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Supporting Student Self-Regulated Learning in Problem- and Project-based Learning

Mary C. English and Anastasia Kitsantas

Abstract

In order to be successful in problem- or project-based learning (PBL), students must take responsibility for the learning process by setting goals, monitoring, reflecting, and sustaining their motivation from the beginning of the project until the end. However, for many students, these processes do not occur naturally or easily. Therefore, the learning environment and teaching practices in PBL must be designed with intention to support students' self-regulated learning (SRL). This paper describes specific learning environment features and teaching practices that have been shown to foster student responsibility for learning in each phase of PBL, with the purpose of providing educators with guidance for developing SRL in PBL, and ultimately, student motivation and ability to learn. To accomplish this, a theoretical model of the relationship between PBL and SRL is presented, along with research-driven guidelines on how to promote student responsibility for learning in PBL.

Keywords: project-based learning, problem-based learning, PBL, self-regulated learning, self-directed learning

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Introduction

The student-centered, inquiry-based pedagogical approaches of problem-based learning and project-based learning, which are collectively referred to here as PBL, have been shown to be effective for facilitating knowledge acquisition and retention (Dochy, Mein, Van Den Bossche, & Gijbels, 2003; Mergendoller, Maxwell, & Bellisimo, 2006; Penuel, Means, & Simkins, 2000; Ross, Sanders, Wright, Stringfield, Wong, & Alberg, 2001), supporting the development of important real-world skills such as solving complex problems, thinking critically, analyzing and evaluating information, working cooperatively, and communicating effectively (Duch, Groh, & Allen, 2011), and for developing flexible knowledge (Boaler, 1997). Further, studies have found PBL to engage students and help them learn how to learn (Newmann, 1991; Newman, Wehlage, & Lamborn, 1992). However, to effectively engage in PBL, students must become responsible for their learning and actively participate in the processes of constructing knowledge and making meaning (Mergendoller, Markham, Ravitz, & Larmer, 2006). For many students, this role conflicts with deeply ingrained habits they have developed through more familiar classroom experiences, in which they have been passive recipients of knowledge (Hung, 2011; Ladewski, Krajcik, & Harvey, 1994; Rasku-Puttonen, Eteläpelto, Arvaja, & Päivi Häkkinen, 2003). In order for the potential of student-centered, inquiry-based approaches to be realized, students must make the shift to their new role as active learners and develop self-regulated learning (SRL) skills. SRL refers to the extent to which learners are metacognitively, motivationally, and behaviorally active in their own learning process (Zimmerman, 1989). Self-regulated learners are able to set goals, plan a course of action, select appropriate strategies, self-monitor, and self-evaluate their learning. They are also intrinsically motivated to learn and report high self-efficacy for learning and performance (Zimmerman & Kitsantas, 2005). Numerous research studies provide evidence that self-regulation is highly predictive of student's academic performance (Zimmerman, 2000, 2008, 2013; Zimmerman & Kitsantas, 1999, 2005). In fact, student inability to self-regulate learning behaviors is related to academic learning difficulties and low motivation (Bembenutty, Cleary, & Kitsantas, 2013; Zimmerman & Schunk, 2008). SRL is an essential skill for effective learning in PBL.

Related to SRL is the construct of self-directed learning (SDL). SDL has been defined in PBL literature as a student's preparedness to engage in learning activities defined by the student, rather than by the teacher (Schmidt, 2000). Like SRL, this definition of SDL considers both motivation to learn autonomously, as well as abilities to do so. SDL in some cases has been used synonymously with SRL (Zimmerman, 2000).

Several studies have examined whether SRL and SDL are promoted in PBL environments. Some have generated evidence that SRL and SDL are fostered in PBL environments (Blumberg 2000; Kivela & Kivela, 2005; Sungur & Tekkaya, 2006), while other studies have found that SDL is supported by specific features of PBL (Hmelo & Lin, 2000). In other cases, SDL development has been shown to be dependent on the size of student groups (Lohman & Finkelstein, 2000). In contrast, some have failed to find evidence that PBL fosters student responsibility for learning (Lloyd-Jones & Hak, 2004). These mixed findings suggest that SRL and SDL in PBL are dependent on multiple variables, including various features of the learning environment. Some studies have provided guidance for supporting related processes of agency (Polman, 2004), responsibility for learning (Peters, 2010), ownership of content (Clayton & Ardito, 2009), and self-directedness (Glazewski & Ertmer, 2010) in PBL. These studies show that the development of such processes is complex, and is shaped by multiple variables, including the nature and structure of the project or problem, support for student articulation and reflection, dialogic structures, activity structures, and level of teacher-directedness versus student autonomy. Taken together, the evidence from these studies suggests that the development of SRL processes in PBL cannot be assumed, and that teachers must be intentional in the design of the learning environment and the enactment of support strategies.

Building on this body of literature, we sought to provide educators with guidance for developing SRL in PBL, for the purpose of supporting students' transition to the role of actively engaged learner. To accomplish this, we present a model that illustrates the relationship of PBL and SRL over three coinciding phases, and, based on the literature, we describe specific learning environment features and teaching practices that have been shown to foster SRL processes in each of the phases. We believe that framing the literature from this unique perspective adds to the understanding of the dynamic relationship between the learning environment and the learner's ability to self-regulate in PBL, and may assist educators in more effectively targeting the development of self-regulated learning throughout the PBL process.

