Designing Online Learning Environments to Support Problem-Based Learning

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Abstract

Problem-based learning (PBL) represents an instructional approach through which learning is gained by investigating, negotiating, and resolving meaningful problems. PBL can be challenging to implement, and the online learning ecology adds another layer of challenges as it demands effective interactions between pedagogy and technology. To inform the design of online learning environments to support PBL, this chapter presents a practical pedagogical framework to support four key aspects of PBL implementation: (1) preparation and planning, (2) design and development, (3) implementation and facilitation, and (4) assessment. Strategies, tools, and examples were drawn from the literature to address each aspect.

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Introduction

Problem-based learning (PBL) has been widely acclaimed as a powerful pedagogical approach to develop learners' twenty-first century skills such as real-world problem-solving, reflective thinking, and self-directed learning (Kek & Huijser, 2017). Research over the past two decades has documented effective strategies, tools, and resources to support PBL. However, most research on PBL has focused on the in-person context, and there has been scant research about designing and facilitating PBL in the online learning environment. With a global trend of moving learning and instruction online, particularly after the COVID-19 pandemic, there has been an increasing demand for a pedagogical framework to guide the design and facilitation of online PBL, which can take an asynchronous, synchronous, or blended format.

PBL educators often encounter challenges in various aspects of PBL in the classroom context, and adapting PBL to an online learning environment presents further challenges to educators. On the other hand, online or hybrid learning environments have the advantage of integrating emerging technologies as cognitive tools (Lajoie, 2000) to scaffold learners' PBL experiences. While pedagogical principles should remain the focus in designing online PBL (Brush & Saye, 2017), Uden and Beaumont (2006) argued that the characteristics of PBL make it a particularly suitable environment in which to blend technology, thus affording the possibility to integrate pedagogy and technology seamlessly to the best effect (Savin-Baden, 2006).

The purpose of this chapter is to present a pedagogical framework based on a synthesis of the literature to help online PBL designers and educators in their practice. We start by introducing the essentials that characterize PBL, followed by a discussion of four key aspects in conducting online PBL: preparation and planning, design and development, implementation and facilitation, and assessments.

The PBL Essentials

PBL was first created as a pedagogical approach in the 1960s to address the disconnection between theories and clinical applications in the medical education curriculum. From the perspective of cognitive psychology, PBL creates conditions to facilitate the processing of new information and retrieval of information from long-term memory (Schmidt, 1983). While working in small groups on a problem, students need to analyze the situation and provide an explanation to the symptoms or phenomena that underlie the causes of the problem. They collect additional information and formulate learning objectives in order to define the problem. The

analysis of the problem calls for a careful examination of the known information, activation of prior knowledge, and development of initial hypotheses. The groups of students will then come up with learning objectives, prioritize tasks, identify relevant resources, and collect information that will help them achieve the learning objectives. As a result, the PBL activities and processes help learners to analyze clinical cases, synthesizing and testing the newly acquired information.

From a sociocultural perspective, PBL is highly contextualized and situated problem-solving. Learners are engaged in the professional activities that enable students to identify with the professionals (Lave & Wenger, 1991). Through community-based learning, students learn not only from peers but also from experts who model their thinking that is made visible to the students and scaffold student learning. The students' learning activities are enculturated in the professional activities, which motivates their learning and makes learning more meaningful to them. In the process of developing their knowledge and identity, students develop self-directed learning skills, communication, and collaboration competence while the instructors serve as tutors or experts to provide facilitation as learners work independently and collaborate with other group members.

A wealth of literature (e.g., Barrows, 1994; Hmelo-Silver, 2004; Norman & Schmidt, 1992) suggests five essentials that characterize PBL: (1) *authentic and complex problems* allow students to simulate real-world reasoning and problem-solving experiences, which affords a learning context that activates students' prior knowledge; (2) learners engage in *information seeking and inquiry* to analyze problems, acquire new information, generate solutions, and develop new understandings; (3) through *communication and collaboration,* learners work together to brainstorm causes of problems, share new information, present multiple perspectives, and negotiate solutions; (4) learners apply and further develop *self-directed learning (SDL)* to identity and bridge their knowledge gaps both within the PBL context and beyond in lifelong learning; and (5) learners take advantage of the skillful *tutoring and facilitation* provided by PBL tutors or computer systems to guide their problem-solving process through modeling, scaffolding, feedback, and gradual withdrawal of support as their competence grows.

