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Targeting Transfer in a STELLAR PBL Course for Preservice Teachers

Cindy E. Hmelo-Silver, Sharon J. Derry, Alan Bitterman, and Natalie Hatrak

Abstract

Helping students in the professions apply conceptual ideas to the problems of practice is a key goal of problem-based learning (PBL). Because PBL is organized around small, collaborative groups, scaling up PBL to large, heterogeneous classes poses significant challenges for implementation. This study presents a hybrid model that mixes online and face-to-face PBL. The STELLAR system was developed to support online and hybrid PBL courses for preservice teachers. It allows PBL to be implemented in larger classes because its scaffolding capabilities allow a small number of facilitators to distribute their attention among multiple small groups. In a quasi-experimental study, we found that students who participated in a hybrid PBL course using STELLAR (n= 33) learned more about targeted course concepts than students in a traditional comparison course (n=37). In addition, we present qualitative data that helps explain these outcomes by demonstrating how students engaged with these concepts during the hybrid PBL course. These results suggest that a hybrid computer-supported collaborative learning approach can be used to scaffold problem-based learning and foster deep understanding.
Keywords: transfer, computer-based learning environments

Targeting Transfer in a STELLAR PBL Course for Preservice Teachers

Helping students in the professions transfer conceptual ideas to the problems of practice is a key goal of problem-based learning (PBL; Barrows, 1996; Savery, 2006). PBL curricula have had positive effects in promoting learning and transfer, particularly in medical education (Dochy, Segers, van den Bossche, & Gijbels, 2003; Hmelo, 1998). PBL is a method of instruction that relies on students working in collaborative groups to learn through solving problems and taking responsibility for their own learning, including setting and researching their learning goals, (i.e., learning issues; Barrows, 1996; Hmelo-Silver, 2004; Savery, 2006). Because PBL is a methodology for student-centered learning that relies

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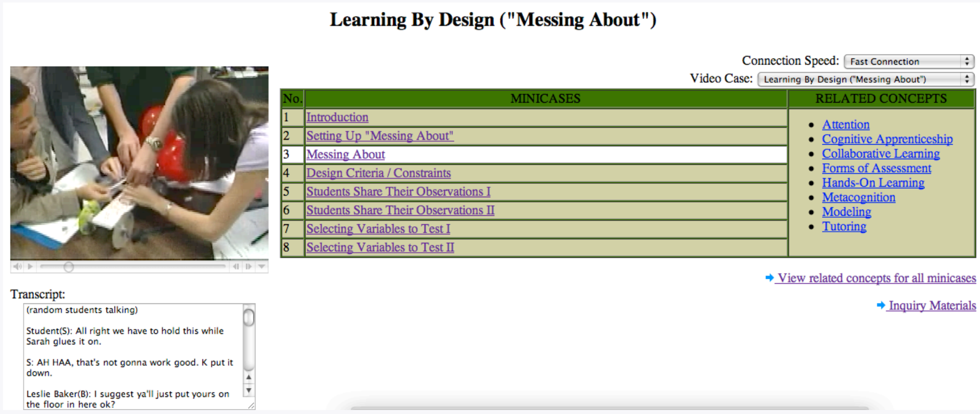
on small, facilitated, collaborative groups (Barrows, 1996), scaling up PBL to large classes poses challenges in terms of providing adequate support for learners (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006; Hmelo-Silver, 2004). In large classes, there is rarely a facilitator for every small group and providing rich problem materials can also be a challenge. Technology can provide affordances to deal with these challenges by offloading some aspects of facilitation on the environment through software-realized scaffolding, extending existing facilitation resources, and providing a database of multimedia problems (Belland, Glazewski, & Richardson, 2008; Hmelo-Silver, 2006; Steinkuehler, Derry, Hmelo-Silver & DelMarcelle, 2002). The goals of this study were to 1) determine whether there were gains in targeted learning outcomes derived from a PBL course in which online technologies were used to scaffold students, supporting and extending the work of two human facilitators working with six groups and 2) understand learning outcomes by examining how students engaged with course concepts as they learned through problem solving.