PBL Definitions and Features

Project based learning has been defined as "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic (real-life) questions and carefully designed products and tasks" (Buck Institute for Education, 2003, p. 4). Similarly, problem based learning has been defined as an instructional method in which students learn through facilitated problem solving that centers on a complex problem that does not have a single correct answer (Hmelo-Silver, 2004). While there are distinctions that define problem based learning and project based learning, Kolodner et al. (2003) found that these and other inquiry approaches are similar in that they engage students as researchers, prompting students to learn how to ask important questions, design and conduct investigations, collect, analyze, and interpret data, and apply what they have learned to new problems or situations. Savery (2006) provided a list of essential features of problem based learning, including an interdisciplinary approach, activities that are authentic or valued in the real world, and problems that are ill-structured. In addition, Savery (2006) emphasized that students must have responsibility for their own learning, that student collaboration is essential, that information collected by individuals must inform the group's decision-making process about the problem, and that the closing analysis and discussion of principles and concepts learned are essential. Additional features on the list include self- and peer-assessment, as well as regular assessment of student progress on knowledge and process. Finally, according to Savery's list, problem based learning must be the pedagogical base of the curriculum, rather than part of a didactic curriculum (2006). These salient features are closely aligned with key concepts of project based learning, as described by Buck Institute for Education (2003). Given the close resemblance between project based learning and problem based learning, we do not distinguish between the two approaches and refer to these pedagogical approaches collectively as PBL.

Learning Challenges of PBL Environments

In PBL environments, students learn primarily by constructing knowledge and making meaning through iterative processes of questioning, active learning, sharing, and reflection (Blumenfeld et al., 1991). Students work together in groups to conduct research, apply logic and reasoning, and devise solutions to complex problems. The teacher's primary role in PBL is to structure activities to stimulate motivation and encourage reflection, and to facilitate learning through scaffolding, feedback, guidance, and prompts for thinking. The student's role in PBL is to take responsibility for their learning and make meaning of the knowledge and concepts they encounter. To do this effectively, it is clear that students in the PBL environment must be motivated to learn and be able to focus their efforts and attention appropriately, monitor and evaluate their progress, and seek help as needed. However, teachers report that many students do not possess these skills (Brush & Saye, 2001; English, 2013). In a recent study, newly prepared PBL teachers frequently cited student struggles such as lack of motivation, lack of ability to take responsibility for learning, poor behavior, and negative attitudes about PBL as hindering factors in PBL implementation efforts (English, 2013).

While studies have documented challenges that students face as they learn to learn in PBL, Caine, Caine, and McClintic (2002) posit that almost all individuals have an internal drive to understand or construct personal meaning in response to the world around them. Further, Bransford, Brown, and Cocking (2000) claim that humans are goal-directed agents who actively seek information. The disconnect between these statements about the inherent nature of humans as learners and teachers' observations of student struggles to take responsibility for learning is an indicator that students need support in harnessing their internal drive to learn. PBL teachers can provide such support by consciously cultivating behaviors, goals, beliefs, and strategies that lead to SRL.

Gradual Shift to New Teaching and Learning Roles

According to theorists, SRL is a developmental skill that is dependent upon the individual as well as characteristics of the environment (Zimmerman, 2000). This means that students may be at differing levels of ability to self-regulate when they are introduced to PBL, and that they can improve in the proper environment. Multiple studies have documented a gradual shift to increased use of SRL processes that takes place when teachers intentionally support their development. For example, in a five-year program of SRL research that took place in elementary classrooms, researchers found that when teaching practices were more supportive of SRL, students demonstrated higher levels of SRL (Perry, VandeKamp, Mercer, & Nordby, 2002). Specifically, using classroom observations of literacy activities, interviews with teachers and students, and student work, the researchers established that, over time, students in classrooms where SRL-supportive practices were employed were able to generate their own strategies for solving problems, they more frequently viewed mistakes as a means of learning, and they more frequently indicated a preference for more challenging tasks—all of which are indicators of SRL. Similarly, Clayton and Ardito (2009), who studied a middle school science teacher's efforts to "teach ownership," reported that while the teacher challenged—and even insisted—that students take on the higher order tasks and inquiry learning, this did not happen right away. Instead, students initially resisted, and sometimes refused the change in classroom authority structure, suggesting low motivation for learning and lack of know-how. However, the transfer of ownership for learning eventually happened. The authors noted that the transition took place on a continuum, with a gradual release of authority and a central focus on metacognition.

In another middle school example, Peters (2010) conducted a case study of a science classroom to explore an exemplary science teacher's implementation of a student-centered science unit with seventh-grade students who had no experience with student-centered instruction at the middle school level. Through daily observations of a four-week unit, the researcher found that in the beginning of the shift to a student-centered inquiry approach, students perceived the teacher as the only person who had the answers, and that they were dependent on immediate teacher evaluation of their answers. Further, it was observed that the students in this class were used to receiving step-by-step instructions and expressed discomfort with having to engage in thinking. Student responses in this case illustrate a lack of ability to self-regulate their learning. After two weeks of intentional efforts by the teacher to scaffold students' ability to learn, and to gradually fade out the level of structure, students had become more comfortable in the environment. This was demonstrated by students' ability to conduct independent research, to rely more heavily on each other for information, and by their increased comfort with asking the teacher clarifying questions—all of which rely on processes of SRL (Peters, 2010).

