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Process and Product in PBL Research

Carl Bereiter and Marlene Scardamalia

OISE/University of Toronto

Let us begin by distinguishing PBL (upper-case) from pbl (lower-case). PBL is a distinctive, well-documented instructional approach that originated in medical education. Although there are variations and although it has been applied in other disciplines, practitioners of PBL acknowledge its medical school origins and tend to adhere to the structure and procedures systematized by Barrow. Lower-case pbl refers to an indefinite range of educational approaches that give problems a central place in learning activity. Mathematics and physics have traditionally done this, but most other disciplines have not. A problem-based literature course, for instance, would be a novelty even today. However, case-based education, as practiced in law schools and business schools would count as lower-case pbl, insofar as the cases are treated as problems to be solved, much like the cases that typically figure in medical PBL.

Lest everything be counted as pbl, however, it is worthwhile to distinguish between exercises and problems. Elementary school mathematics, for instance, is full of exercises that are often glorified as problems. But this is a far cry from the kind of mathematics education that Lampert (1990) has pioneered, where the problems students wrestle with are problems of method and justification, or the kinds of mathematics problems presented in the Jasper Woodbury adventures (Cognition and Technology Group at Vanderbilt, 1994), which are complex realistic problems much more like medical cases than like typical schoolbook word problems. Upper-case PBL entails more than a focus on problems, however. It also entails a collaborative group process, and it is mainly this aspect of PBL that is treated in the chapters on which we comment. Collaborative group work, certainly a novelty in the early days of PBL, has caught on much more widely since then and is now to be found associated with many forms of lower-case pbl as well.

Our own work, which provides the vantage point from which we write this commentary, is lower-case rather than upper-case pbl. The label we attach to it is 'collaborative knowledge building' (Scardamalia, Bereiter, & Lamon, 1994; Scardamalia & Bereiter, 1994). Although our work has been mainly with elementary and middle school students and with graduate students in education, there are notable similarities to PBL as practiced in medical schools:

1. Problems play a central role in the educational process.
2. Dialogue is the principal vehicle for problem solving.
3. An important part of work on a problem is identifying what needs to be found out in order to advance.
4. Small groups work collaboratively on solving the problem.

5. Information search and other tasks are distributed among group members instead of everyone's doing the same things.
6. The focus is on achieving a cognitive outcome rather than on producing an artifact or a presentation, thus distinguishing it from much of what is called 'project-based learning' (Marx et al, 1997).

However, there are also notable differences:

1. The problems are usually at the level of principles rather than cases; for instance, "How does heat affect matter?" rather than "Why doesn't the ball go through the ring?"
2. The focus is on understanding rather than on reaching a conclusion.
3. Problems themselves are expected to undergo transformation in the course of inquiry, as they do in science. Thus it is not expected that problems will be solved but that the state of collective knowledge will advance.
4. The teacher functions as a coinvestigator more than seems to be typical of tutors in PBL.
5. Much of the collaborative problem solving work is computer mediated and asynchronous rather than being conducted face-to-face. It uses technology generically known as CSILE™ (Scardamalia & Bereiter, 1994), the most current version of which is Knowledge Forum™.
6. The software environment supports and structures interactions in ways that would be the responsibility of the tutor in PBL.

These differences raise several points for discussion in light of the research reported in preceding chapters.

Theory Building: General Theories and Theories of the Case

It is interesting that in several of the excerpts from PBL discussions, students speak of what they are doing as advancing and testing theories. This struck some of the participants in the AERA discussion (Chapter 6) as curious, and they took it as indicating the student's recognition of the tentative character of her ideas. That is no doubt true, but calling something a theory implies more than uncertainty. Some might regard it as a bit pompous. But if we take a theory to be a coherent explanation of a body of facts, then theory building is precisely what students are supposed to be doing in PBL. We wonder if it would not be helpful to both students and tutors to make this more explicit.

Theories are commonly thought of as general in nature, like Newtonian or Darwinian theory. But there are theories of dinosaur extinction, and they are explanations of a particular case, albeit a very large one. That is, they don't explain species extinction in general but a one-time-only event. However, as Thagard (1989) shows, the same kind of explanation is involved, subject to the same standards of judgment. It is 'argument to the best explanation.' The best explanation is one that explains all the facts and that does not imply anything contrary to fact. What constitute the facts needing explaining is a major issue in its own right, but one that we need not go into for present purposes. It is, however, relevant to note that in the typical case-based PBL session the facts to be explained are all laid out for the students, whereas in Collaborative Knowledge Building, the domain of facts in need of explanation is not constrained and tends to grow as the problem deepens (Bereiter et al, 1997). This is characteristic of science, where powerful theoretical principles, such as

Newton's laws, turn out to explain facts quite remote from those that initially motivated theory building.

