The Development Of Self-Directed Learning Strategies in Problem-Based Learning

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Introduction

Students often leave school without the skills needed for lifelong learning. This is particularly problematic in technical fields such as medicine and engineering where the knowledge is continually changing and advancing [Eden, et al., 1996]. To prepare students for the lifelong learning required for success in such fields, students need to have experience in self-directed learning (SDL) while in school. An innovative approach to learning that explicitly does this is problem-based learning, an educational methodology that applies cognitive science theory to the real world setting of education by having students learn in the context of solving complex problems. Problem-based learning is being used at many medical schools and is increasingly being applied to other settings [Barrows, 1985; Williams, 1993]. Because the problems used are complex, students work in groups, where they pool their expertise and experience and together grapple with the complexities of the issues that must be considered. Facilitators guide student reflection on these experiences, facilitating learning of the cognitive skills needed for problem solving and SDL. Because students direct their learning, skills needed for life-long learning are also acquired, as they manage their learning goals while coping with the problems they are trying to solve [Barrows, 1985]. In this paper, we present a model of self-directed learning and the results of a study that examines components of this model in the context of medical education.

Self-directed learning is initiated in PBL as students are faced with a problem that they do not have the knowledge resources to solve, as indicated in Figure 1. In medical education, the problems are taken from actual patient cases. As the students identify gaps in their understanding, they set goals for learning. In PBL terminology, these are called learning issues (LI). This step is necessary but not sufficient for self-directed learning to occur. The learner also needs to generate a plan to address the LI by identifying and using various information resources. These resources may be texts such as internal medicine or pathology references or they may be expert physicians in the case of medical education. The learner then needs to integrate the information from the resources into their understanding and bring it to bear on solving the problem faced. In addition, the learner needs to evaluate the success or failure of their information search and determine whether or not there is a need to iterate through the SDL cycle again.

Although this model discusses the importance of SDL, it does not provide direction as to the nature of a good strategy. There is little empirical research that clearly defines the nature of good SDL strategies but cognitive science theory offers some suggestions [Bassok & Holyoak, 1993]. Bassok and Holyoak suggest that SDL which proceeds in a hypothesis-driven manner should lead to more flexible knowledge, as compared with a data-driven strategy. Data-driven learning requires that students make generalizations from multiple examples. The learners do not engage in deep analysis of principles and may end up knowing sets of correlated features (including some that are irrelevant). A search that proceeds by investigating the significance of isolated data (e.g., symptoms) may not effectively narrow the search space. In contrast, when one has a hypothesis, choosing to search for information in a hypothesis-driven manner may be more efficient than a search that is data-driven. Hypothesis-driven learning depends on prior knowledge of the domain coupled with active learning strategies that allow the learner to make principled judgments about the importance of features to the learner's goals. To the extent that hypothesis-driven learning enables learners to successfully identify relevant but nonobvious features of a problem, more flexible transfer will be promoted [Bassok & Holyoak, 1993; Patel & Kaufman, 1993]. Students may have fragmented domain-knowledge though and need assistance in directing their attention to goal-relevant information.

In the PBL curriculum implemented in medical schools, the students are encouraged to think about the patient problems with the underlying scientific principles in mind rather than just collecting sets of features. As cases are connected to domain principles, the learner can begin to understand how knowledge can be applied to solving problems [Chi et al., 1989]. In this study, we examined how medical students in a PBL curriculum assess their learning needs and develop plans to address those needs. In addition, we examined the students' perceptions of how successful their learning has been. We expect that self-directed learning that proceeds in a hypothesis-driven manner should lead to more flexible knowledge.