The course was supported by the STELLAR (Socio-Technical Environment for Learning and Learning-Activity Research) system, an experimental online PBL environment that enabled preservice teachers to engage with educational psychology concepts as they solved collaborative lesson design problems that employed video cases as supporting instructional materials (Derry et al., 2006). The system, which has been described extensively elsewhere (e.g., Derry & Hmelo-Silver, 2005), allowed us to create three course components:

1. A library of video cases containing examples of classroom practice that could be used as materials for instructional problems;
2. An online educational psychology hypertextbook comprising detailed explanations of course concepts linked to examples of those concepts found in video cases (the Knowledge Web);
3. A set of online instructional design problems, linked to selected video cases that followed a PBL format and provided the instructional activities for the course.[1]

The video cases provided rich contexts for discussions that took place as students engaged in the problems of design or redesign based on cases of instruction depicted in videos. Links from problems to the Knowledge Web (figure 1) helped students identify fruitful learning issues during problem solving. The STELLAR system's PBL online module allowed us to design problems that incorporated a general script with steps for students to follow (Dillenbourg, 2002), as well as make available online tools that the students used in implementing the script. These tools included a personal notebook where students recorded initial observations, a threaded discussion where students shared research, and a whiteboard where students posted, discussed and edited "proposals" for lesson redesigns (figure 2). The scripted steps required students to think using a backward design

Figure 1. Videocase linked to knowledge web..



logic (Wiggins & McTighe, 1998), in which they first considered the problem goals, then how they would assess completion of goals, and finally what activities would accomplish those goals.

As described, our course design provided many forms of *scaffolding* to support student learning. The notion of scaffolding is now increasingly used to refer to all human and technological prompts, supports and hints provided to support learning. However, researchers like Pea (2004) and Puntambekar and Hübscher (2005) have discussed how current usage of the concept has deviated from Bruner's (1975) original meaning in which scaffolding referred to interactions between a parent or tutor and a child that provided just enough support based on an ongoing assessment of the child's progress. Pea (2004) discussed the importance and difficulty of distinguishing between tools for supporting performance that are designed to remain in place after learning, versus scaffolding that is gradually faded and removed as learning is achieved. In typical PBL, scaffolding is provided to each small group by a trained tutor who participates in the discourse and is able to gauge what aspects of learning and understanding are problematic for students and need to be supported. The tutor's goal in PBL is to gradually remove supports, encouraging not only unsupported (by the tutor) use of course concepts in problem solving, but also a more student-controlled learning process. In their study of an expert PBL tutor, Hmelo-Silver and Barrows (2008) illustrated how scaffolding was provided and faded by the tutor's use of different types of questions.

However, in large courses, one or two less-experienced tutors (usually TAs) must distribute their attention across multiple groups and cannot participate in real time with each group. An online PBL environment, therefore, provides design features that act as static scaffolding (e.g., problem-solving steps and deadlines, structured discussion boards) to support students when the tutor cannot be immediately present. In addition, the persistence of online discourse collected by the environment as well as the slower pace of the asynchronous interaction required by the tools enables a tutor to examine discourse as it unfolds at a slower pace, to determine which groups require most support. Hence the human presence is strategically altered to support groups and individuals at appropriate levels, providing more assistance for students who struggle. Furthermore, although the system provides static forms of scaffolding that do not change dynamically in accordance with students' needs, the design of an online PBL course can be implemented in accordance with general scaffolding principles. For example, there can be more detailed or explicit requirements for students in early problem statements, which are faded and withdrawn, in later problems. These static and dynamic scaffolds work synergistically to support learning (Tabak, 2004).

In addition, building in redundancy, by designing multiple tools and scaffolding strategies, may help make up for the lack of direct attention and graduated assistance provided by a talented PBL tutor, since multiple ways and multiple levels of scaffolding can accommodate varied levels of ability that are found in any classroom. Rather than looking at a single tool as providing scaffolding, we need to look at how well entire learning environments, employing suites of strategies and tools, provide scaffolding to students. In order to gauge the effectiveness of a complex technology-supported environment in which a human tutor cannot constantly monitor student progress, it is necessary to conduct studies to understand how students are responding to and using scaffolding and whether they are actually able to work independently when the scaffolding is removed (Puntambekar & Hübscher, 2005). We view the current research as such a study.

Figure 2. STELLAR personal notebook and group whiteboard.