A Pedagogical Framework for Online PBL Design

Guided by the PBL essentials, we present a pedagogical framework in this section to support online PBL focusing on four key aspects: (1) preparation and planning, (2) design and development, (3) implementation and facilitation, and (4) assessment. For each aspect, we draw from the literature specific strategies, learning activities, digital tools, and online resources for optimizing the learning experience.

Preparation and Planning

Planning is particularly important for online PBL that integrates PBL and online instruction in one learning experience (Savin-Baden, 2007). The literature suggests four planning considerations. The first consideration is the *scope*: Is the online PBL intended for part of a course, an entire course, or a program? Does it involve a single or multiple instructors (Grant & Glazewski, 2017)? A one-time implementation within a course may require less time and effort, but as the scope increases, more time and efforts are necessary for planning. Since program-level PBL involves comprehensive curriculum planning, we choose not to focus on it in this chapter. On the other hand, we suggest that online PBL should build on the experience gained from previous in-person PBL implementations.

With a determined scope, an important next consideration is the *learning goals* – that is, what learners are expected to achieve from the online PBL. The formulation of learning goals is no different between online and in-person PBL. As such, readers are referred to Savin-Baden (2007) for a discussion of PBL learning goals. Of particular note is that learning goals should take into account the context where learners will act as members of a community of practice (Lave & Wenger, 1991) and aim for developing learners' strategic and metacognitive knowledge, which would contribute to SDL and lifelong learning (Brush & Saye, 2017).

Another important consideration is the *delivery format* of the online PBL. Will it be completely online or blending some in-person components, and will it be mostly synchronous, asynchronous, or blended? Blended can be blending of online and in-person learning, or blending of synchronous and asynchronous online learning, namely, bichronous online learning according Martin (2021). Some PBL programs are carried out completely online in a synchronous format. For example, an international online PBL enabled medical students from Canada and Hong Kong to work together synchronously (Lajoie et al., 2014). The COVID-19 pandemic also forced many in-person PBL into online synchronous sessions (Coiado, Yodh, Galvez, & Ahmad, 2020; Murata, Moss, Wright, & Pardi, 2021).

Other PBL programs are asynchronous, where the instructor and students do not participate concurrently. For example, the aforementioned international online PBL was later changed to the asynchronous format to address the challenge of meeting synchronously from different time zones (Lajoie et al., 2020). In many asynchronous online courses, PBL is often conducted asynchronously as part of a course (e.g., Huang, Ge, & Law, 2017).

Still, other PBL programs blend online sessions with in-person meetings. For example, in a dental education online PBL program in Saudi Arabia, students met on the first day to clarify terms, identify the problems to work on, and formulate learning objectives, followed by online asynchronous discussions to share, debate, refine, and reach common understandings. After the asynchronous online phase, students had another in-person meeting to synthesize and wrap up their learning (Saqr, Nouri, Vartiainen, & Malmberg, 2020).

While different programs choose different delivery formats out of their needs, contexts, and constraints, it appears that a blended approach has the potential to

harness the benefits of different formats: in-person or synchronous meetings can help students and the facilitator to know each other, promoting a sense of social presence (Garrison, 2007; Lajoie et al., 2020), while the asynchronous modality affords in-depth and thoughtful interactions, permanently accessible discussion records, and the possibility to ensure that all students respond to a given topic (Lajoie et al., 2020).

Lastly, another important planning consideration is *technology readiness*. When it comes to the adoption of technology for online PBL, it is critical that technology should serve pedagogical purposes (Uden & Beaumont, 2006). Many educational institutions now use a learning management system (LMS) for online education, and online PBL often makes use of the same platform with its suite of tools. In other cases, some PBL programs adopt technology to support specific learning activities. For example, online conferencing tools such as *Zoom* and *Skype* are particularly helpful for synchronous online PBL (Savin-Baden & Bhakta, 2019). Some programs conduct online PBL in immersive virtual worlds such as *Second Life* or *Terf* (Araújo, 2019). Of particular note is Maastricht University's experiment with a MOOC PBL (Verstegen et al., 2019). There are also tools developed specifically for PBL such as *STEP* for case-based teacher education (Derry, Siegel, Stampen,, & the STEP team., 2002) and *Compsoft* for PBL in medical education (Kaufman, Ireland, & Sauvé, 2009). Regardless of the tools adopted, the planning should ensure that both instructors and students have adequate access and support for using the tools.