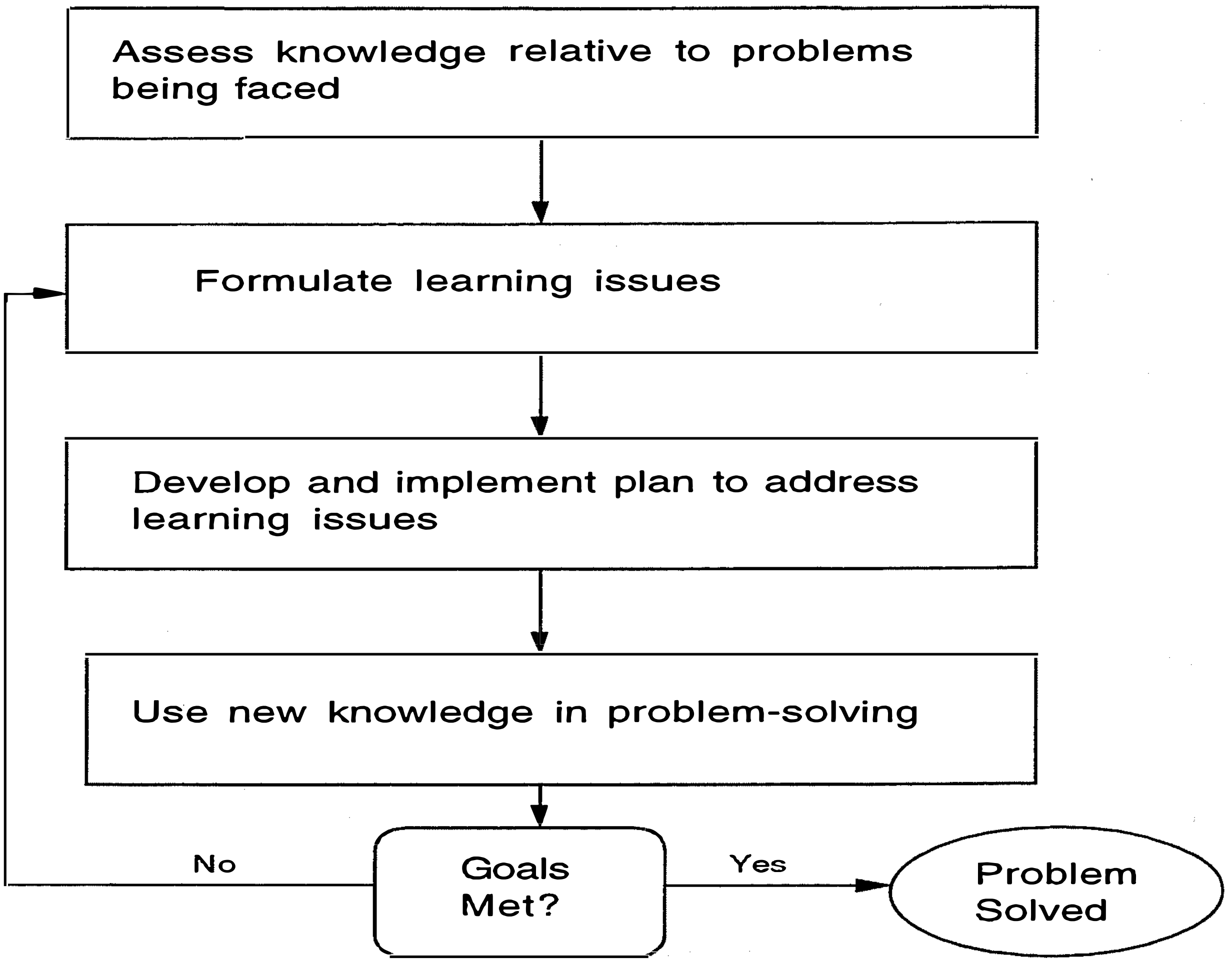

Figure 1. Self-directed learning model

Methods

Students from two medical schools participated in this study. At School A, a midwestern medical school, 35 first-year students participated. Sixteen students were from the school's traditional curriculum and 19 were from the PBL curriculum. The students in the traditional curriculum spent approximately 40 hours a week in lecture and laboratory courses in the basic biomedical sciences, whereas the PBL students had two 3-hour sessions for their PBL group meetings and a third optional 1-hour session a week where resource faculty were available to answer questions. At School B, a southern medical school, 39 first-year students participated. Of these, 19 students were in a PBL elective and 20 students were in a different (non- problem-based) elective. In School B, these electives were in addition to a traditional curriculum. The actual PBL group meetings were very similar at the two schools except that the School A students had a much more intense PBL experience than the School B group. Students were paid $45 for participating in 3 two-hour sessions during their first year of medical school. The sessions took place before the start of classes, after 3 months, and after 7 months of medical school.