Similar research findings have also been reported at the post-secondary level. Following a study of the impact of pedagogy on self-regulated learning, White (2007) reported that during the first term of a PBL-based medical program, 18 students who were accustomed to traditional classrooms, where they learned primarily from reading and memorizing, lacked intrinsic motivation and ability to learn autonomously (White, 2007). Based on semi-structured interviews with the students, the author found that the students were instead motivated primarily by attaining a high grade, and that they relied heavily on faculty to direct and control their learning—behaviors indicative of underdeveloped SRL skills. Based on an analysis of data collected through semi-structured interviews with students, the researcher concluded that with practice and increased clarity of the expectations for their performance, students improved in their ability to identify what they needed to know, set learning goals, and learn according to their own learning style and preference. The findings from this study provide further evidence of the developmental nature of SRL skills.

While these findings provide evidence that students have the potential to gradually develop SRL skills, the research on how specific SRL processes and motivational beliefs (such as self-efficacy and attributions) can be supported in each phase of PBL is limited. In the current manuscript, we propose a model of how the gradual transition to SRL can take place over the course of a project when students who are new to PBL are in an environment that supports SRL. Figure 1, which represents this model, illustrates that as teachers carefully fade the amount of direction they provide to students with appropriate structure, scaffolds, and guidance, students may simultaneously begin to develop SRL skills and construct knowledge during the problem or project. In the section below we describe the three phases of PBL and the SRL processes necessary in each phase.

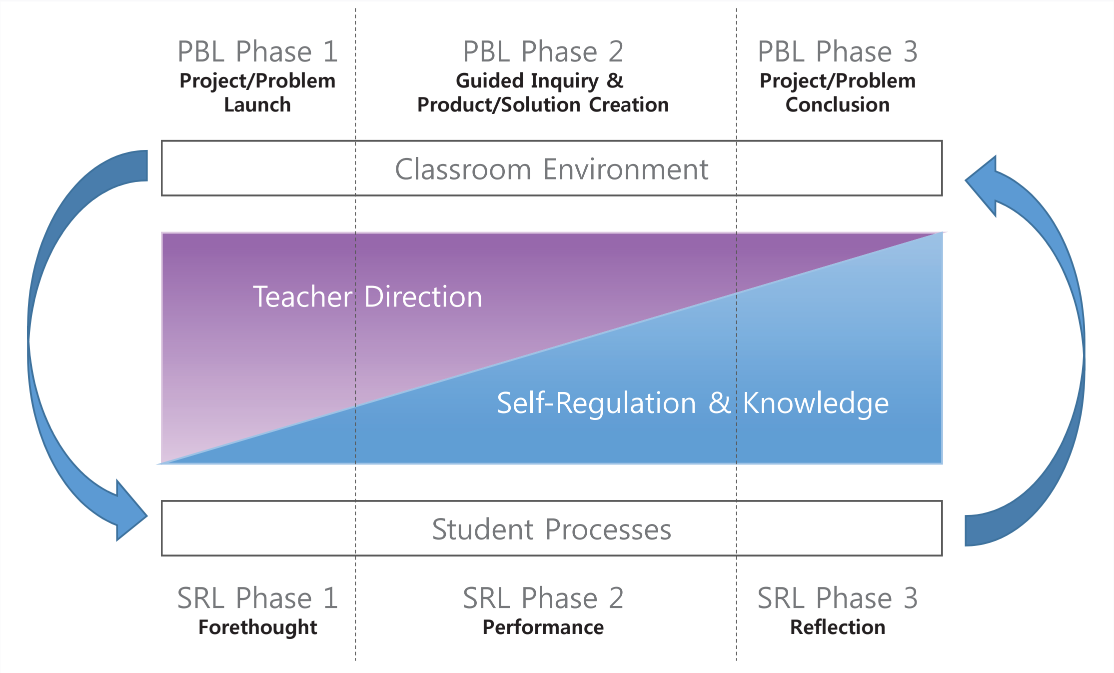

Figure 1. A model depicting the relationships among the phases of PBL and SRL.

A Theoretical Relationship between PBL and SRL Processes

Learning in PBL typically takes place through cycles of questioning, researching, applying logic and reasoning, developing and testing hypotheses, evaluating evidence, synthesizing information, and integrating peer and teacher input that lead to deeper levels of understanding (Mergendoller et al., 2006). These activities occur in three main phases: 1) project/problem launch, 2) guided inquiry and product/solution creation, and 3) project/problem conclusion (Mergendoller et al., 2006). According to the social cognitive perspective, self-regulatory processes fall into three cyclical phases: 1) forethought, 2) performance or volitional control, and 3) self-reflection (Zimmerman, 2000). In this section, we propose that a dynamic, reciprocal relationship exists between PBL activities in the classroom and the SRL processes that are internal to the student. Given the nature of this relationship, each phase of PBL presents opportunities for specific self-regulatory processes to be employed; in turn, effective self-regulated learning can improve performance in all three phases of PBL. Linking the specific activities in each phase of PBL to corresponding SRL processes to be cultivated offers a framework for focusing educators' efforts to foster SRL. The three phases of PBL and the role of SRL processes in each PBL phase are described below.