In addition to access to technology, a consistent challenge in online PBL is the instructor's use of technology, especially sophisticated tools such as simulations (Brown, Lawless, & Boyer, 2015). Instructors should be well versed in not only the tools per se but also supporting students' use of the tools in their PBL inquiry. Sufficient time, training, and resources should be allocated to prepare instructors' technology readiness (Savin-Baden & Bhakta, 2019).

Design and Development

Following the preparation and planning, the design and development phase plays a key pedagogical role in online PBL. This phase involves, in a sense, another level of planning, which is the design and development of the problem, learning resources, and inquiry activities *before* the start of online PBL. Throughout this phase, technology continuously plays a critical role in supporting and augmenting pedagogical decisions.

The problem. Online PBL similarly to traditional PBL holds the problem as the linchpin that drives, structures, and inspires learning (Barrows, 1994; Hung, 2019). Guidelines for designing the problem in traditional PBL apply equally to the online counterpart. Readers are referred to the 3C3R framework (Hung, 2019) for designing effective problems that offer sufficient content coverage, support the development of problem-solving skills, and maintain learner motivation. Of particular note is 3C3R's emphasis on affective factors, problem difficulty, and teamwork functions in problem design. For instance, instilling different roles in a problem is likely to promote

teamwork (Hung, 2019). As an example, in Brown et al.'s (2015) web-based PBL, middle-school students acted as science advisors representing different countries to negotiate issues and develop policies related to science-based global concerns.

The online modality of PBL offers unique advantages for the design and presentation of the problem. The availability of different media types can offer rich contexts to enhance the authenticity of a problem. On the "low-tech" end, a slideshow that presents a patient case can incorporate photographs, patient diaries, and journal entries to depict rich narratives about the case (Bizzocchi & Schelle, 2009; Chen, 2016). At a more advanced level, Derry et al. (2002) used classroom video cases to present problems to preservice teachers.

Compared with texts, video problems have a few advantages: they offer nonverbal cues which, in medical education, can help learners develop more personalized perceptions of real patients and their problems (Bizzocchi & Schelle, 2009); video cases also contribute to a higher level of problem exploration activities in situated contexts (Chan, Lu, Ip, & Yip, 2012). At an even more advanced level, problem scenarios in virtual worlds such as *Second Life* offer immersive experiences that allow learners to manipulate and interact (Savin-Baden & Bhakta, 2019).

In designing problems for online PBL, one often does not have to start from scratch. Online databases such as *PBL Clearinghouse* and *National Center for Case Study Teaching in Science* can be good places to start. In developing video problems based on written cases, Bizzocchi and Schelle (2009) suggested the consideration of several narrative components: language, audience, point of view, time frame, crisis point, dialog, and character development. While video problems can be powerful, the quality of a video can affect its effectiveness, and PBL educators are recommended to collaborate with learning technologists to produce videos (Bizzocchi & Schelle, 2009; Savin-Baden & Bhakta, 2019).

Learning resources. Along with the problem, resources are also essential in the design and development phase of online PBL. We refer to resources as any information, data, or tools that learners will use to explore the subject matter of the problem. Online PBL makes it convenient to provide or access online resources. The resources can be adopted, adapted, or created by the instructor, ranging from assigned readings, mini-lectures, websites, databases, simulations, invited speakers, or other tools. For example, Saye and Brush (2017) provided more than 1,000 multimedia artifacts to secondary students' historical inquiry PBL.

In STEM education, computer-based modeling and simulations such as *Excel, NetLogo*, and *Python* serve as unique resources for learners to explore and test their hypotheses (Morge, Narayan, & Tagliarini, 2019). Organization of learning resources is particularly important for online PBL, especially when a large volume of resources is provided. In the case of Saye and Brush (2017), more than 1,000 multimedia resources were organized into a chronological and conceptual architecture to facilitate students' exploration. Appropriate scope is also necessary for resources to avoid being too overwhelming to students (Saye & Brush, 2017). In addition to instructor-provided resources, learners can also make use of the vast resources online to locate information pertaining to the problem.

