The Effectiveness of Problem-Based Instruction:

A Comparative Study of Instructional Methods and Student Characteristics

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Abstract

This study examined the potential differences between Problem Based Learning (PBL) and traditional instructional approaches in building high school students' knowledge of macroeconomic concepts and principles. Using a within-teacher, quasi-experimental design with data from 246 students in 11 classes taught by five teachers, we found a statistically significant ($p < .05$) difference between the problem-based and traditional Lecture/Discussion approach classes in the development of students' economic knowledge, with students in the problem based classes learning more. Results suggest that PBL effectiveness is differentially associated with the following student characteristics: verbal ability, interest in economics, and problem solving efficacy.

Educational reformers seeking to make schools and classrooms more effective learning environments have frequently proposed restructuring traditional curriculum and instruction to engage students in meaningful problem solving (Cognition and Technology Group at Vanderbilt [CTGV], 1997; Hiebert, Carpenter, Fennema, Fuson, Human, Murray, Alwyn, & Wearne, 1996, May). Problem-Based Learning (PBL) is an instructional approach where students are confronted with simulated, real-world problems, and is frequently advanced as a powerful and engaging learning strategy that leads to sustained and transferable learning (e.g., Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Jones Rasmussen, & Moffitt, 1996; Stepien & Gallagher, 1993; Stepien, Gallagher, & Workman, 1993). By engaging students in a realistic problem that reflects the context and constraints of the "real world," and by requiring students to clarify the problem and to conduct research necessary to solve the problem, it is argued that PBL encourages students to retain newly gained knowledge and solution strategies, fosters the development of self-directed learning strategies, and enables them to apply what they have learned to new and unfamiliar situations (Blumberg, 2000; CTGV, 1997; Maxwell, Bellisimo, & Mergendoller, 2001).

PBL deviates from more conventional instructional strategies by restructuring traditional teacher/student interaction toward active, self-directed learning by the student, rather than didactic, teacher-directed instruction (e.g., Barrows, 1988; Birch, 1986; Savery & Duffy, 1994; Smith & Ragan, 1999; Stepien & Gallagher, 1993; Torp & Sage, 1998). In PBL, teachers coach students with suggestions for further study or inquiry but do not assign predetermined learning activities. Instead, students pursue their own problem solutions by clarifying a problem, posing necessary questions, researching these questions, and producing a product that displays their thinking. These activities are generally conducted in collaborative learning groups, and these groups often solve the same problem in different ways and arrive at different answers.

The design of the PBL instructional approach used in the current study (Maxwell, et. al., 2001) is instantiated in a series of curriculum units focused on the knowledge, concepts, and principles that make up the American high school economics curriculum (Buck Institute for Education, nd). These units, which can take from one day to three weeks to complete, depending upon the unit, scaffold and, to some degree, constrain teacher and student behavior. Each unit contains seven interrelated phases: entry, problem framing, knowledge inventory, problem research and resources, problem twist, problem log, problem exit, and problem debriefing. Student groups generally move through the phases in the order indicated, but may return to a previous phase or linger for a while in a phase as they consider a particularly difficult part of the problem. The teacher takes a facilitative role, answering questions, moving groups along, monitoring and sanctioning positive and negative behavior, and watching for opportunities to direct students to specific resources or provide clarifying explanations. In this version of PBL, students do not learn entirely on their own; teachers still "teach," but the timing and extent of their instructional interventions differ from teachers using traditional Lecture/Discussion approaches. PBL teachers wait for teachable moments when students want to understand specific content or recognize that they must learn something before intervening or providing needed content explanations.

PBL: A Look at the Evidence

Although the theoretical basis for the PBL argument is compelling (Norman and Schmidt, 1992; Regehr & Norman, 1990), little empirical literature exists on the impact of PBL at the high school level. The bulk of the research conducted on PBL instruction has taken place in medical schools (i.e., http://meds.queensu.ca/medicine/pbl/PBLAbstracts.htm), where the PBL instructional model is increasingly at the heart of curriculum reform efforts (Armstrong, 1997; Kaufman, 1985).