The students' task was to generate pathophysiological explanations, in writing, for the mechanisms underlying a medical problem. At the end of each problem, the students were asked to identify additional knowledge that they needed to understand the patient problem (the learning issues) and to develop a plan to address those learning issues. They were also asked to rate their scientific and clinical knowledge relative to the problem using a Likert scale. Six different problems were used that covered a variety of body systems and disease processes. Students were randomly assigned to 6 different orders that were counterbalanced across conditions. At each session, the subject received 2 problems. The problems were presented in a format similar to those used in the PBL classes. Although the nonPBL students had not seen this problem format, they had been exposed to patient cases used to illustrate various biomedical concepts.

The protocols were coded as to whether the students' learning issues were hypothesis-related or data-related. The particular resources mentioned in the learning plan were also categorized. A random sample of 20% of the protocols was scored by a second independent rater blind to condition. Interrater agreement was 96%.

Results

The learning issues (LI) the students identified fell into two categories: hypothesis-related or data-related. Hypothesis-related (HR) learning issues included issues related both to diseases and basic-science mechanisms. An example of a disease-driven HR learning issue is the student needing to know more about "complications of diabetes." A basic-science driven HR learning issue might be learning about "acid-base physiology." An example from the second category, data-driven LI, is needing to learn about the significance of an elevated respiratory rate. Additional examples from the students' protocols are displayed in Table 1. If the students' SDL strategies are consistent with their reasoning strategies, the PBL students should generate more disease-driven and basic science LI because the PBL students tend to learn hypothesis-driven reasoning strategies [Hmelo, 1995]. In other work, we have found that this distinction between data and hypothesis-related SDL strategies discriminated between PBL and nonPBL students [Hmelo & Gotterer, 1994]. For analytical purposes, the subjects' responses were classified into 3 patterns of learning issues: those which did not involve any or only vague issues; those which involve strictly hypothesis-related LI; and those in which the LI referred to data. Because the differences between the schools were minimal and were not related to the hypotheses being tested, the data reported here are collapsed across the two schools.

Category	Example
Hypothesis-related	
Basic Science	"..the physiology of the adrenal gland: what are the compounds which it synthesizes, and what are the systemic effects of their release into blood in abnormally elevated levels?"
Disease	"What are the risk factors which disposed Rosie for disseminated Mycobacterial infection?"
Data-related	"What were those crystals in his ankle, where do they come from and what do they do?"

Table 1. Examples of Learning Issues

The LI that the students generated after working through each case were counted and classified in terms of their content. The PBL students initially generated more learning issues (M=3.34; SD=1.84) than the nonPBL students (M=2.03, SD=1.15) but they decreased the number of LI generated over the course of the year so that at the end of the year, there was very little difference in the number of LI between the two groups (Time 2: PBL: M=3.00, SD=1.69; nonPBL: M=1.93; SD=0.94; Time 3: PBL M=2.25, SD=1.00; nonPBL M=2.01, SD=1.04; F (1,68)= 14.11, p<.001, MS_e=1.40). This puzzling result can be better understood by examining how the subjects' qualitative patterns of LI changed over the course of the year. Initially the PBL students started out by having many data-related LI but over the course of the year, they switched to more hypothesis-related LI, as indicated in Figure 2 (χ^2 (4)=16.82, p<.005). The nonPBL students did not change much over the year. The change for the PBL students may reflect the expectations that they had about using patient cases. It is likely that they expected an emphasis on clinical issues as part of PBL. It may also be that over the course of the year, the PBL students realized that researching isolated data (i.e., signs and symptoms) is less efficient than using their hypotheses as the context for their search. As we show in the following section, the qualitative results from the students' learning plans suggest that the latter explanation is more likely.