Phase 1

During Phase 1 of PBL (Project/Problem Launch), students gain an understanding of the driving question (essential question or problem statement), the learning goals, and their "need to know" (Mergendoller et al., 2006). A hypothetical example of a driving question is "what can we do to protect endangered animals?" This is a complex question that does not have one correct answer or one correct path for learning. To answer this question, rather than looking up the answer in a textbook, students would rely on existing knowledge, inquiry, and other learning processes to construct an original response. In this example, the goal of the lesson is to learn more about animal habitats and how ecosystems work, and students are given the choice of what specific animal to study.

This phase of PBL relates to the forethought phase of SRL. There are two separate categories of forethought processes: Task analysis (goal setting, strategic planning, etc.), and motivational beliefs (stemming from sources such as self-efficacy beliefs, task interest, expectations for success, etc.) (Zimmerman, 2000). During this phase, SRL processes that support the PBL activities include activating thoughts and feelings needed for motivation, generating vision, and activating prior knowledge. These processes enable learners to complete necessary PBL Project/Problem Launch tasks, such as developing intermediate goals, identifying the resources they will consult to find the needed information, establishing a timeline of tasks, establishing the roles of team members, and communicating plans.

During Phase 1 of the hypothetical PBL example given here, the teacher would facilitate a process that supports students in identifying what they already know about manatees and what they need to know. For example, students may already know that manatees are on the endangered species list. They may have learned in previous study that the manatee population is declining as a result of boat propeller strikes and construction run-off in the water. Their "need to knows" might include information such as what other environmental factors are negatively impacting manatees, what manatees need in their habitat to thrive, what circumstances led to the changes in the environment, why manatees are important to the ecosystem, and what can be done to make the conditions more favorable for manatees. The gap between what they know and what they need to know drives the plan for inquiry. The teacher's role in setting up the inquiry is to create the environment and allow students voice and choice in planning how to conduct the inquiry strategically and what resources to use.

Practices that have been shown to be effective in this phase of PBL include using a well-crafted driving question (Jonassen, 2000; Barron et al., 1998), conducting "launcher activities," (Kolodner et al., 2003), and providing handouts that outline the project or problem structure and key milestones (Polman, 2004). To further support the SRL processes related to Phase 1, when students are new to PBL, the teacher will need to provide more structure, explicit instruction, and modeling.

Phase 2

Phase 2 of PBL (Guided Inquiry and Product/Solution Creation) activities include iterative cycles of gathering information, making meaning, reflecting and testing findings (through evidence checking, experimentation, application of logic and reason, and input from peers and the teacher), and revising as needed (Mergendoller et al., 2006). Continuing with the hypothetical manatee example described above, students might consult web sites such as those published by National Wildlife Federation, Discovery TV, U.S. Fish and Wildlife Services, *National Geographic*, and the Save the Manatee Club. They might obtain books and videos from the library. They may also have an opportunity to speak with a local biologist about the topic, or visit a local aquarium for additional information. Students would discuss their findings with each other, interpret the findings, develop insights and discoveries, and make decisions about how best to present their conclusions.

This phase of learning corresponds to the performance or volitional control phase of SRL. In this phase, the SRL processes necessary to support knowledge construction include self-control and self-observation processes. Specific examples include managing strategy use, engaging in self-observation, monitoring progress toward the goal, and maintaining attention on important information related to goals. In Phase 2, students engage in complex learning tasks, such as choosing their own path to learning, constructing meaning, reflecting, incorporating feedback, and revising their ideas. SRL is essential and must be supported.

In order to support students through this phase, teachers must focus on making students' thinking visible (Linn, 1995). As the teacher intentionally elicits the student's articulation of thoughts, reasoning, and processes, the student gains practice in self-observation, monitoring, and help-seeking, while the teacher is able to assess the student's level of understanding and progress, and ensure students are linking their activities to the learning goals. Thinking can be made visible through techniques such as whiteboarding (Kolodner et al., 2003), small and large group discussions (Davis, 2000), formative assessments (Barron et al., 1998), journaling (Schunk & Zimmerman, 2008), and prompts for explanation (Peters & Kitsantas, 2010; Davis, 2000).

In the current example, the teacher might ask to see students' draft findings, and then ask probing questions about the draft to examine thinking and understanding. If misunderstandings or misconceptions are identified, the teacher might ask how the conclusion was reached and, without giving them the answer, suggest that the student revisit their thinking, possibly offering prompts or cues. If the teacher sees patterns in misconceptions among multiple students, he or she might decide to provide some direct instruction, or facilitate a group discussion to clarify key points. Eventually, students apply their findings to create a final product or solution that not only answers the driving question, but also demonstrates their level of conceptual understanding and achievement of the learning goal.

Phase 3

During Phase 3 of PBL (Project/Problem Conclusion), students reflect on the overall learning outcomes and process outcomes, as they relate to the project goals and expectations (Mergendoller et al., 2006). This is a formal session that is designed with the intent to further the learning of the content and concepts as well as the learning process. During this phase, students share their project or solution and how they came to their conclusions. Phase 3 of the SRL model includes processes such as self-evaluation and self-reactions (Zimmerman, 2008). Using self-monitored outcomes, learners compare their own performance to standards, learn how others approached the problem, make strategic attributions about why they succeeded or failed at tasks throughout the project, assess whether they are satisfied with their performance, and identify adjustments that need to be made in their efforts to learn, such as seeking help from peers or the teacher.