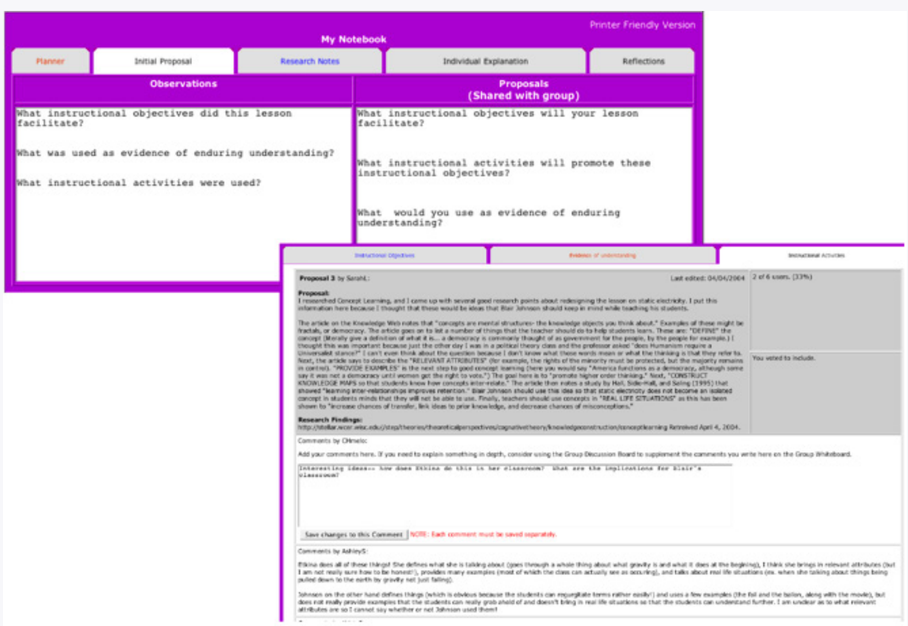
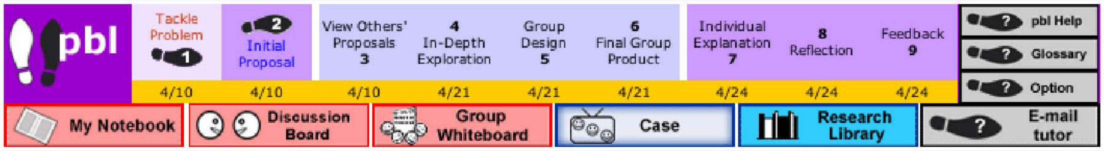


Figure 3. STELLAR sidewalk.



Description of Hybrid PBL Course

The goal of our course design, which employed multiple human and nonhuman tools and strategies to scaffold a PBL approach, was to support preservice teachers in gaining an understanding of concepts from educational psychology that they can transfer to their classroom practice. The course consisted of 4 problems, each lasting 2-3 weeks, using a hybrid online and face-to-face course structure. Each problem required students to view assigned videos as a context and to collaboratively design or redesign some aspect of the instruction illustrated in the videos. Scaffolding of various types encouraged students to understand, discuss, and justify their work based on educational psychology principles as they worked in their small groups.

The STELLAR sidewalk (figure 3), providing steps, instructions, and deadlines for students, supplied scaffolding that helped structure students' problem solving. Students began by individually studying a video case (step 1).

In step 2, they recorded observations and created brief individual redesign proposals in an online personal notebook that contained prompts to focus on features relevant for redesign. This work was shared with members of the students' small group in step 3.[2] The group then collaboratively identified concepts they needed to explore for redesign (step 4), conducted and shared research (step 5), and collaboratively designed lessons (step 6). They used threaded discussions and a structured group whiteboard, which required them to submit design proposals and justifications, as shared workspaces in steps 4-6. The design or redesign was shared at a poster session during class. The students also met face-to-face for step 4 and again as they presented solutions at the completion of step 6. Each student was required to provide an individual explanation of the group proposal in step 7 and reflection on their learning and collaboration in step 8.

As the groups worked on each problem, they had two face-to-face meetings during steps 4 and 6. Each of these meetings was for 80 minutes. In the first meeting, the students worked in small groups to discuss their initial ideas from step 3 and to brainstorm their concepts to explore in step 4. In the last 15 minutes of the class session, a whole class discussion was used to allow students to share and compare the concepts they identified as relevant for learning about the case. In the last session of a problem, the students met in their small groups for the first 20 minutes of the session. They used this time to make any final decisions on their solutions that they had not accomplished online. They completed their posters during this time. The next 40 minutes of the class were used for a poster session, in which students took turns standing by their group posters and exploring the posters that the other groups had completed (see Hmelo-Silver, Katic, Nagarajan, & Chernobilsky, 2007 for further discussion of the poster session). The remaining 20 minutes of the class were used for a whole class discussion of what students had learned from other groups' posters. Between these two class sessions, groups worked online.