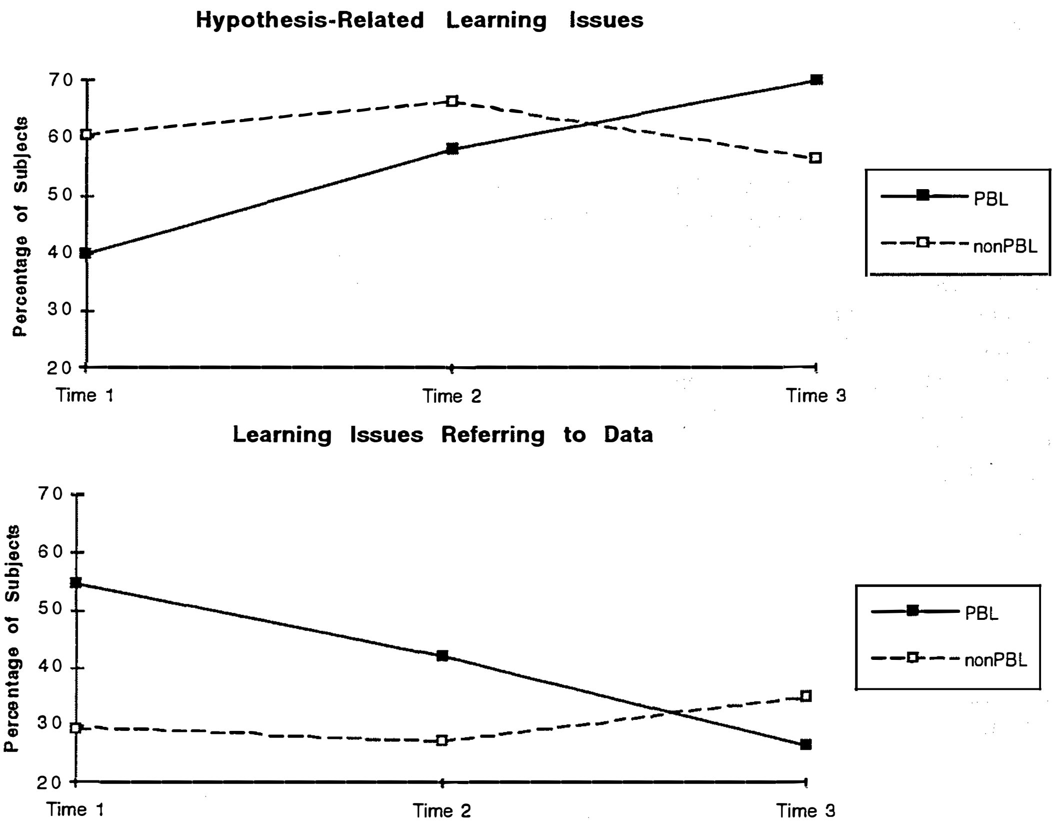

Figure 2. Distribution of learning issues

Generating LI's is the first step toward SDL, but, as shown in Figure 1, the students also need to determine what resources they will use. We predicted that given their experience, the PBL students would be more facile with choosing the learning resources for this task. However, the nonPBL students also have considerable experience in writing papers and using the library. Thus, we made no predictions about which group would use more resources but we did expect them to use different resources.

The learning resources that the students used were counted and categorized into basic science textbooks, clinical textbooks, unspecified textbooks, and use of expert consultants. The PBL students (across all time periods) used more resources than the nonPBL students (PBL M=2.96; nonPBL= 2.53; F(1,68)=4.95; p<.05; MS_e=3.85) but there was no change over time. The qualitative results are more informative in understanding how the students' learning plans changed over time.

Although the students' learning plans clearly differed at the beginning of year, there were differing trends for the

2 groups (see Table 2). At the beginning of the year, the PBL students were more likely to use science texts and experts. A substantial number of them used nonspecific texts although a not as many as the nonPBL students. Over the course of the year, the PBL students became more likely to use clinical and science texts and less likely to use experts and nonspecific texts whereas the nonPBL students became more likely to use experts and unspecified texts (clinical texts: $\chi^2(4)=11.54$ $p<.05$; science texts: $\chi^2(4)=9.38$, $p=.05$; experts: $\chi^2(4)=10.05$, $p<.05$; nonspecific texts: $\chi^2(2)=15.30$, $p<.001$). This suggests that the PBL students developed a better understanding of the range of resources available. Although the students' goal for the first year of medical school was to learn science, given a patient case, many PBL students wanted to first look in a clinical textbook such as Harrison's Internal Medicine. Such a textbook, although emphasizing clinical information, also contains information about the causal mechanisms of the illness as well. In contrast, the nonPBL students only seemed to have undifferentiated plans about how to get started.