Inquiry activities. Another important consideration is the design of inquiry activities for online PBL. Saye and Brush (2002) distinguished hard and soft scaffolds to support learning. While soft scaffolds offer dynamic and situation-specific support, hard scaffolds provide static support that can be anticipated and preplanned. In the PBL context, hard scaffolds are preplanned activities and assignments. Savin-Baden (2007) used a table to illustrate the systematic planning of inquiry activities: the rows represented activities at different stages, while the columns specified details of each activity including necessary time, corresponding learning intentions, locations, and available resources. For online PBL, the design of learning activities cannot be separated from consideration of the *location*, or the online space where an activity takes place.

The selection of the location should take into account not only the nature of a PBL activity but also necessary group communication and collaboration in carrying out the activity. Ryberg (2019) classified four types of PBL-related activities: inquiry and exploration, resource management, dialogue and communication, and production. The locations and associated cognitive tools for each type can be planned in advance. *Inquiry and exploration* of the problem space can take place in a database provided by the instructor or in library databases, search engines, or even academic social networking sites, such as *Twitter* or *ResearchGate*. *Resource management* can take place on note-taking platforms, such as *Evernote*, social bookmarking sites such as *Diigo*, bibliographic reference managers such as *Zotero*, file sharing services, such as *Google Drive*. For multimedia resource management in particular, annotation tools and embedded notebooks can be helpful for interpretation and analysis (Lajoie et al., 2020; Saye & Brush, 2017). The third type, *dialogue and communication*, can take place synchronously via audio conferencing, online chat, or interactive whiteboard, or asynchronously on discussion boards, social media channels, or mobile apps, which were found to promote reflective thinking, information sharing, and social knowledge construction (Lan, Tsai, Yang, & Hung, 2012). The last type, *production activities* such as sharing and collaborating, can take place on collaborative writing sites such as *Google Docs* and wikis.

In online PBL, predesigned activities and assignments, which serve as hard scaffolds, often appear to students in the form of guidelines. These guidelines are particularly important for asynchronous online PBL because an "adjust as you go" approach would not work well (Caroni & Nikoulina, 2021). The guidelines organize the complex PBL process into different stages, which become the vehicle leading students to the creation of problem solutions (Childs, van Oostveen, Flynn, & Clarkson, 2015). The stages can be organized by cognitive processes of problem-solving (e.g., problem representation and solution generation, Ge, Law, & Huang, 2016) or activity phases (e.g., research, interaction, and debriefing, Brown et al., 2015).

In designing the guidelines, it is important that directions, deliverables, and expectations are clearly outlined and communicated to students (Caroni & Nikoulina, 2021; Huang, Lee, & Dugan, 2017). The guidelines should offer a tailored yet flexible structure (An & Reigeluth, 2008). Further, appropriate scaffolds should be provided to help students produce deliverables, especially targeting

student weaknesses. For example, noticing that students often did not attend to competing narratives in historical inquiries, Saye and Brush (2017) designed an argumentation storyboard to intentionally scaffold students' presentations. Ge and Land (2003) used a template with guiding questions to support students' problem representation and solution formulation.

Implementation and Facilitation

With the completion of planning, design, and development, students are ready to participate in online PBL. Similar to the design phase, the implementation and facilitation phase plays an important pedagogical role. This phase, on the other hand, is challenging due to its fluid and interactive nature. Key aspects in this phase include student readiness and instructor facilitation.

Student readiness. One cannot assume that students are ready to participate in PBL at the beginning. The success of online PBL hinges on students' readiness in at least three areas: the PBL pedagogy, the online platform and tools, and group formation. Online PBL is often implemented in one course or as part of a course while the rest of learning is more lecture-based (Savin-Baden & Bhakta, 2019). To prepare students for PBL, students should be clearly told their roles and expected quantity and quality of contributions (Valaitis, Sword, Jones, & Hodges, 2005). Further, students are often unfamiliar with the online platform and related technologies. They prefer an orientation that introduces only the essentials (Chen, 2016).