Reviewers who have examined PBL medical school research have reached contradictory conclusions. Albanese and Mitchell (1993) concluded that problem-based instructional approaches are less effective in teaching basic science content (as measured by Part I of the National Board of Medical Examiners Exam), while Vernon and Blake (1993) reported that PBL approaches were more effective in generating student interest, sustaining motivation, and preparing students for the clinical interactions with patients. Berkson (1993) found that “the graduate of PBL is not distinguishable from his or her traditional counterpart”; this conclusion is consistent with a number of studies have shown no statistically significant difference in learner performance compared to students receiving lecture-based instruction (Albano, Cavallo, Hoogenboom, Magni, Majoor, Manenti, Schwirth, Steigler, & Van, 1996; Blake, Hosokawa, & Riley, 2000; Chang, Cook, Maguire, Skakun, Yakimets, & Warnock, 1995; Farquhar, Haf, & Kotabe, 1986; Kaufman & Mann, 1988; Login, Ransil, Meyer, Truong, Donoff, & McArdle, 1997). Culver (2000) conducted a metanalysis of literature reviews comparing the impact of PBL and Lecture/Discussion instruction and concluded that there is “no convincing evidence that PBL improves knowledge base and clinical performance….” Culver argues that the effects reported in the literature were either too small to be of consequence (generally less than .2 SD), or resulted from selection bias and other methodological defects. In response to Culver, Norman (2001) disputed the general approach of using high-stakes examinations, such as the National Board of Medical Examiners Exam, as a comparative outcome measure. He pointed out that many medical students “cram” or take special preparation courses to prepare for this exam. As a result, the impact of a curriculum design may well make a minor contribution to exam results (Norman, 2001).

Problems abound in generalizing research conducted on students in medical schools to a high school population (Maxwell, et. al., 2001). Medical students are an elite group with superior verbal and quantitative skills. They are older than high school students and their intellectual development has progressed further. They are, presumably, more experienced with and accomplished in the use of hypothetical-deductive reasoning. They have chosen to attend medical school and view their training as instrumental to future occupational success. Given these differences in student characteristics and learning context, it is dubious that findings based on research with medical students can be applied directly to high school courses structured around a PBL format and enrolling a diverse group of students.

Little research has been conducted within high schools comparing the effectiveness of PBL and traditional instructional approaches. Mergendoller, Maxwell, & Bellisimo (2000) compared the learning and attitudes of high school students studying economics using problem-based and lecture discussion methods. They found no statistically significant differences on unit-specific learning outcomes, although there was a difference in changes in general economics knowledge measured at the beginning and end of the semester, with the Lecture/Discussion classes learning more. Visser (2002) compared the effects of problem-based and lecture based instruction on student problem solving and attitudes in a high school genetics class. She found statistically significant differences ($p<.05$) in learning outcomes and motivation for students in the PBL and Lecture/Discussion treatments, with the PBL students reporting less motivation and learning less while recounting more confidence in their learning. Gallagher, Stepien, & Rosenthal (1992) compared the spontaneous problem solving of two groups of gifted high school students: one group had been enrolled in a problem-based Science and Society course, and a comparison group who were not enrolled in the problem-based course. They found that students enrolled in the problem-based course were more proficient in “problem finding” and engaged in problem-solving more successfully and spontaneously than the comparison students (who had not been taught a specific problem-solving process). Given the lack of decisive evidence that a PBL instructional approach is more effective than traditional Lecture/Discussion methodology, we hypothesized that in the current study there would be no difference in learning outcomes between students in PBL and traditional instructional environments.