	Time 1				Time 2				Time 3			
	Clin	Sci	Expert	Unsp Text	Clin	Sci	Expert	Unsp Text	Clin	Sci	Expert	Unsp Text
PBL	24%	46%	55%	27%	61%	61%	40%	16%	57%	59%	37%	9%
nonPBL	21%	24%	57%	41%	18%	27%	83%	46%	24%	38%	57%	31%

Note: "Clin" refers to clinical texts, "Sci" refers to basic science textbooks, "Expert" refers to human consultants, "Unsp text" refers to textbooks that did not have any descriptors that would allow it to be classified.

Table 2. Percentage of Students using Different Learning Resources

The students' success at their SDL was indirectly measured by their knowledge ratings following each case. Both the PBL and nonPBL students increased in their self-perceived science knowledge over the course of the year (overall mean rating at Time 1: 2.22 out of a possible 5, Time 2: 2.82, Time 3: 3.29, $F(1,68)=72.87$, $p<.001$, $MS_e=1.19$) but only the PBL students grew significantly in their self-perceived clinical knowledge (Means: PBL Time 1: 1.75, Time 2: 2.82 Time 3: 3.10 nonPBL Time 1: 1.74, Time 2: 2.00, Time 3: 2.49; $F(1,68)=9.06$, $p<.005$; $MS_e=.62$). Although the evidence is indirect, a possible explanation for the PBL students' greater growth in self-perceived clinical knowledge is that, in the problem-based environment, students learned to integrate basic science with clinical information. For example, they may have been more likely to learn about the contexts in which particular scientific concepts are likely to be relevant and the symptoms through which they are manifested.

Conclusion

In this study we provided evidence that PBL is effective in facilitating the development of SDL strategies. Specifically we have shown that:

- PBL students are likely to identify hypothesis-related learning issues.
- PBL students are more likely to develop a well-specified starting point for their self-directed learning in the plans they generate.

Dolmans (1994) suggests that there may be additional dynamics involved in SDL. She found that what students planned to do was not necessarily related to what they actually did while pursuing independent study. This suggests that the model in Figure 1 is incomplete and that there may be additional cognitive activity between developing a plan, implementing it, and using the new knowledge-- and that the linear model may be an oversimplification. She suggests that there is a complex relationship between student-generated learning issues and the subsequent activities and resources used. Some of the factors identified as influential include: the availability of relevant literature, the breadth of the learning issues, motivation, self-assessment tests, and other examinations. In addition, Dolmans' results suggest that utilization of learning resources may be a dynamic phenomenon and that, while perusing the literature and having discussions with experts, additional issues may arise that receive the learners' attention. This still suggests that where students start their learning (i.e., what resources they initially use) will influence subsequent learning.We note that the students' initial learning plans are likely to evolve from where they start as Dolman's (1994) work has shown. However, having a definite idea of where to begin should still help the PBL students more efficiently direct their learning. Clearly, further research needs to be done to test this last hypothesis as well as to examine whether a hypothesis-related strategy for directing one's learning is more effective. Examining the dynamic nature of effective SDL strategies is important in order to understand how to facilitate the development of effective strategies.

Finally, we have yet to evaluate the last step in the SDL model involving the integration of new knowledge into existing knowledge frameworks that students use to solve problems. These are important issues both for cognitive science and for education. PBL is a rich example of an educational innovation that provides an opportunity to inform (and learn from) cognitive theory.

Preparing students to become lifelong learners is an emphasis in many cognitively-informed curriculum innovations [Bereiter & Scardamalia, 1989; CTGV, 1994]. This is particularly important in medical education given the rapid advances in medical knowledge. As the medical students mature into physicians, they are also developing the attitudes and strategies needed for lifelong learning. It remains an empirical question to determine if the effect of PBL on SDL strategies persists throughout an individual's career. Future work is planned to address this question.

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