In problem one, the students engaged in mathematical problem using manipulatives. Then, they watched a video of a sixth-grade student engaging in sophisticated analogical reasoning and were asked to construct a psychological explanation (Maher, 1998). In problem two, students watched a video of an inquiry-oriented science classroom in which children were engaged in design activities (Kolodner et al., 2003). In this problem, the students were asked to design an approach to assessment. This extended the task from the first problem (i.e., explaining what could be inferred from one child's performance) to considering what might be inferred on a larger scale by designing an assessment strategy. In problem three, students viewed two contrasting video cases. One showed a traditional, lecture-oriented approach to teaching physics and the other showed a more inquiry-oriented constructivist approach. The students were asked to help the first teacher adapt some of the techniques the second teacher used to redesign his lesson. Problem four presented a case in which a foreign language teacher depicted in a teaching video wanted to redesign her lesson to meet new teaching standards for foreign language; students in our course were asked to advise her on this redesign.

Transfer as a Tracer Concept

Because students in a PBL course learn about a range of concepts as they work on ill-structured instructional design problems, we employed the idea of *tracer concepts (*see Newman, Griffin, & Cole, 1989) in evaluating the efficacy of our approach. Tracer concepts are those ideas that are central to course goals that we would expect students to embrace as part of their discourse and use in increasingly sophisticated ways throughout the course if (and only if) the instructional scaffolding successfully supported students' learning about them. In prior research, we demonstrated that students who participated in STELLAR-supported PBL courses improved their understanding of and ability to use the concepts *comprehension* and *understanding* in an authentic instructional design assessment task, to be described in more detail, which required individual students to analyze a classroom video. Students in the PBL environment gained more and performed better on this task compared to a comparison group taught in a traditional course covering the same material (Derry et al., 2006). In the current study we used the same data to determine whether students also learned more about the concept of *transfer*. More specifically, we examined 1) students' acquisition of knowledge about the concept and principles of transfer and 2) their ability to generate ideas about instructional methods that would facilitate transfer and the learning process. The written responses to our assessment task enabled us to assess students' knowledge of the tracer concept transfer. The hypothesis underlying the current research was that students in our PBL sections would outperform students in a traditional class on their application of knowledge of transfer.

Methods

Participants

Seventy preservice teachers taking Educational Psychology classes in a state university in the northeast United States participated in the research. Thirty-three participants were taught Educational Psychology in the PBL class. The remaining thirty-seven participants were drawn from the Educational Psychology subject pool and received course credit for their participation. Most of the participants were planning to be teachers in elementary education or secondary math, science, world language, social studies, or English and were in their second or third year of undergraduate study.[3] In the PBL class, 80% of the students were female, which is consistent with the overall population of the educational psychology classes, which range from 75-85% female.

This study was a quasi-experimental study that used intact course sections and statistical controls rather than random assignment to treatment. Random assignment to treatment was not possible to accomplish. There were five sections of the course offered and students enrolled in a section of their choice based on their time schedules and availability of open spaces. Students were not aware in advance of which section would use a PBL format, so there is no reason to believe there would be any systematic differences between the PBL group and the larger student population that would bias this study. All students were required to participate in research, so there is no reason to believe that students in comparison groups who signed up to participate in this study were unrepresentative of their larger student populations. Based on comparisons of pretest scores, we believe students in the PBL and comparison groups were equivalent on measures relevant to this study. However, we acknowledge that lack of random assignment is a limitation of our study design and our analyses control for this statistically.

Course contexts

Participants in the PBL section had access to the STELLAR environment described above. They were required to work in groups to discuss their understanding of material and construct group learning artifacts. The groups were formed to be heterogeneous with respect to the different planned teaching specialties. The comparison students in the subject pool were drawn from the four other sections of educational psychology. These comparison classes were a treatment-as-usual group that used standard textbooks. Participants in the traditional classes met face-to-face and participated in lectures and other activities that their course instructors deemed appropriate. Although we do not have detailed information about the comparison classrooms, the key difference is that they were organized around a textbook rather than around problems.

