forms a green ribbon in the desert country in southeastern Arizona. The San Pedro River Watershed is the home of more than four hundred bird species (nearly half the U.S. total), which either live in or migrate through the basin, 180 species of butterflies, 87 species of mammals, and 68 species of amphibians and reptiles. The interaction of biogeography, topography, vegetation, and climate in the area makes the San Pedro River Watershed one of the most biologically diverse ecosystems in the world. The San Pedro has the highest diversity of vertebrate species in the inland U.S. and the second-highest diversity of land mammals in the world. In 1988, a 45-mile stretch of the upper river was designated by Congress as the first national Riparian National Conservation Area in recognition of its biodiversity value and to protect the health of the ecosystem.

However, the Commission for Environmental Cooperation (CEC) reported that the river's low flow has steadily decreased since 1935. The hydrologists estimated that the base-flows have decreased 75% in the last 50 years. The bird watchers have reported more and more dry sections in the river during the normal season. The hydrologist also found that the water levels were in general stable in the basin, except in the Fort Huachuca and Sierra Vista area. Over last 10 years, the Sierra Vista population increased 14.5 percent. During the 1990s, Sierra Vista was the 57th fastest-growing city out of 87 cities in Arizona. A large cone of depression in the water table was first found under the Fort Huachuca-Sierra Vista area in 1973. The researchers reported that the water-level declines within the cone averaged 1.4 feet per year from 1968 to 1986. The health of the San Pedro River is essential to the local ecosystem, which directly affects the wildlife's survival in the area.

You're a member of the investigation team for studying the cause of the San Pedro River's drying up. You will need to work closely with your team members to investigate and report what the possible causes are for the San Pedro River's drying up, and what the impacts to the area are if San Pedro River dries up, how and why the cone of depression in water table under the area of Fort Huachuca and Sierra Vista was formed, and what needs to be done to save the San Pedro River.

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Table 1
Summary of Components in 3C3R PBL Problem Design Model

	Components	Functions	Inter-component relationships	Issues to be considered
Core	Content	• Meeting curriculum standards • Validating appropriate alignment between the scope of the problem and intended content area in breadth and depth	• Providing knowledge base for Researching, Reasoning, and Reflecting	1. Does the scope of the problem sufficiently support the curriculum standards (or learning goal and objectives)? 2. Does the knowledge involved in solving the problem correspond to intended content? 3. Is an excessive amount of knowledge that is not within the intended content area needed for solving the problem (is the scope of the problem too large)?
	Context	• Validating appropriateness of problem context • Determining degree of contextualization • Contextualizing domain knowledge • Indexing domain knowledge to situational knowledge	• Contextualizing Content • Supporting Connection • Directing Researching, Reasoning, and Reflecting	1. Is the problem's contextual information correct and sufficient to make the problem authentic? 2. How relevant is the problem context to learners' future professional setting? 3. How relevant is the problem context to learners' personal needs or lives (motivation issue)?
	Connection	• Faciliatating domain knowledge and related knowledge integration • Forming a conceptual framework about the topic	• Integrating Content • Interweaving Content and Context • Supporting Researching, Reasoning, and Reflecting processes	1. Which approach is the most appropriate for inter-connecting PBL problem to help learners integrate the domain knowledge (prerequisite, overlapping, or multi-faceted)? 2. Are the PBL problems in the curriculum logically and conceptually interconnected? 3. Are all the concepts and basic knowledge involved in the PBL problem in a curriculum sufficient to form a sound conceptual framework of the subject?

Core	Researching	• Calibrating problem-solving researching process to learner-appropriate level by adjusting appropriate amount of information provided in the problem • Guiding researching process to acquire intended content	• Activating Core components • Acquiring Content • Considering Context specification • Making Connection to prior knowledge • Supporting Reasoning and Reflecting processes	1. How proficient is the learners' information researching ability? 2. How is the learners' familiarity/comfort level with PBL? 3. Is the amount of information provided in the PBL problem suitable for the learners' levels of researching and familiarity with PBL? 4. Are there unique concerns in the learners' future professional setting? 5. Is the contextual information adequately specific and explicit to direct the learners to research information for the primary concerns in the field?
	Reasoning	• Calibrating reasoning process to learner-appropriate level by adjusting appropriate amount of information provided in the problem • Guiding reasoning process to comprehend, analyze, and apply the intended content into practice	• Activating Core components • Processing Content • Considering Context specification • Making Connection to prior knowledge • Supporting Researching and Reflecting processes	1. How proficient is the learners' information interpretation and reasoning ability? 2. How is the learners' familiarity/comfort level with PBL? 3. Is the amount of information provided in the PBL problem suitable for the learners' levels of reasoning ability and familiarity with PBL? 4. Are there unique primary concerns in the learners' future professional setting? 5. Is the contextual information specific enough to cultivate the learners to reason as the professionals do in the field?
	Reflecting	• Act as a built-in meta-cognitive constituent/guide • Guiding reflecting process to synthesize and integrate knowledge learned • Cultivating the learners' habits of mind of self-directed and life-long learning	• Integrating Content, Context, Connection, Researching, and Reasoning components	1. What type of reflective process is more suitable for the targeted learners (formative, summative, or both)? 2. Is the requirement (statement in the problem) for the reflection component in the PBL problem looked at as part of the problem, project, or task? (Is it a natural part of the problem?)