Studies of expertise in medical diagnosis make it clear that argument to the best explanation is the expert's way, whereas the novice's way is to reason backward from a tentative diagnosis (Patel & Groen, 1991). Experts are not content with a diagnosis (read here 'a theory of the case') that fits the main symptoms. They want to 'tie up loose ends,' to account for all the facts. Accordingly, learning to pursue argument to the best explanation would seem to be an important part of professional education in medicine. There are indications throughout the chapters under review that tutors recognize this. They are continually trying to nudge students in this direction, pointing out facts that their theories do not explain or pointing out implications that are incompatible with facts. What is worrisome to us is that this high-level monitoring of theory construction may remain in the hands of the tutor, that there does not seem to be any organized effort to turn it over to the students. Until that is done, there would seem to be little reason for students to abandon the labor-saving novice strategy: Stick with a diagnosis until somebody shows you what is wrong with it.

In Collaborative Knowledge Building, problem-centered theory construction is singled out as one of the major activities students may engage in. Scaffolds are provided which signal "My Theory," "I Need to Understand," "New Information," and "What We Have Learned." Teachers are encouraged to shift the focus of work from *finding answers* to *improving theories.* This has, first of all, the effect of raising the quality of the problems that students formulate. Students have been found to formulate quite different kinds of questions, depending on whether they anticipate that they will be expected to find answers to them (Scardamalia & Bereiter, 1992). When they are expected to find answers, they tend to ask what we call "text-based" questions, questions of the kind that routinely accompany textbooks and for which the answers are to be found in the text. When freed of the obligation to find answers, they ask what we call "knowledge-based" questions, questions that arise from their own puzzlement or perceived lack of understanding. These are questions that teachers and independent raters judge to be of considerably greater educational potential than text-based questions. We have found that shifting the emphasis from finding answers to improving theories encourages students to formulate knowledge-based problems (Scardamalia, Bereiter, Hewitt, & Webb, 1996) . Having posed a problem, students next advance their initial theories as solutions. Then, as they acquire additional information by whatever means, they work to improve their theories. This is always possible, whereas finding an answer to a knowledge-based question often is not. The second advantage of shifting from finding answers to improving theories is that it engages students in a process much more like real science, where practitioners seldom expect to discover final answers but rather work to improve upon existing knowledge (Bereiter et al, 1997).

Building Dispositions Toward Lifelong Learning

Is PBL merely an alternative way of covering subject matter or is it supposed to produce a different kind of educated person? The expressed intent, of course, is the latter, with the emphasis being on producing people able and willing to solve problems in their fields. Another sort of whole-person outcome that is receiving attention these days, however, is that of producing people who will remain able and willing throughout life to pursue new learning. The need for this is highlighted by technological changes that alter job requirements. In scientifically grounded professions like medicine, there is not only the need to master new technology but the need to continually revise practice in the light of advances in knowledge.

Standard PBL practice sends students out in search of knowledge required to solve the immediate problem. To the extent that this experience has long-term effects on dispositions, it should promote one kind of lifelong learning. You could call it a lifelong disposition to do Web searches. That is not a trivial development. The way things are heading, we may see a widening divide between those who utilize Web searches in dealing with life's problems and those who do not, with those who do not making poorer decisions, receiving poorer services, and paying more money for inferior goods. But there is another side to lifelong learning, which is not a matter of obtaining information relevant to immediate action. It is exploiting the potentialities of new knowledge—revising ones beliefs and practices in light of it, building more powerful conceptual frameworks, coming up with new ideas.

This second kind of lifelong learning is problem-based as well, but the problems are of a different kind. They are not means-end problems with new knowledge providing the means. Rather, they are knowledge-building problems. They concern the knowledge itself—its meaning, validity, and implications, its relation to other knowledge, and its possibilities of application.