Materials and Procedures

Our quantitative analysis focused on the degree to which student participants understood and used the concept of transfer in a video analysis task. All participants viewed a brief video in which high school students learned about electricity, electrical circuits, and how a light bulb works. Before viewing the video, they received a brief written explanation describing how the video clip illustrated a problem the teacher had identified in his teaching: that even top students were maintaining their pre-course misconceptions about electricity after instruction. The video explained how the teacher had spent a month covering advanced topics in electricity and provided hands-on experience designed to reinforce those concepts and illustrate how electricity enabled a light bulb to work. The video also showed an interview with a good student before and after instruction and demonstrated that she maintained the same misconceptions following instruction. After viewing the video, the participants in both the traditional and hybrid PBL classes were given pretest questions. They had thirty minutes to answer the following four questions: 1) How do you know that the student failed to learn? 2) Why did the student fail to learn? 3) What recommendations would you make to the teacher to help him improve his teaching? and 4) What else do you need to know to better understand the teaching-learning situation? What additional questions would you ask? At the end of the semester, the participants in both the traditional and STELLAR classes completed an identical posttest.

Coding and Analysis

A scoring rubric was developed for evaluating participants' understanding and use of the concept of transfer in their written work. The rubric, which was used for both the pre- and posttests, awarded points for students' understanding that transfer: 1) requires understanding, 2) involves activating appropriate prior knowledge and applying something learned in a new situation, 3) involves abstraction and cognitive flexibility, 4) can be near or far transfer, and 5) can be preparation for future learning. The ratings were based on the degree to which the participants included and elaborated upon these features of transfer in their written answers to the four questions noted above. The ratings indicated progressively greater understanding of the concept of transfer and its application. Table 1 presents example responses for each scoring level. Answers that received a level 0 rating indicated that there was no evidence that the target concept was understood. A level 1 rating indicated incomplete understanding and a lack of causal explanation or application of concepts. A level 2 rating showed greater understanding and elaboration. A

Table 1. Examples of Student Reponses and their Ratings.

Rating	Question: How do you know the student failed to learn?
0	Because she made the same mistake (failing to light the single bulb) before the teachers lesson plan, as well as after. A lesson plan should help to improve a student's concept, however, not only did the student fail, so did the lesson plan.
1	She could only do it in the classroom situation…she could not apply it in another slightly different situation.
2	She lacks the ability to transfer the information to a new situation (and demonstrating the ability to transfer is evidence of understanding). She could not reproduce or even begin to describe how to man an electrical circuit work using different tools and artifacts than the ones used in the original lesson.
3	The student was unable to transfer the fundamentals of electricity to provide a systematic and justified explanation. She did not successfully benefit from inventing models to illustrate the process….Her attempt at subsequent elaboration of the problem was overly contextualized because she could not apply to the same process to similar tools/artifacts….She failed to connect "school talk" to "real world"….She seemed to have focused more on memorization of facts as opposed to genuine flexible understanding.
Rating	**Question: Why did the student fail to learn?**
0	She failed to change her existing ideas about electricity. She did not use the information provided by the lesson other than inside the classroom.
1	She appeared to only memorize exactly what she needed to know to pass the lesson that day. She didn't figure out how to apply the lesson when she didn't have exactly what was needed.
2	…the teacher must give the students many examples of the lessons applicability to other situations. He only taught the lesson in one setting. Jennifer was not metacognitive in her thinking and knowledge construction. The teacher failed to demonstrate the experiment in an authentic, real-life situation.
3	…she did not relate learning to her own experience. She did not appear to regulate her understanding throughout the activity (metacognition) nor did she evaluate the process. An initial prediction and self exploration of the process was not clearly visible. She did not…develop adaptive expertise in considering each alternative. There was a lack of modeling of the activity for her to adapt the principles involved….
Rating	**What recommendations would you make to help him improve his teaching?**
0	I would recommend possibly giving quizzes more frequently so to have a more accurate assessment of students' progress.
1	Explain why each item is used and if that item is not available what could be used in place of it and why it would still work.