In addition to incomplete knowledge regarding the effectiveness of PBL instructional approaches with high school students, we know little about the relationship of individual differences *among* high school students to content learning in PBL instructional environments. In a review of the implications of cognitive theory for problem-solving instruction, Fredericksen (1984) noted, “there is considerable evidence that aptitude-treatment interactions exist.” (Aptitude-treatment interactions occur when certain treatments have differential effects on students with different aptitudes.) We are interested in two general categories of aptitudes which may shed light on the efficacy of PBL environments with different students.

The first category of aptitudes include academic ability and subject matter interest. These relatively stable student characteristics are of interest as some authors have argued that lower ability and chronically uninterested students, who often do not thrive in traditional, Lecture/Discussion learning situations, are more likely to succeed in content rich, socially collaborative, contextually meaningful learning environments, such as those established in well-implemented PBL (e.g., Delisle, 1997; Glasgow, 1977; Jones et al., 1996). Our review of the PBL research literature, however, revealed no empirical studies suggesting that PBL is an effective instructional approach for lower ability high school students. In fact, it may be just the opposite. One of the best known American high schools incorporating a PBL approach is the Illinois Mathematics and Science Academy (www.imsa.edu). In addition to advocating the use of PBL instructional methodology, IMSA conducts research on the impact of PBL and trains teachers from other schools in PBL methodology. IMSA students, however, are chosen in a highly selective admission process and demonstrate superior ability in mathematics and science. A previous study by the current authors (Mergendoller, et al, 2000) found that verbal ability was positively associated with successful learning in *both* PBL and traditional, Lecture/Discussion high school courses. Given the scant research on problem-based instruction in high school, it is evident that more research is needed before claims of PBL's superior efficacy with lower-achieving students can be accepted.

In addition to academic ability, there is a question of whether interest in the subject matter being addressed is related to attainment in PBL learning environments, as students who are interested in learning a particular subject may be more willing to engage in the complex cognitive and interactional tasks required by PBL. Such active intellectual and social engagement is generally more demanding than listening to a lecture or participating in a class discussion (Blumenfeld, Mergendoller, & Swarthout, 1987; Doyle, 1983). Throughout a PBL experience, students take an active role in their learning as they discuss and decide on problem-solving strategies, divide research and other responsibilities among group members, communicate the results of their research back to the group, and finally craft a problem solution which is often presented to an external audience. In response to these considerations, we hypothesized that verbal ability and student content interest would be related to learning in PBL environments, and students with superior verbal ability and stronger interest in learning economics would learn more in PBL classes.

A second category of student aptitudes include those which are more directly related to the task and interactional demands of the PBL learning environment. Meyer, Turner, & Spencer (1997) reported that individual differences in motivation and self perception influenced mathematics attainment in investigative, activity-based group learning, an instructional modality with many characteristics in common with PBL. Ethnographic research by Anderson, Holland, & Palincsar (1997) documented how interpersonal dynamics and perceptions of the capability of other group members can alter the task demands and participatory behavior, and can limit the learning opportunities available to less academically talented group members.

Given this research and our own observations of PBL learning environments, we hypothesized that students who preferred to learn in groups and who perceived themselves to be competent problem-solvers would learn more in PBL learning environments.

Finally, Brown, Johnson, Mayall, Boyer, Reis, Butler, Weir, & Florea (2002) examined whether gender is associated with differences in PBL participation and learning, and identified little differentiation between males and females. We hypothesized that in the current study there would be no gender differences in relation to learning outcomes.

The following study addresses four questions:

1) Is the Problem Based instructional method more effective than a traditional Lecture/Discussion approach in teaching high school students about macroeconomic concepts?

2) Is verbal ability or content interest associated with student success in PBL learning environments?

3) Is student preference for group work, and perceived problem-solving efficacy associated with student success in PBL learning environments?

4) Are the learning outcomes for boys and girls different in PBL learning environments?