Both kinds of problem-based learning are of obvious lifelong importance. Both are essential to staying on top of one's field. When professional journals arrive we are likely to read them with a knowledge-building purpose. Then we put them on the shelf where, if they are ever taken down, it is likely to be with a means-end purpose in mind. PBL gives students abundant experience with the means-end kind of inquiry, but could be criticized for slighting the more open-ended, knowledge-centered kind of inquiry.

Fuller and More Balanced Participation

Several of the studies reported in the preceding chapters indicate wide individual differences in level of participation by students in the PBL process. There are also some reports of whole groups exhibiting a low level of engagement. None of this is peculiar to PBL, of course, but it is a matter of particular concern because of the expectation that PBL should produce fuller and deeper involvement in the learning. In the next section we will consider the role that technology might play in achieving this result, but here we want to consider a more fundamental issue. What are the motivators in PBL? What are students trying to get out of it? Lacking empirical answers to these questions, we can only speculate on the basis of adaptationist assumptions (Anderson, 1990).

Educators tend to be process people and to believe that if they can get the process right it will be intrinsically rewarding. That is the faith that has given rise to most educational innovations of the past century—the activity method, the English infant school, open education, learning by discovery, project-based learning, not to mention a host of more specific inventions such as the microsociety school (Richmond, 1973). PBL clearly reflects the same faith. The inevitable finding is that any given process will be much more engaging for some students than for others. Looking critically at her own lower-case pbl innovations, Lampert, Rittenhouse, and Crumbaugh (1996) discovered a number of students who found the public airing, criticizing, and defending of ideas aversive. Of course, everyone is likely to find it painful at times. We persist because there are other rewards, which come from achievement rather than process.

Apart from the variable pleasures of participating in the process, the rewards coming from PBL would seem to be the following, in likely order of importance to the student: good grades, awareness of having learned things of future professional value, and sense of achievement from solving a problem. In principle the order should be reversed, but it is easy to see why this would not be the case in reality. The presented problems in PBL are not real problems. They are actually puzzles. Real problems are such that when you solve them your situation in the world improves; you can now do something you couldn't do before or understand something you didn't understand before. To the extent that real problems arise in PBL, they are likely to arise as 'learning issues' incidental to solving the puzzle. Solving a puzzle can be rewarding to many people, as evidenced by the popularity of puzzles in newspapers. But for most people it is a fairly weak attraction, easily overridden by other concerns, such as anxiety over making it through medical school. As for the rewards of acquiring useful knowledge, the evidence is pretty clear. The pay-off from PBL comes later than from traditional instruction. On measures of immediate learning traditional instruction does better, whereas PBL does better on long-term retention (Chapter 2). That is fine as far as cognitive outcomes are concerned, but in terms of motivation it means that students in traditional classes are more likely to have a sense that they are gaining knowledge of value.

That brings us to grades, whose motivational importance typically transcends instructional method. Instructional designers can do little to influence the importance of grades, but they do a lot to determine what grades are based on. If grades are based on measures of individual learning, as they evidently usually are in PBL, it is natural for students to opt for any strategy that will enhance their mastery of testable subject matter. Active participation in collaborative problem solving may not figure prominently in such strategies. If grades are based on performance and participation in the PBL process itself, a grade-maximizing strategy may well call for the kinds of 'overparticipation' identified by Dueck (Chapter 4). Basing grades on a combination of learning and participation may encourage some to dominate the process while others withdraw and hit the books.

The research on levels of participation would suggest follow-up with experiments to alter reward structures and conditions of adaptation. Three suggested directions are (1) replacing puzzles with real problems, preferably problems arising from the students, (2) finding ways to make what is learned more immediately visible and its importance more salient, and (3) basing grades in part on contribution to others' knowledge advancement.

Roles for Technology in PBL

Because the focus of this book is on process, we will confine our attention to technology that supports processes and will ignore such other potentially important technology as computerized presentation and indexing of cases and use of Web resources for researching learning issues. The technology we have been developing is of the process-supporting kind, suggested by its generic name, Computer Supported Intentional Learning Environments. Other, more limited kinds of process supports are bulletin boards, chat rooms, and threaded conferencing software, all of which have found some use in versions of PBL. There is also software that supports specific social or cognitive processes. One that could be especially relevant to PBL is Convince Me (Schank, Ranney, & Hoadley, 1995), which provides a way of evaluating 'argument to the best explanation,' as discussed earlier.