In the current example, the final product might be a public service announcement (PSA) video designed to bring awareness to the problem of the declining manatee population and to provide information about steps the public can take to help. Students could share their final products with the teacher and their peers, as well as members of the community, who could provide feedback about whether the PSA was informative and whether it might influence their behaviors. As students share their products and processes with an audience, they continue to learn through other students by seeing how others approached the problem and from feedback and questions they receive from the audience.

During this phase, the learner reflects on new knowledge and conceptual understanding and on the learning process itself. The teacher's role in this stage is to encourage peer evaluation and reflection, to facilitate peer-to-peer comparisons, and to continually relate findings back to the learning goal. The teacher should also prompt students to share what worked well during the learning process and what they might do differently next time. This practice elicits the SRL process of self-evaluation. Further, to contribute to student self-efficacy and motivation, the teacher should provide praise focused on student efforts (not just the outcomes), and attribute successes to level of effort and use of effective strategies, rather than abilities (Schunk & Zimmerman, 2008).

Given PBL's emphasis on reflection, this pedagogy naturally provides opportunity for students to engage in self-judgment. However, in order to be more fully developed, teachers should target these processes directly. These SRL processes are not only critical to students' success in their current project, but they play a critical role in shaping students' forethought for future courses of action, such as adjusting goals and strategic planning. It is important to note that while Phase 3 of PBL is focused specifically on reflection, this is not the only time that reflection happens in PBL; in fact, ongoing reflection is critical to learning throughout the project or problem. Depending on the complexity of the task, the students may engage in multiple cyclical feedback loops.

In this section we proposed a relationship between PBL and SRL that take place over three corresponding phases. PBL provides an opportunity for specific SRL processes to be evoked in each of its phases; as SRL processes are evoked, learning in PBL is supported. Using this model as a framework for project design, educators will be enabled to better support the development of SRL in PBL. In the next section we present a review of literature that examines how teachers can provide support for SRL processes in each phase of PBL.

Practical Application of the PBL-SRL Theoretical Relationship

Based on the theoretical relationship between PBL and SRL described above, this section highlights strategies, as reported in research, that teachers have employed to support student responsibility for learning, and how these strategies relate to the theory of SRL. It should be noted that the articles reviewed here do not focus on SRL, specifically. Rather, they use terms such as "agency," "student responsibility for learning," and "student ownership," all of which encapsulate processes of self-regulated learning.

Phase 1: Project Launch

During project launch, students gain an understanding of the driving question, activate their prior knowledge, and identify what they need to know and do to answer the driving question (Mergendoller et al., 2006). Learning is most effective in this phase of the project when students are able to skillfully employ SRL processes related to forethought. With strong skills in forethought, students are able to effectively recall prior learning, set incremental goals, select learning strategies that will help them achieve the learning goals, and generate the necessary motivation to carry out the inquiry. To support these SRL processes in the beginning of the project, when students are new to PBL, the teacher will need to provide more structure, explicit instruction, and modeling. Additional practices that researchers have found to be effective in this phase of PBL include using a well-crafted problem or driving question (Barron et al., 1998; Jonassen, 2000), conducting "launcher activities," (Kolodner et al., 2003), clearly stating the learning goals (Barron et al., 1998), and providing handouts that outline the project or problem structure and key milestones (Polman, 2004).

Well-crafted driving question

While PBL offers potential for deep, meaningful student learning experiences, without a well-crafted driving question (or problem statement) and appropriate support, students may become focused on the activity while losing sight of the learning goals (Barron et al., 1998)—particularly if they are not skilled in self-regulation. Jonassen (2000) created a typology of 11 different types of problems categorized by several characteristics, including structuredness. The degree of structuredness is one important consideration in developing problems, as problems that are too structured may dampen the motivation of high SRL learners, while problems that are too unstructured could lessen the motivation of low SRL learners.

Clearly stating the learning goals

Successful project or problem launch may be largely dependent on student engagement with the problem (Ertmer & Simons, 2006). One important strategy for doing this is making connections between the activities that are to be conducted and the concepts that are to be learned so that the activities are the vehicle for learning, and not the focus (Barron et al., 1998). An example of what happens when these connections are not made for students was reported in a study of sixth grade students who built and launched model rockets (Peterosino, 1998). The activity was designed to help students learn how the design of the rocket affects how high it goes when launched. The findings revealed that while the students who completed this activity were enthusiastic about it, many of them learned very little from it, and in fact, when asked, they were unclear about the purpose of the activity. It was concluded that this happened because clear connections between the activity and the goal were not made. In follow-up research, students were given specific questions to guide their inquiry: 1) Will the rockets go higher if we sand and paint them or leave them unfinished? 2) Will the number of fins have any effect on the height of the rockets? 3) Does the shape of the nose have an effect on the rocket height? Based on exit interviews with students, the researcher concluded that learning outcomes were improved with the revised project (Peterosino, 1998). This illustrates the gains that can be achieved by helping students focus their attention and linking activities to learning. As students are developing their ability to regulate their own learning, they need this type of direct and specific guidance to make connections between the learning activity and the learning goals.