Method

Design. Our study employed a within-teacher, quasi-experimental design with non-random assignment of students to classes. Five veteran teachers at four different high schools participated in the study. All of the high schools were located in a large metropolitan area in Northern California. Two of the high schools were suburban, and two were urban. To control for teacher effects, all teachers taught the same macroeconomics content using a PBL approach with one or more classes and a traditional Lecture/Discussion approach with one class. Teachers were allowed to select which class they would instruct using a Lecture/Discussion approach, but this choice was made before the school year began, and before teachers had received their class lists. Consequently, teachers had no advance indication of the student composition of each class. PBL and traditional classes were distributed throughout the school day, with four of the five teachers teaching the PBL and traditional classes within 2 periods of each other. The remaining teacher's PBL and traditional classes were within 3 periods of each other.

The focus of the units in both the PBL and Lecture/Discussion classes consisted of the macroeconomics content defined by the *National Voluntary Content Standards in Economics* (www.economicsamerica.org), and *A Framework for Teaching Basic Economic Concepts* (Sanders and Gilliard, 1995).[1] The problem-based unit, *The President's Dilemma*, casts students as teams of economic advisors to the president during a time when the increasing cost of oil has resulted in sluggish economic growth, high unemployment and high inflation. Solution of this problem requires students to recommend fiscal and monetary policy alternatives that will address these economic problems and get the economy growing again. To determine the best policy alternatives, students must develop a knowledge of monetary and fiscal policies, gross domestic product, unemployment and inflation, economic incentives, public policy alternatives and costs. As the problem unfolds, students discover that scarcity dictates societal tradeoffs and opportunity costs in pursuing a healthy economy.

This problem is ill-structured in that information necessary to solve the problem is not "pre-packaged," but exists in a variety of places. Students' judgments of relevant and irrelevant information and their definition of the problem being solved changes as they delve deeper into the problem. There are also, as in real-world problems, multiple correct solutions to the problem as well as multiple incorrect ones (Maxwell et al., 2001). The problem, although allowing for student discovery and independent learning, proceeds in a structured manner. Students work in groups, they clarify the nature of the problem and determine what economic concepts and relationships are necessary to solve it, and they undertake the research and reading necessary to understand the relevant economic theory. The problem concludes with a presentation of the solution each group has fashioned to an audience of interest group representatives (e.g., the elderly, labor unions, business owners, etc.). These representatives (usually played by other teachers or interested parents) are primed with specific questions that elicit students understanding – and misunderstanding – of economic concepts and principles (e.g., “Given the fiscal policy actions you have proposed, what would be the impact if the Federal Reserve unexpectedly raised the discount rate?”). Although one student gives the group’s speech, questions are addressed to individual group members. This procedure, and the potential for public embarrassment, increases the pressure on students to understand the economic concepts at the heart of the unit.

Teachers were asked to spend the same amount of time and address the same concepts in both the Lecture/Discussion and PBL classes. All teachers had attended weeklong training workshops (under the guidance of a university economics professor and co-developer of the problem) to prepare them to use the PBL economics units in their classes. Two of the five participating teachers have worked as trainers for subsequent workshops. All instructional resources necessary to teach the PBL units were provided, including a carefully prepared curriculum guide and tips and strategies for guiding students through the problems. Conversations with teachers as they taught the units and at debriefings when they had completed the unit suggested that the PBL and Lecture/Discussion approaches were implemented as intended by the materials developers and researchers.[2]

Student Participants. A total of 346 twelfth-grade students in 11 classes completed one or more of the instruments used in the study. The following data analysis is based on data collected from the 246 students who completed the pre- and post-macroeconomics knowledge instrument and the verbal ability measure. These students make up 71% of all the students in the classes. The amount of student attrition is testament to the elevated absence rates among graduating seniors during the second semester of the senior year.

Instruments. At the beginning of the semester, students in both the traditional and PBL classes completed the aptitude measures (academic ability, attitude toward economics, preference for group work and problem-solving efficacy). Immediately before (pretest) and immediately after (posttest) the macroeconomics unit, students completed a multiple choice content test.