The most comprehensive effort that we know of to create a computer supported environment for PBL is the one reported by Koschmann, et al. (1995). Koschmann et al. have taken each of 6 phases of PBL and looked for ways that technology could support each of the processes, from problem presentation to reflection. They suggest that use of technological supports should subtlely change pedagogy—and presumably the communicative process through which it is mediated— although they do not specify in what ways. They indicate that only three kinds of communication are to be mediated by computer: transfer of raw data, candidate contributions to an electronic "blackboard," and polling.

The research reported in preceding sections suggests, however, that a more 'problem-based' approach to technology for PBL might be justified. Two of the problems that technology might help to solve are

1. The tendency of many tutors to assume too directive a role, complemented by a tendency of students to depend too much on the tutor (Chapters 4 and 5).
2. Disparities in participation and involvement, as noted in the preceding section, resulting in some students dominating the group process while others withdraw.

Any sort of computer conferencing system could be expected to alleviate these problems to some extent. The tutor is no longer at the center of the communication web. Asynchronous communication means that students do not have to capture a conversational turn in order to contribute to discussions, and so it becomes less likely that a few students will dominate. The more reticent or less verbal student may also benefit from having more time to formulate an utterance. The only drawback to this pretty picture is what Mark Guzdial (1997), in a public address, called "the dirty little secret" of computer supported collaborative learning: that students don't like computer conferencing very much, that participation is scanty and hard to maintain. We have seen this in CSILE classrooms, where teachers complain that they can't get students to comment or where discussions all peter out after one or two responses. But more commonly we see students enthusiastic about carrying out inquiries through CSILE/Knowledge Forum and many instances of sustained collaboration.

The solution, we believe, cannot be through software design alone, but neither can it be through better engineering of social processes. The situation is the same one discussed in the preceding section, whether or not computer support is involved. Computer conferencing is a process, and if participation in the process is the only reward, that will not be sufficient for most. Indeed, in comparison to face-to-face discussion, computer conferencing probably reduces both the social pains and the social pleasures. If computer support of sociocognitve processes is to be valued by the learners, it has to provide more than an enjoyable experience. It has to pay off in things that the students value. In CSILE classes that take on a knowledge-building mission, students report cognitive, not just social rewards. They are aware of solving problems that matter to them and achieving important gains in knowledge. But that requires designing the whole learning situation so as to produce those yields. When educators set about designing a high-yield environment for building knowledge and solving real problems, it becomes quickly obvious that technology can help. If, instead, they start with technology and with existing classroom processes, it is often questionable whether the two go together.

We see the kind of research reported in these chapters as providing one important kind of data for further development of PBL. It would be a misuse of the research, however, to start tinkering with participatory structures in the belief that those could be improved without giving serious attention to what makes it worth the students' while to participate at all. For an educational approach with the high aspirations of PBL, that means looking for ways to make participation cognitively more rewarding to the students. That is a large challenge but one that, in our experience, can be met as long as it is kept firmly in view.

Directions for Future Research

The authors of the preceding chapters appear to share with us a belief that the point of PBL research is the improvement of practice. On this basis, the reported research must be judged as preliminary, for it is almost all descriptive or correlational. Such research may at times indicate what needs changing, but it cannot be expected to guide invention and experimentation. Still, as Peter Drucker (1985) pointed out in a different context, one of the great spurs to innovation is unexpected findings. Accordingly, it is worth considering further analytic research that holds promise of unexpected findings. The following are a few ideas as to what might lie beyond the current research:

- Research into PBL tutorials as self-organizing systems. The Koschmann, Glenn, and Conlee study (Chapter 3) is a case study that strongly suggests the potential of this approach. What emerges in the tutorial process cannot be explained by the individual actions of tutor and students, but neither can it be illuminatingly explained by an additive combination of factors, as in the Schmidt and Moust model (Chapter 2). Self-organizing systems are characterized by emergent complexity, giving rise to structures that are not predictable from the inputs. Accordingly, they frustrate research of the variable-manipulating kind. But if, as seems obvious, the definitive task for social research on PBL is to understand emergent behavioral patterns, then it is necessary to bite the bullet.
- Development of proximal outcome measures. Faidley et al. (Chapter 5), after demonstrating a coherent pattern of relationships among student perceptions and observed group performance, noted that their measures were "probably too unrefined to test for the relation between performance and group effectiveness." Although effectiveness must ultimately be judged by what students have learned, learning measures are too distant from the process to be helpful in improving it. A more immediate result that needs to be evaluated is whether a collaborative problem-solving episode made progress—advanced toward a solution or toward fuller understanding. Assessing the progress of a discourse remains a challenge that discourse analysts have not fully met, but it is a challenge that surely needs to be taken up by PBL researchers.