2	Focus their attention on key concepts....Provide some scaffolding and encourage discourse in the collaborative groups….Question the students as to the how's…Create activities to promote the transfer from short to long-term memory….
3	In addition to providing analogical problems, I would recommend that he gauge students' prior knowledge…This can be done to follow up on authentic instruction of related material to real world contexts to promote transfer…His role is to provide well-defined problems so that students are given a framework for self/social (co)construction of knowledge…He would need to probe students to elaborate and give principled support or dissent for various theories/perspectives…He could also include a journal reflection after each trial for students to predict, reflect, evaluate, elaborate, and record evidence of understanding….
Rating	**What else do you need to know to better understand the teaching-learning situation? What additional questions would you ask?**
0	Did the students have any homework or tests on the topic of electricity? How did the student do when she was evaluated that way?
1	You should try to figure out why she didn't grasp the concept. Did other students misunderstand the same way as well? A lot of students are good at regurgitating information, but not all of them can apply it to life-like situations. You need to figure out if they can apply it.
2	I would like to see if there was quality feedback, formative and summative assessment.…They should elaborate and practice what they know. This helps with memory and provides opportunities for feedback to formative assessment. The activities could also facilitate transfer and the deconceptualization of the concept.
3	How and where did Jennifer's prior knowledge of electrical circuits come from? What forms of assessment were used throughout the lessons? How poorly did Jennifer understand in comparison with other students? How well did Jennifer understand, interact and contribute to the group when developing the experiment? Were there prior lessons…relating to electricity that would allow Jennifer to transfer prior knowledge and misunderstanding to the electricity lessons?

level 3 rating showed sophisticated understanding, with explanations that demonstrated awareness of causal mechanisms and appropriate connections to other concepts within larger frameworks of understanding. This was adapted from the rubric for the concept *understanding* used in Derry et al. (2006). Participants' written responses were scored blind to condition. To check interrater reliability, two independent raters initially scored 30% of the data and had interrater agreement of 83.33%. The remaining 70% of the data were scored independently by both raters and disagreements were subsequently resolved through discussion.

In addition to these quantitative scores, the discourse contained in online whiteboards was examined to look for instances in which participants discussed transfer. Quantitative results were expected to reveal whether PBL students were better able to discuss and use their ideas about transfer after the course, but the qualitative analyses were expected to illuminate the ways in which acquisition of the transfer concept was scaffolded and acquired during earlier stages of the learning process. Two small groups were selected to focus this qualitative analysis: one group that represented a group with a smooth and unproblematic group learning process and another in which there was some evidence of struggle during learning. All online whiteboards were examined for both groups from all of the PBL problems. We conducted a qualitative content analysis of the online whiteboards. Each problem was examined for evidence that students were discussing the concept transfer in their online whiteboard. In addition, the data were examined to see how many students within each problem mentioned transfer. This allowed us to examine whether students were continuing to use ideas over multiple problems and the extent to which most of the group was involved in this discussion.

Results

Quantitative Results

The dependent measure for the quantitative analyses was the transfer rubric score on the pre and posttests. Recall that the maximum score was three for this measure. Table 2 shows the means and standard deviations on the transfer rubric for both PBL and traditional Educational Psychology classes. Because treatments were not randomly assigned, we conducted an analysis of covariance with the pretest transfer score as the covariate. The results of the ANCOVA showed a large effect of the PBL treatment, ($F(1,67) = 114.323$, $p < .001$, $d=2.55$).

Qualitative Results

Qualitative analyses were conducted in order to examine changes in how students used the concept of transfer. For these analyses, we examined the whiteboards of two different PBL groups that were nominated by the instructors as representing groups with stronger and weaker group learning processes. We chose to examine the whiteboards because this

Table 2. Pretest and Posttest Scores by Class Type.

Type of Class	N	Pretest	Posttest
STELLAR	33	0.71 (0.31)	2.02 (0.69)
Traditional	37	0.61 (0.36)	0.68 (0.34)

was the collaboration space in which students applied their knowledge of course concepts to collaboratively solving the PBL problems. Group A was a group that consisted of 6 female students who had some difficulty, as demonstrated by the need for the teaching assistant to frequently intervene and facilitate this group's work. Group B, also consisting of 6 female students, rarely needed any assistance from the facilitator. Inspection of the whiteboards from both groups suggested that both groups engaged with the concept of transfer in the first online problem and to some degree in other problems. Interestingly, both groups gained similar amounts from pre- to posttest on the transfer rubric although performance variance in the group that struggled was somewhat greater (Mean gain: Group A= 1.40, SD=0.89; Group B=1.33, SD= 0.61). Despite similarities between the results of Group A and Group B, there were also some marked differences in how they used ideas related to transfer during their PBL interactions.

The students in Group A used concepts related to transfer in problems 1 and 2 and to some extent in problem 3. In problem 1, all students were engaged in the discussion of transfer. Four of five students mentioned transfer in problem 2. In problem 3, two students discussed the concept of transfer. Thus, in three of the four problems, various aspects of transfer were discussed by the group. However, the number of students who discussed transfer diminished in later problems. It is also notable that all the students in this group used transfer in their independent proposals but did not use it as an idea in commenting on other proposals, suggesting that the members of this group used the concept in parallel without real knowledge building (Scardamalia & Bereiter, 2006). Similar to results obtained in earlier research in a face-to-face class (Hmelo-Silver, 2000), the way that students used the concept in discourse began with a very literal and elaborated application, such as making reference to the concept and providing a definition from learning materials, to a progressively more encapsulated version in which the term was used in a way that implied they had acquired a shared understanding of it (Boshuizen & Schmidt, 1992).