Verbal ability. Academic ability was measured using the Quick Word Test: Level 1 (Borgatta, 1964). Each item consisted of a target word in capital letters followed by four lower-case words. Students were asked to circle the appropriate synonym for the target word. A student's score was calculated by summing the correct answers. The test authors report strong validity and reliability, including correlations greater than 0.80 with the Verbal, Total, and IQ scales of the Weschler Adult Intelligence Scale and split-half reliability coefficients of greater than 0.90 (Borgatta & Corsini, 1964, 1967).

Interest in learning economics. We searched for an instrument appropriate to measure high school students' interest in learning economics, and did not find anything suitable. The instruments we reviewed assumed a basic knowledge of economics, and contained items such as "I enjoy economics" or "Economics is practical" (Hodgin, 1984). Since the majority of high school students have never studied economics, and consequently have incomplete or erroneous knowledge of economic concepts and principles, asking them about interest in economics is like asking them their interest in biophysics – they may have heard the word, but generally don't know enough about the concept to express a valid opinion. A result we designed our own instrument asking students about their interest in learning about economic issues. The instrument consisted of the stem: "How interested are you in reading newspaper and/or magazine articles about. . . " followed by four items describing the economic plight of various groups (e.g., economic issues faced by the poor) and two items describing general economic issues (e.g., unemployment). Students responded on a five-point Likert scale running from Very Interested to Not Interested. We calculated scores by taking the mean response across all six items. Cronbach's alpha for the instrument was 0.80.

Preference for group work. We measured preference for group work using four items sharing the common stem, "When I work with my classmates in small groups, I usually find that . . . ." Items included: "it does not help me learn, " "it gives me new ways to think about what we are studying," and "it is an excellent way to study for tests." Students indicated their response on a five-point Likert scale running from Strongly Agree to Strongly Disagree. After reversing negatively worded items, we calculated student scores using the mean of the four items. Cronbach's alpha for this scale was 0.79.

Problem-solving efficacy. We measured students' perceptions of their own problem solving skills by asking them about the behaviors required in PBL learning environments. The instrument consisted of the stem: "I have difficulty solving problems when . . . . " Items described processes of problem solving, negotiation, and discussion such as "I have to find my own resources and information," and "I have to argue my own point of view. Students responded on a five-point Likert scale running from Strongly Agree to Strongly Disagree, and their scores reflect the mean of the six items. Cronbach's alpha for this scale was 0.82.

Macroeconomics knowledge. We created a unit-specific content test using 16 four-part, multiple choice items drawn from the Test of Economic Literacy (Soper & Walstad, 1987) and the test bank accompanying a widely used high school economics textbook (Marlin, Mings, & Swanson, 1995). The items addressed the full range of cognitive objectives (knowledge, comprehension, application, analysis, and evaluation) described by Bloom, Englehart, Furst, Hill, & Krathwohl (1956), and were focused on the specific concepts to be covered in the classes. Students' scores were obtained by summing the number of correct items. Inspection of histograms for both the pretests and posttests suggest a normal distribution with no outliers.

Results

Table 1 displays descriptive information about the students and classes participating in the research, as well as mean posttest-pretest gain and effect size by teacher and instructional condition. As can be seen, there was considerable heterogeneity among teachers in the verbal ability of their students, ranging from a mean of 36.67 for students in Teacher E's PBL class to a mean of 59.51 for students Teacher C's Lecture discussion class. Similar heterogeneity is seen in mean pretest score, ranging from 4.42 to 8.57. For four of the teachers, comparisons of the verbal ability and pretest scores among students in the PBL and traditional instruction approaches did not reach statistical significance, suggesting that for each of these teachers the students in the PBL and traditional classes were of similar academic ability. For one teacher (D), there was a statistically significant difference between the pretest scores, but not the verbal ability scores, of students in the PBL and traditional instructional approaches. This teacher also showed the greatest difference between the gains demonstrated by students in the PBL and traditional classes.