• Opportunistic research. When graduate students undertake research using transcripts or recordings, they typically strive for exhaustive classification, using some predetermined scheme. They don't want to miss anything. Yet if they find out anything interesting, it almost comes from noticing something that lies outside their classification scheme. Chapter 6 provides a sampling of approaches to analysis of a single segment of videotaped PBL. The approaches range from "What's interesting here?" to "How can we exhaustively describe the multi-layered processes represented here?" The situation does not permit a fair comparison of these approaches, but based on our readings of related research over the years, we would say that the first approach is decidedly superior, provided there is a sufficiently well developed conceptual framework within which to judge what is interesting. We therefore want to conclude our punditry by urging researchers to be less concerned about coding, to stand back from their data, ask themselves "What's interesting here?" and then pursue those interesting observations until they begin to yield insight.

If the ultimate objective is improvement of PBL, however, then at some point there needs to be a shift to design experiments (Brown, 1992), where results are fed back into further cycles of design. In earlier sections we have suggested innovations such as moving away from exclusively case-based problems and making theory construction a more salient aspect of the process. Of course, there are already many variations in practice, creating quite a fuzzy boundary between upper-case PBL and lower-case. Those who think there is something special about the pure version that should not be lost are rightly suspicious of innovations that threaten to obliterate its identity so that it becomes lost amid the host of educational approaches that are in some sense problem-based. But few, we assume, want PBL to be a cult. The only alternative that we can see is for PBL to become a principled program of ongoing instructional design, and it is in sympathy with that conception that we offer this commentary.

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The PBL learning process allows students to problem-solve and look for solutions that may be outside the original scope of the problem. This worksheet will help you create performance indicators to measure student performance for both project deliverables and the problem solving process.Â The rubric lists suggested performance indicators specific to the problem-based learning process (Need to Know process, and open-ended problem-solving) and provides space to create performance indicators specific to other skill areas practiced in your PBL: research skills, technical skills, team work, oral presentation skills, quality of written product, project management skills, or other skill areas. PBL fits best with process-oriented course outcomes such as collaboration, research, and problem solving. It can help students acquire content or conceptual knowledge, or develop disciplinary habits such as writing or communication. After determining whether your course has learning outcomes that fit with PBL, you will develop formative and summative assessments to measure student learning. Group contracts, self/peer-evaluation forms, learning reflections, writing samples, and rubrics are potential PBL assessments. Step Two: Design the Scenario.Â After researching, the students create products and presentations that synthesize their research, solutions, and learning. The format of the summative assessment is completely up to you. We treat this step like a research fair. Problem-based learning (PBL) is a student-centered pedagogy in which students learn about a subject through the experience of solving an open-ended problem found in trigger material. The PBL process does not focus on problem solving with a defined solution, but it allows for the development of other desirable skills and attributes. This includes knowledge acquisition, enhanced group collaboration and communication. The PBL process was developed for medical education and has since been broadened in 3.3.13 Product/process-centred 3.4 Conclusion. Part II. PBL & Research Skills.Â Research-based education however (top right in model), while perfectly achievable through PBL, remains under-represented in the curriculum until students start writing their thesis. Regarding research-based education, there is room for improvement in the quality of intended learning outcomes on the course level and structural coherence of research skills training in the curriculum. Project rationale This project starts from the paradoxical observation that PBL at UM, on the one hand, seems perfectly fit for training research skills because it mimics the research process, while on the other han Requires students to present their problems, research process, methods, and results. Following fifteen years of literature review and distilled educational experience, the Buck Institute for Education also identified seven essential elements for PBL but focsed them on project design.Â Teams of students propose and design a product based upon a challenging need or intricate problem. These young entrepreneurs pitch their ideas to business and community leaders in an effort to gain support for launching their product.Â Research from Nell K. Duke and researchers Putting PBL to the Test: The Impact of Project-Based Learning on Second-Grade Students' Social Studies and Literacy Learning and Motivation. See this research >>.