Lastly, students need to form small groups. Web-based sticky notes, such as *Linoit*, can facilitate online group formation. Students can share their background and interests on a sticky note and post it near peers' notes similar to theirs. The instructor can then finalize the group formation based on student input (Huang, Lee, & Dugan, 2017). In online PBL, smaller group sizes were found to positively correlate with student performance (Saqr, Fors, & Nouri, 2018). Once groups are formed, an informal in-person meeting or online icebreaker activity can help students to know each other while establishing common understandings of their roles and rules for group communication and collaboration (de Jong, Krumeich, & Verstegen, 2017; Verstegen et al., 2019).

Instructor facilitation. After students have been working on PBL tasks over a period of time, ranging from one to several class sessions or weeks, the predesigned hard scaffolds (guidelines for inquiry activities and assignments) can be offered to guide students through the key problem-solving stages. Meanwhile, the instructor's key role at this stage is to provide soft scaffolds throughout the stages of inquiry, both synchronously and asynchronously. The facilitation focuses on three intertwining aspects: (1) collaboration and communication among students, (2) the problem-solving process, and (3) the social-emotional aspect.

Facilitation of collaboration and communication. The facilitation can be different between synchronous and asynchronous PBL. In synchronous sessions, structure and clarity are important in maximizing efficiency, helping students to focus on PBL tasks, and avoiding unnecessary cognitive demand. Students should be asked to

review the problem before a session begins (Savin-Baden, 2007). During the session, the instructor should manage the time by being explicit about the stages in the session, the current stage, allocated time, and goals for each stage (Chen, 2016). Sufficient time should be allocated to the research stage to allow for adequate information retrieval and critical appraisal of information (Chen, 2016). Ground rules and etiquettes should be clearly established for communication and discussion (e.g., students should take turns to speak to avoid multiple individuals speaking at once, de Jong et al., 2017; Nagge, Killeen, & Jennings, 2018). In communicating directions and expectations to students, the instructor should be clear and specific to overcome any ambiguity or misunderstanding (de Jong et al., 2017).

In addition to structure and clarity, instructors should also be aware of various issues or patterns typically found in synchronous communications: There can be audio delays (Chen, 2016); students are comfortable with longer periods of silence (Nagge et al., 2018); there tends to be fewer side conversations; quieter students may participate more (Chen, 2016); students are less aggressive and show more mutual respect compared with in-face sessions (Lajoie et al., 2014); the pace can be slower to allow people to speak; slow typing may affect synchronous chat (Valaitis et al., 2005); and students tend to be distracted with increased screen time (Coiado et al., 2020).

The instructor should also model and encourage students to take advantage of different synchronous communication and collaboration tools. In addition to audio conversations, text chat affords thoughtful comments or questions, digital whiteboard enables students to visualize and share their thinking (Chen, 2016), file sharing tools allow students to share useful resources, and collaborative writing tools help groups to document progress and record ideas. In fact, tutors found that students' use of online file sharing and collaborative notes contributed to smoother synchronous sessions that required fewer interventions (Ng, Bridges, Law, & Whitehill, 2013).

A variety of strategies and tools can help engage students and facilitate collaboration in synchronous PBL. Students can be assigned to breakout rooms to meet in small groups and engage in critical thoughts around class topics (Chen, 2016). Online polling keeps students actively engaged while seeing how others approach the same questions. Private chat allows the instructor to provide immediate feedback regarding participation, roles, performance, and behaviors (Coiado et al., 2020).

To improve collaboration, An and Reigeluth (2008) suggested that the instructor should help groups divide tasks properly for members to collaborate rather than mostly working on their own parts. *Google Docs* or other collaborative task management tools can document each member's charges and timeline for completion. Role assignment is another strategy to engage students in synchronous sessions. For example, Coiado et al. (2020) required students to rotate eight different roles: leader, innovator, searcher, scribe, reader, synthesizer, inquisitor, and AV-tech. A unique challenge for PBL instructors in synchronous sessions is the additional tasks of offering technology support to students while attending to multiple communication channels such as text chat or whiteboard (Chen, 2016; Ng et al., 2013). A support person would be very helpful in monitoring communications and pointing the instructor to issues that need attention (Lajoie et al., 2014).