Launcher activities

Launcher activities, or pre-project activities, that provide a model of desired behaviors can be effective in communicating expectations for student performance (Kolodner et al., 2003). In one example launcher activity, students watched the movie *Apollo 13* and then discussed how the scientists in the movie went about their work, and how they interacted with each other (2003). By doing so, students learned that they were expected to behave like the scientists they had observed.

In another example, pre-project activities were utilized as a means of scaffolding the learning process of middle school science students (Peters, 2010). Because the teacher in this case recognized the need to scaffold student responsibility for learning, she gave them an opportunity to practice this in a finite task prior to the project launch. She did this by assigning students to work together on a loosely structured lab activity that required them to figure out the details, work together to develop a response to a question, and then share and reflect on their findings. Launcher activities and pre-project practice activities are two examples of methods for igniting SRL processes before a project begins (Peters, 2010).

Activity Structures

Researchers have also found that students in PBL and other student-centered learning environments need to have freedom to be successful; however, the freedom needs to be balanced with structure (Polman, 2004; Peters, 2010). Research has shown that students in PBL environments that were too prescriptive lost sight of the learning because they were simply following step-by-step procedures. On the other hand, students in PBL environments that were not prescriptive enough either did not learn because they were focused on tinkering with the project (Barron et al., 1998), or because they became frustrated (Peters, 2010; Ertmer & Simons, 2006).

Through a case study, Polman (2004) explored how project unit activity structures were employed to provide some general structure in a PBL unit. The activity structures supported the development of self-regulated learning processes by establishing classroom protocols, patterns, and routines to guide student learning. Polman (2004) used the term project unit activity structures to describe physical arrangements, templates, and other materials that are used to guide and shape student learning. In the high school science classroom under study, the teacher provided two handouts during Project Launch to structure the students' learning. The first handout provided an overview of how to do a science project. The teacher focused attention on certain key points in the document, and emphasized criteria of a good project. From there, students selected a topic to research and attempted to develop research questions. Because the students were not skilled at PBL and SRL, they needed guidance in shaping the scope of the research questions. The teacher provided feedback to help students make their research questions productive. The project structure was balanced by giving students choices in the learning process, such as choice of research topic, and the details of how to complete the project within the overarching framework. The second handout provided a list of project deliverables, including time estimates, serving as milestones. The deliverables and time estimates were: Group and topic (3 days), background information (2 weeks), research proposal (1 week), data collection (2 weeks), data analysis (1 week), complete research paper (1 week), and presentation (1 week). Each deliverable was a component of the final deliverable. The list of milestones, then, provided structure for students to follow to complete their projects in an incremental fashion. As Polman (2004) noted, however, the overall structure was quite different from the more structured, step-by-step labs that students were familiar with. Such labs provide detailed instructions that enable students to get to a desired result, which is counter to learning in PBL. In contrast, the milestones provided by the teacher in this case study provided only a broad framework of the major steps, leaving the decisions about exact steps to student groups, which is consistent with the requirement of PBL learning environments to allow freedom with structure. Supporting the findings of this case study, research on SRL suggests that teachers can help students develop effective time management skills by encouraging goal setting, communicating deadlines and due dates clearly, and providing students with checklists and organizers for checking their progress (Schunk & Zimmerman, 2008).

Phase 2: Guided Inquiry and Product/Solution Creation

Students spend most of their time in PBL in Phase 2, as they conduct inquiry and create products or solutions to problems. During this phase, students actively construct knowledge by iteratively gathering information, making meaning, reflecting on and testing findings, and revising as needed (Mergendoller et al., 2006). In order to learn effectively in this phase of PBL, students need to employ SRL skills in the performance or volitional phase. This phase includes applying learning strategies and monitoring of those strategies.

An important practice during this phase is for the teacher to gradually fade instruction and transition into the role of guide (Glazewski & Ertmer, 2010; Polman, 2004; Barron et al., 1998). As noted by Ertmer and Simons (2006), constraining students may inhibit their independence. Another important practice for teachers in Phase 2 is making students' thinking visible (Linn, 1995). As the teacher intentionally elicits the student's articulation of thoughts, reasoning and processes, the student gains practice in self-observation and monitoring and can identify when they need additional information, while the teacher is able to assess the student's level of understanding and progress and provide appropriate guidance and scaffolding. Thinking can be made visible through techniques such as whiteboarding (Kolodner et al., 2003), reflection prompts (Davis, 2000), and formative assessment (Barron et al., 1998; Polman, 2004; Kolodner et al., 2003).

Becoming a guide

In student-centered environments, learning is dynamic, requiring teachers to observe students' level of understanding and respond accordingly (Saye & Brush, 2002; Ertmer & Simons, 2006). According to Perry et al. (2002), high SRL environments challenge students without threatening their self-efficacy; that is, the level of support given meets the level of support needed.

Also, research has shown that feedback that is non-threatening and mastery-oriented is more highly correlated with SRL than performance orientation (Greene & Azevedo, 2007). In Polman's case study (2004) of a high school science classroom during a PBL unit, the teacher was able to elicit student ownership for learning by gradually offering less direct instruction and unsolicited feedback. The teacher in this case used a small amount of lecture in the beginning of the project to explain how the project would work, but as the project progressed, the teacher intentionally assumed a less directive role, waiting for students to initiate dialogue. Polman noted that the student-initiated dialog enabled the teacher to provide guidance while prompting and enabling students to maintain their sense of agency. Relying heavily on students to raise issues enhanced student ownership for learning.