This will be illustrated with an example drawn from the first online problem, a case in which participants had viewed a video of a student engaging in a mathematics problem about possible combinations of pizza toppings. Jenny,[4] a student from Group A, wrote a proposed explanation for an enduring understanding that the child in the video developed:[5]

> In the case of Brandon, he needed to have an understanding of how and why he was able to solve the block problem in order to transfer his ideas onto the pizza problem. "The first factor that influences successful transfer is degree of mastery of the original subject" (How People Learn, 53). Brandon was able to continue to solve such a problem because of his complete understanding of how he was able to arrive at the solution for the block problem.

This excerpt shows that the student brought in ideas about transfer through direct quotes that define the concept. This is much like knowledge telling (Bereiter & Scardamalia, 1987), as Jenny shared relatively unprocessed information with her group. Although this group continued to use the concept in independent proposals, it later became encapsulated as part of the group's language and no longer required detailed explanation. In problem 2, Rina used the concept of transfer in thinking about assessment as she offered this proposal:

> The portfolio should have a final summary of the students' work and questions regarding the students' learning, so that the students can explain and evaluate their own thinking. (knowlege web) The students should be able to transfer their prior knowledge of concepts such as force and motion in order to create their vehicle, while also allowing the activity to expand on that knowledge. . . . another important facet of understanding is application. Ms. Baker will know whether the students acquired enduring understanding by how much they can apply this knowledge to real world problems. One way of doing is to have Ms. Baker create another problem that will use the same concepts in a real world setting, and evaluating whether the students were able to apply the concepts they had learned.

This example illustrates a more fluid use of the concept of transfer without needing to provide all the definitions, suggesting that the group members had achieved a shared understanding. This use of conceptual ideas was seen to an even greater degree in Group B.

Group B used the concept of transfer in all four problems. In problem 1, all students discussed transfer in their proposals, comments on others' proposals, or both. Between two and four students used this concept in each of the remaining problems. Unlike Group A, this group used ideas about transfer in both their proposals and in their comments about other students' proposals. However, similar to Group A, the group members began by incorporating direct quotes as they shared information, as this excerpt from Kathy shows:

> Second, Brandon was able to recognize a connection between the pizza problem and the tower problem that he did weeks earlier. Moreover, he made this connection relatively quickly and without much effort. He was able to show us, by using his chart and the manipulatives (blocks), exactly how the pizza problem mapped into the tower problem. His understanding of the pizza problem therefore facilitated a new, and deeper, understanding of the block problem; this process is called transfer. Brandon's seemingly effortless use of transfer provides evidence that he understood the problem, because "transfer and wide application of learning are most likely to occur when learners achieve an organized and coherent understanding of the material." (How People Learn, p. 238-239)

In addition to the direct quotes, Kathy made a point of defining transfer, as it was not yet a term that she could assume that everyone understood in the same way. As students worked together on subsequent problems, the concept of transfer became part of the group's shared understanding and could be used fluidly without the need for explanation as this comment from Micki shows:

> . . . another way to look for enduring understanding would be the students' transfer and application of principles of force and motion especially to real world situations. This would show the student's understandings of information previously and transfer it to the problem at hand, which is a real world problem that allows students to work with hands-on material.

Mimi followed this up by incorporating Micki's comment and a previous proposal from another group member:

> To put these two ideas together, [t]he teacher could bring together individual explanation and transfer as evidence of enduring understanding. An activity could be created at the end of each project that would ask the individual members of the group to use the principles gained to explain a real world scenario. Likewise, an activity could be designed to facilitate transfer of the instructional objectives. For instance, one of the objectives was learning the scientific inquiry process. The teacher could present a real world problem that would require the students to use the same scientific process to solve. (This would also facilitate transfer)

These examples demonstrate that the PBL setting provided opportunities for students to repeatedly engage with concepts in the context of classroom problems. They also suggest that, although there is variability among the groups, students moved from simple descriptions and limited applications of concepts to increasingly deeper understanding and more fluid application of those understandings.