For asynchronous sessions, the facilitation of communication and collaboration shares many similarities to the synchronous format. It is equally important to communicate expectations clearly to students. Take asynchronous online discussions, for example – the instructor should make clear the requirements of the discussion and specify student contributions in terms of quantity, timing, and expectations. On the other hand, asynchronous sessions are more paced, which offers more time and space for instructor's management and intervention. Further, the variety of collaboration tools (e.g., blogs, wikis, chats, group emails, tasks, and discussions) makes students' thinking visible to the instructor (Ertmer & Glazewski, 2019). It should be noted that the instructor does not have to participate in all discussions. Instead, facilitation is achieved through accessing ongoing discussions and intervening as needed (Savin-Baden & Bhakta, 2019).

Facilitation of the problem-solving process. In addition to facilitating communication and collaboration, instructors should focus on facilitating students' problem-solving process to help them engage with the disciplinary knowledge and the self-regulative processes of problem-solving. The preplanned hard scaffolds offer a level of support but are not sufficient. Appropriate soft scaffolds are necessary to offer flexible guidance and support at different PBL stages. Instructors should maintain a balance between being overly silent and overly directive (Savin-Baden, 2006). Three areas of facilitation are necessary: the problem-solving stages, deep learning and engagement, and metacognition and self-directed learning.

Ge et al. (2016) stipulated that problem-solving involves two iterative stages: problem representation and solution generation. Naive problem solvers often spend little time on problem representation or lack necessary iterations between the two stages (Huang, Lee, & Dugan, 2017). To ensure that students develop adequate problem representations, mindmap tools can help students illustrate their understanding of the problem, which can provide the instructor a clear knowledge about students' problem-space coverage (Imafuku, Kataoka, Mayahara, Suzuki, & Saiki, 2014). The instructor can also prepare a set of questions to prompt students to consider what is known and unknown and what information they need to seek further.

To encourage meaningful iterations between the two problem-solving stages, the instructor can prompt students to critically examine their emerging solutions to determine if further revisions or iterations are necessary. Synchronous online sessions can dedicate a time period for students to consider the prompts. In asynchronous PBL, these considerations can be facilitated with an online discussion board. In either case, as students record their ideas and reasoning with digital tools, the instructor is afforded a "window" to observe their problem-solving process and intervene as necessary. Such facilitated discussions could lead to greater and deeper problem space coverage than non-facilitated ones (Ertmer & Koehler, 2015).

In addition to facilitating students through problem-solving stages, the second aspect of facilitating the problem-solving process is to promote students' deep engagement in the process. In both synchronous and asynchronous PBL, students often go through the motions while not developing a deep understanding (Erickson, Neilson, O'Halloran, Bruce, & McLaughlin, 2021; Hmelo-Silver, Bridges, &

McKeown, 2019). Their inquiries often stay at the exploration stage while not reaching the resolution level (Garrison, 2007).

In game- or simulation-based PBL, measures must be taken to prevent PBL from becoming a mere game without any educational dimension (Brown et al., 2015). To promote deep engagement in online discussions, Lan et al. (2012) emphasized justifications in their guidelines for students: "(1) finding learning resources, (2) making logical inferences, (3) offering opinions with reasons, (4) comparing and evaluating evidences, (5) asking relevant questions and seeking answers, (6) making criteria-based judgments, (7) making evidence-based decisions, and (8) reflexivity" (p.1125). Jolly, Brodie, and Jolly's (2011) analysis of tutor interactions in PBL identified desirable tutor patterns that promote deep engagement (pointing out problems, questioning, confirmation, prompting learning behaviors), as well undesirable patterns (prompting students to include certain content in their work, directly giving content to students). Readers are referred to Kanuka, Rourke, and Laflamme (2007) and Gilbert and Dabbagh (2005) for more strategies to promote quality online discussions.