A similar type of feedback was exemplified in a study featuring a project in which fifth grade students created blueprints for a playground site (Barron et al., 1998). The teacher in this case regularly monitored student progress and provided general feedback and guidance instead of specific direction for correcting errors. Rather than telling students that a particular measurement was wrong, and what the correct answer was, the teacher let the student know that she came up with different measurements for some parts of the blueprint, suggested that the student recheck the measurements, and pointed the student to a specific resource for additional information about the concepts. This feedback led the student to check her own work, work independently to find the information she needed to do the work correctly, and to apply the information to make the correction. The authors noted that this style of feedback is designed to empower students with intellectual responsibility (Barron et al., 1998).

Recognizing small successes during the project is another way that teachers, in the role of guide, can support student responsibility for learning. Employing this type of feedback during the project can help students improve self-efficacy beliefs and decrease performance-related anxiety during the project (Bandura, 1997).

Whiteboarding

Formatted, openly displayed whiteboards can be an effective means of making students' thinking visible (Kolodner et al., 2003). Students may use the whiteboards to document their ideas, solve problems together, and keep track of their progress. This approach allows students to think about their thinking, provides an opportunity to stimulate ideas among students, and allows the teacher to identify and address misconceptions that students may have.

Reflection prompts

Research evidence suggests that continually prompting students to explain their hypotheses, reasoning, and processes helps them makes connections between learning activities, goals, and their processes (Kolodner et al., 2003). Davis (2000) has described two types of reflection prompts (activity prompts and self-monitoring prompts) that may be beneficial in encouraging autonomy and providing an explicit place for reflection at multiple points in a project. Activity prompts are defined as questions designed to encourage students to improve on their work. An example of an activity prompt about a writing product would be, "readers would get more from my article if the article . . ." (p. 821). Self-monitoring prompts are questions that cue students to plan for and reflect on learning activities. An example of a self-monitoring prompt would be, "the part of critiquing that is hardest for me is . . ." (p. 821).

Formative assessment

Effective learning in PBL depends on students testing their ideas, making mistakes, and learning from those mistakes (Barron et al., 1998; Kolodner et al., 2003; Mergendoller et al., 2006). Teachers can facilitate this process in PBL by providing opportunities for formative assessment, as well as iterative cycles of feedback and revision during inquiry and product creation (Barron et al., 1998; Kolodner et al., 2003). In the Polman case study (2004), the project milestones described above served as opportunities to provide scaffolds within the final project deliverable. At each milestone, the teacher had an opportunity to review student progress and provide feedback.

In the study of the fifth grade blueprint project (Barron et al., 1998), students learned concepts such as scale, area, and measurement—all of which were new concepts for them. To scaffold the learning in this project, the teacher conducted iterative cycles of design, feedback, and revision. As students completed specific discrete tasks within the project, the teacher reviewed their work. Based on student understanding of the concepts at each review point, the teacher could identify where students' measurements were incorrect and prompt them to think about how they derived their answers, guide them to additional resources, and to make revisions. With each iteration, students deepened their understanding of the concepts and developed metacognition, or awareness of their learning process (Barron et al., 1998), an important SRL process.

Gradually moving into the role of guide and making thinking visible through tools such as whiteboarding, reflection prompts, and formative assessments are techniques that teachers can apply to cultivate students' SRL skills. By employing these practices, teachers model and provide opportunities for desired processes, and gain access to information about students' learning so that they can provide an appropriate level of support.

Phase 3: Project/Problem Conclusion

During Phase 3 of PBL, students reflect on learning outcomes as well as the learning process (Mergendoller et al., 2006). The learning continues as students share their solution or project, discuss their rationale, receive feedback, and compare their findings and processes to those of other students, as well as to standards. Some researchers have found that when teachers skip or minimize the conclusion process (a frequent tendency), students learn less (Gertzman & Kolodner, 1996; Hmelo, Holton, & Kolodner, 2000).

In order for learning to be effective during this phase of the project, students will need to apply SRL skills of reflection (Zimmerman, 2008). Skilled self-regulated learners in this phase become cognizant of what they learned, the ways in which they did or did not achieve their goals, what questions they still have, and how their processes compared to those of others (Zimmerman, 2008). The teacher should facilitate discussions to prompt students to examine what resources were most useful, what strategies were most effective, where they struggled, and what might have worked better.

Various formats for the project or problem conclusion have been utilized. In addition to having each group stand up and present their solutions and projects to the entire audience, poster sessions, pin-up sessions, gallery walks (Kolodner, 2003), and role plays (Barron et al., 1998; Peters, 2010) are examples of formats that have been employed. Providing an authentic context for the presentation of results can also add value (Barron et al., 1998). The rocket project described above, for example, required students to submit their rocket kit designs to NASA for use by other students. In another example, students were to submit their playhouse designs to an outside organization to be evaluated for accuracy, safety, and consistency (Barron et al., 1998). Knowing that projects will be submitted for formal, outside review, with specified criteria, can facilitate students' self-reflection and motivate students' thoroughness.