Discussion

The results of this research indicate that students who participated in the STELLAR PBL course constructed a deeper understanding of the concept of transfer than did the students in comparison classes as demonstrated by their performances on the posttest. They were also able to apply their understandings of the concept to generate recommendations for improvements of instructional methods. This evidence helps provide generality to the results of Derry et al. (2006), which demonstrated similar results for another targeted course concept. The qualitative analysis suggests that, as students continue to engage with ideas in an online PBL environment, their understanding becomes shared, new language is adopted, and the concept becomes part of their repertoire of tools for flexible thinking about problems. The qualitative and quantitative results converge to demonstrate how a PBL class with rich multimedia problems, access to information, and activity structures can promote learning and engagement with important concepts in educational psychology. Such learning and engagement is not likely to occur unless students have the opportunity to engage with ideas over extended periods of time, such as the extended time period for the STELLAR course (Brush & Saye, 2008), and have repeated opportunities to bring together the conceptual ideas with varied problems of practice (Derry, 2006; Spiro, Feltovich, Jacobson, & Coulson, 1992).

The STELLAR PBL approach represents an example of a computer-supported collaborative learning (CSCL) approach to PBL. These results suggest that 1) problem-based approaches can foster deep learning and 2) a hybrid CSCL approach can be used to scaffold PBL. Moreover, we have evidence that suggests that the adaptation of the PBL activity structure in an online environment helped scaffold deep understanding in a domain that is related to the preservice teachers' future classroom practice. Further research would prove helpful in determining the various ways in which students engage with conceptual knowledge as they interact with an online PBL course, with each other, and with the facilitator and how these affect what students learn. Because the traditional courses were organized around textbooks rather than the problems of practice as in the hybrid PBL course, we conjecture that the course was more aligned than a text-based course with the goals of using educational psychology as a tool to help prepare teachers for thinking about classrooms.

There are several limitations of the study and some possible alternative explanations. This was a small-scale quasi-experimental study. Students were not randomly assigned to classes, and although desirable, this is almost never possible in a real university setting. However, we argue that the disadvantages of nonrandom assignment, for which we can statistically control, are counteracted by the advantages of achieving greater validity when comparative research is conducted in real courses using real curricula and assessments in totally authentic university settings. Thus, we cannot rule out the effects of nonequivalent groups. Another possible explanation for the results is the effect of the online conversation, however this explanation seems unlikely. The hybrid course included scaffolding to help focus the students' talk and rich video contexts to help them learn about the conditions under which their knowledge would be applied. A simple online discussion might provide an opportunity for extended engagement but would not have the set of scaffolds used in the hybrid PBL course. Finally, we note that there may have been differences due to students' experiences with video cases for the STELLAR PBL group. Although other classes may have used supplemental video, they did not do so in any systematic way. Despite these limitations, we doubt such large effects could be accounted for by these alternative explanations. However, the purpose of a continuing research program is to shed further light on these issues. Like all good research, our study points the way to additional questions regarding the effectiveness of online PBL that should be addressed. Our work provides strong indication that it is possible to design effective courses that distribute the scaffolding of PBL so that it is shared by both human tutors and online tools. This increases the possibility that PBL can be employed on a larger scale.

Our overall conclusion from this study is not merely that PBL works in this setting but that it provides students with opportunities to extensively engage with ideas in a variety of contexts and that such engagement leads to learning. But such engagement does not happen without a combination of static and dynamic scaffolds working synergistically. However, many unanswered questions still remain regarding PBL in general and the use of PBL in an online learning environment in particular. For example, here we provided a particular kind of activity structure for a particular domain with particular kinds of multimedia resources. It remains an open question regarding how this would generalize to other domains. In addition, we need to better understand how different kinds of scaffolding techniques and resources afford engaging with different professional practices and constructing different kinds of knowledge and skills. These are critical issues for understanding how technology can be used to support PBL more broadly as well as how PBL can be adapted to a variety of contexts and domains.

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Notes

1. The STELLAR System is no longer supported. Current implementations of this course using a hybrid PBL format are carried out using the open source environment, Moodle or other course management systems.
2. The class consisted of 6 small groups of 5-7 students in each group.
3. Although demographic data were not collected on this specific group of comparison students, this is the general trend for this population over many years.
4. All names are pseudonyms.
5. All quotes are exactly as typed by the participants, other than being edited for length. An ellipsis indicates that text was deleted. Any errors in grammar or writing mechanics were exactly as written by the students.

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