The third and final aspect of facilitating the problem-solving process is the facilitation of students' development of SDL and metacognitive skills. When students feel overwhelmed by a vast amount of online information, it is necessary to support their information seeking. Providing guiding questions and helping to clarify the goal of inquiry can help students focus on their information search, identify relevant information, and evaluate and integrate different sources of information as a group (Jeong & Hmelo-Silver, 2010). Problem-solving requires the self-regulative processes of planning, execution, and reflection, but students often lack skills in planning and reflection (Ge et al., 2016). The instructor should explicitly emphasize planning and reflection through planning worksheets and reflective prompts. Well-guided debriefing activities, such as sharing group solutions online and private reflective writing, can help to promote reflection, metacognition, and transfer after the conclusion of a PBL (An & Reigeluth, 2008; Brown et al., 2015; Lajoie et al., 2020).

Facilitation of social, emotional, and motivational aspects of PBL. While the cognitive and metacognitive aspects of PBL have been extensively studied, the social, emotional, and motivational aspects have received much less attention, especially in online PBL. Students may be disinterested in the PBL topic, perceive little value in the PBL approach, not feel competent in performing PBL tasks, or feel overwhelmed by the uncertainties in PBL inquiries. The online setting presents additional challenges, such as a lack of peer response (Valaitis et al., 2005) and difficulties in rapport building (Erickson et al., 2021). Instructors also find it hard to establish a social presence in online PBL (Fonteijn, 2015).

While the literature offers few suggestions for online PBL, online networking sessions, weekly hangouts with the instructor, or the use of emoticons can help to build social presence in online PBL (Verstegen et al., 2019). The instructor should maintain a continuous and active presence for both cognitive and emotional benefits of students. While not intended for online PBL, readers are referred to Belland, Kim,

and Hannafin (2013) and Ge and Chua (2019) for strategies such as helping students establish perceived task value and promoting mastery learning goals.

Assessment

Assessments are an integral part of PBL and have been discussed extensively in the research literature. Assessments should align with PBL learning intentions and can be done individually or by groups, based on products, processes, or a combination of multiple artifacts (Grant & Glazewski, 2017). Assessments for online PBL can take a variety of formats, such as team presentations, essays, portfolios, or peer assessment (Savin-Baden, 2007). This chapter does not intend to give an exhaustive account of assessments in online PBL, but instead focuses on two aspects, namely process-oriented assessment and analytics-supported assessment.

Process-oriented assessment. In online PBL, students' problem-solving processes are recorded in different digital media (e.g., synchronous meeting videos, online discussions, group blogs and wikis, whiteboards, chats). Thus, the instructor should take advantage of the rich online records to incorporate the PBL processes in the assessment (Childs et al., 2015). The instructor can "prime" the PBL process by assigning a considerable portion of the grade to the problem-solving and learning process (An & Reigeluth, 2008), and by emphasizing desirable process performance in the assessment criteria. For example, in a rubric assessing case discussions, Murata et al. (2021) emphasized such qualities as evaluating evidence, organizing and prioritizing hypotheses, and making logical inferences.

Analytics-supported assessments. This type of assessment has received much attention in recent years. Through mining and analysis of analytics data generated in PBL, a variety of processes can be formatively assessed to inform instructor facilitation. Lajoie et al. (2020) described an example platform, *HOWARD*, which was intended to scale up costly small-group PBL tutoring to be able to monitor and scaffold multiple PBL groups asynchronously. The system can analyze discussion boards and interactive whiteboards and generate visual indicators of students' participation in group discussions, progress on tasks, group cohesion, and interaction patterns. Based on the visual displays, the instructor can recognize when group interactions go awry and facilitate accordingly. Similarly, Saqr et al. (2020) used social network analysis to examine the relationship between students' interaction variables and PBL performance, which can inform analytics-supported formative assessments and facilitation.

By now we have presented a pedagogical framework focusing on four key areas based on a critical and thorough literature review. The framework has been discussed with specific details focusing on the strategies and rationales for planning, designing, developing, implementing, facilitating, and assessing online PBL. For the convenience of processing and retrieving the information represented by the framework, the pedagogical framework is summarized and displayed in Table 1.