Implications for Practice and Future Directions

Implications for Practice

In this paper, we presented a theoretical model that illustrates a dynamic, reciprocal relationship of PBL and SRL over three phases of PBL. In order to be successful in each phase of PBL, students must be skillful self-regulated learners. Because many students' SRL skills are underdeveloped, the PBL learning environment must be designed to foster SRL. We presented research that describes learning environment features and teaching practices that have been shown to promote student self-regulatory processes in PBL. As illustrated in Figure 1, this research indicates that self-regulatory processes develop gradually, within an environment that balances structure with opportunity for autonomy.

During Phase 1 (Project/Problem Launch), a well-crafted driving question or problem that provides an appropriate amount of structure, clearly stated learning goals, launcher activities, and activity structures can support the SRL skills of goal setting, strategic planning, and self-motivation. During Phase 2 (Inquiry and Product/Solution Creation), the teacher can support the SRL skills of self-control and self-observation by employing techniques that make students' thinking visible, such as whiteboarding, formative assessments, journaling, and prompts for explanation. Further, the teacher should interact with students in the role of guide, encouraging help seeking, prompting for reflection and revision, and providing instructional support as needed in response to specific knowledge gaps identified through observations and formative assessments. During Phase 3 (Conclusion), presentations, role plays, poster sessions, pin-up sessions, and gallery walks are examples of PBL conclusion formats that can facilitate reflection. While reflection is a central learning process throughout the three phases of PBL, the formal reflection that takes place during the project/problem conclusion provides an opportunity for students to engage in thinking about their learning outcomes in relation to their goals, to identify the strategies and resources worked well and those that didn't, and to determine what questions they still have. This practice lays the groundwork for students' development of this important intellectual habit, and should not be skipped or minimized.

As discussed here, SRL is a critical skill for student success in PBL. The lack of such skills poses an obstacle to learning. While teachers may agree that they need to support students' development of SRL, research has shown that many do not know how to do so (Perry, Hutchinson, & Thauberger, 2008; English 2013). Therefore, there would be significant benefit from including training and education on SRL development as an integral part of pre-service and professional development activities. With knowledge of the important role of SRL in PBL, and how SRL can be fostered in each phase of PBL, teachers will be better prepared to improve student motivation and ability to learn when encountering this pedagogical approach. Lesson study (Lewis, 2002) and video clubs (Sherin & Han, 2004), along with coaching are examples of professional development models that would be appropriate means of furthering teachers' knowledge and skills of how to develop student SRL skills.

Future Directions

Research has generated ample evidence demonstrating that SRL can contribute to students' learning, motivation, and achievement (Zimmerman, 2013). Further, research has shown that teachers can employ specific classroom structures and teaching methods to develop students' SRL skills (Zimmerman, 2013). However, explicit guidance on how to implement these practices in PBL is limited. This paper described the relationship between the three phases of PBL and the three phases of SRL and provided specific suggestions on how teachers might leverage the understanding of this relationship to foster students' SRL skills in PBL. Empirical research is needed to examine whether the recommended practices in each phase of PBL lead to improvements in the targeted SRL processes. Sample research questions could include examining the relationship between the structuredness of the project or problem and student motivation and engagement in SRL; the role of launcher activities before the project/problem launches on students' goal-goal setting, strategic planning, and self-motivation; and the type of teacher feedback that would enhance students' autonomous thinking and self-directed behaviors while engaged in PBL.

While a number of tools exist for measuring SRL through surveys and observation (Zimmerman, 2000; 2013), newer methods that provide a more fine-grained look at SRL processes within each phase in PBL environments are also needed. The use of the micro-analytic method may be an effective means of capturing SRL process development during PBL. This method is designed to intensively examine an individual's beliefs and reasoning during a specific activity (Bandura, 1997). This is accomplished through context-specific questions that are asked while students are engaging in a task (Kitsantas & Zimmerman, 2002). With this method, data about self-regulation and motivational processes can be collected at key points during the activity to answer the example research questions provided here, and others. This approach to data collection will help researchers understand how students approach, perform, and reflect on their learning in PBL environments. Additionally, the use of video analysis would be advantageous for documenting behaviors and identifying associations between teacher interventions and student responses. Overall, findings from such studies using these more fine-grained methods of data collection could collectively inform the development of professional development programs that can equip teachers with knowledge of SRL theory and skills on how to foster SRL in PBL settings.

In conclusion, in order to be successful in PBL, students must take responsibility for their own learning process. This includes self-regulatory processes of sustaining motivation, setting goals, monitoring progress, and engaging in self-reflection. For many students, the use of these processes does not come naturally or easily; therefore, the learning environment and teaching practices in PBL must be designed with intention to support students' SRL. The model and recommendations for developing SRL that were presented in this paper resulted from a synthesis of previous PBL studies that examined constructs related to SRL and SDL. By framing these findings according to the proposed model, we attempted to clarify the relationship between SRL and PBL, thereby further elucidating how SRL can be fostered in each phase of PBL. This topic deserves substantial attention as the interest in and use of PBL increases in both K-12 and higher education settings. We believe that teachers who are equipped with the knowledge and skills to support SRL in PBL will be better prepared to support student success in such environments.

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