Table 1 A pedagogical framework for online PBL environments

Key aspects	Areas of consideration	Suggestions
Preparation and planning	Scope	Consider the scope (module/course/program; single/multiple instructors)
	Learning goals	Consider professional context Aim for developing SDL
	Delivery format	Adopt in-person and synchronous formats to promote social presence Use asynchronous online format for thoughtful interactions and permanently accessible records Use blended format to harness the benefits of both in-person and asynchronous formats
	Technology readiness	Ensure access to all technology for PBL pedagogy Ensure instructor readiness for pedagogical use of technology
Design and development	The problem	Present with low or advanced technology Use videos to depict nonverbal cues and complexity of situations to promote problem exploration Adapt from existing resources
	Learning resources	Adopt, adapt, created by instructor, or identified by learners Keep resources organized Avoid too big a scope
	Inquiry activities	Delineate stages of inquiry and plan specifics for each stage Select online "locations" for each inquiry stage based on types of inquiry activities Predesigned activity guidelines serve as hard scaffolds Provide clear guidelines c(directions, deliverables, and expectations) and address known student weaknesses
Implementation and facilitation	Student readiness	Communicate student roles and expectations Orient learners to online platform and technology with only the essentials Take advantage of online tools to form and prepare groups
	Instructor facilitation	Facilitate collaboration and communication: Communicate with structure and clarity Model and encourage the use of tools for communication and collaboration Prepare for unique communication patterns and use a support person in synchronous sessions Monitor student interactions in asynchronous PBL; intervene as needed Facilitate problem-solving process: Use dedicated time/location in synchronous/asynchronous PBL to facilitate each problem-solving stage

(continued)

Table 1 (continued)

Key aspects	Areas of consideration	Suggestions
		Emphasize justifications; employ strategies to promote deep learning and engagement Support information seeking; use well-guided debriefing to facilitate SDL Facilitate social, emotional, and motivational aspects Use online networking sessions, weekly hangouts, and emoticons Maintain a continuous and active presence
Assessment	Process-oriented assessment	Take advantage of rich online records to examine PBL processes Assign a considerable portion of grades to problem-solving and learning processes
	Analytics-supported assessment	Use mining and analysis of analytic data to generate visual performance indicators Use formative assessment to inform instructor facilitation

Conclusion

Through this chapter, we have shared examples, strategies, rationales, and considerations for designing online PBL environments. Although online PBL shares many similarities with in-person PBL, it has its unique challenges. The existing literature helps us to put together a pedagogical framework for designing online PBL environments. Despite the limited empirical findings to test this framework, this chapter offers helpful and practical guidelines to design and facilitate various aspects of online PBL.

This chapter is intended to lead to a productive discussion and empirical research to refine the pedagogical framework. There are many research questions to be empirically investigated using various research methods. Priorities should be placed on testing the validity of the framework by using practical research methods, such as design-based research. Research is also needed for examining each of the PBL phases indicated in the framework; for example, comparing different delivery modes for different scope, goals, and PBL activities, examining the effects of students' or instructor's technology readiness on students' online PBL experiences, investigating effects of various facilitation strategies in online PBL. In addition, we can also use social network analysis to examine the relationship between students' interaction variables and PBL performance.

At the conclusion of the chapter, we offer a few suggestions that are not unique to online PBL but general to online learning. Because multimedia is an essential part of online PBL, their successful use for PBL learning purposes depends on the effective management of learners' cognitive load. Multimedia learning principles should be followed in the design, development, and use of multimedia in online PBL (Chen,

2016; Mayer, 2014). Further, best practices for online learning apply equally to online PBL. The navigation, structure, and organization of the PBL resource site should be easy for learners to navigate and locate content and materials. This is especially important when an online PBL adopts an asynchronous format.

Cross-References

- ▶ Artificial Intelligence in Education and Ethics
- ▶ Asynchronous Tools for Interaction and Collaboration
- ▶ Design, Delivery, and Assessment
- ▶ Designing Interaction in Digital Learning
- ▶ Designing Online Learning Communities
- ▶ Designing Online Learning in Higher Education
- ▶ Learning Analytics
- ▶ Motivation of Learners in ODDE
- ▶ Open Educational Resources
- ▶ Student Engagement in ODDE
- ▶ Synchronous Tools for Interaction and Collaboration
- ▶ Technology Applications and LMS
- ▶ The Role of the Online Instructor
- ▶ Theories of Motivation and Empowerment in Open, Distance, and Digital Education
- ▶ Using Social Media in Open, Distance, and Digital Education

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