Independent-Samples T Tests were used to examine whether students in the PBL and Lecture/Discussion classes showed statistically significant differences in their Verbal Ability, Interest in Learning Economics, Problem Solving Efficacy, and Preference for Group Work. Across instructional conditions, there were no statistically significant differences, but Interest in Learning Economics came close ($t = 1.89$, $p = .06$) with PBL students reporting more interest at the beginning of the study than Lecture/Discussion students.

Independent-samples T tests were also used to compare posttest-pretest change scores by instructional condition across all teachers and within teachers. Across all classes, the posttest/pretest gain was +1.48 (SD=2.52) for the PBL students and +.82 (SD=2.81) for the Lecture/Discussion students. This difference is statistically significant, $t = 1.94$, $p = .05$, and equivalent to an effect size of .59 for students in the PBL instructional approach and .29 for students in the Lecture/Discussion approach. This indicates that on average students in the PBL classes gained more on the macroeconomics content test than students in the traditional classes. Looking at the within-teacher comparisons displayed on Table 1, we see that PBL classes taught by four of the five teachers gained more than the traditional classes, although only two of these comparisons reach statistical significance. For one teacher (C), students gained more in the traditional class, although this difference was not statistically significant at the .05 level.

Insert Table 1 About Here

The above data suggest that the answer to the first research question is that the PBL instructional approach was more effective than a traditional Lecture/Discussion approach in helping students to learn basic macroeconomic concepts, contrary to what we had hypothesized based on the medical education literature.

The remaining research questions examine whether the PBL approach is more effective for students with certain characteristics. For this analysis, we treated each student characteristic separately and created tertiles containing students with “high,” “medium,” and low levels of each characteristic (except for gender). Thus the “high” tertile included students whose scored in the 67^{th} to 99^{th} percentile for that characteristic. Conversely, the “low” tertile included students scoring in the 0 to 33^{rd} percentile. The “medium” tertile contained the remaining students. After splitting the population into these three groups, we conducted four separate Analyses of Variance within each instructional condition. Post-hoc comparisons with Bonferroni corrections were used to evaluate whether the posttest-pretest score differed between students in any of the tertiles. We found no differences statistically significant at the .05 level within either the PBL or Lecture/Discussion students.

Insert Table 2 About Here

For each variable, we also conducted Independent-Samples T-Tests within tertile comparing mean posttest-pretest scores of students in the PBL and Lecture/Discussion classes. Table 2 displays the data used in this analysis, the T-Tests results, and the effect size for each comparison. We include effect size information as many researchers believe that effect sizes provide important additional information about the magnitude of differences, whether or not they reach statistical significance, which is directly related to sample size (e.g., Huberty, & Pike, 1999; Kier, 1999).

Except for students in the "high" Interest in Learning Economics tertile, there were no statistically significant differences at the .05 level in the mean posttest-pretest change of students in PBL and Lecture/Discussion classes. At the same time there are some interesting differences in effect size to which we will return in the Discussion section.

Insert Table 3 About Here

Finally, Table 3 displays mean posttest-pretest change by gender. The raw data suggests that both genders learned more in the PBL classes, although these differences were not statistically significant at the .05 level. The effect size statistics suggest that the PBL classes were slightly more beneficial to females than to males.

Discussion

While not wanting to overstate the import of a single study, our results provide some support for those who advocate PBL instructional approaches. Students' content learning in high school economics classes, as measured by a traditional multiple-choice measure, was greater in PBL classes than in Lecture/Discussion classes. We believe this to be a compelling finding, given that the statistically significant difference in posttest-pretest score across all classes is mirrored by differences at the teacher level favoring PBL classes for four out of the five teachers. Across all teachers, the average effect size difference for PBL-Lecture/Discussion comparisons was .25 or 1/4th of a standard deviation. Interestingly, this is roughly the effect size difference reported by Culver (2000) in his metanalysis of the comparative impact of PBL and traditional instruction in medical schools. Unlike Culver, however, we do not consider the size of this difference to be negligible. Instead, we would apply the convention established by Cohen (1988) defining effect sizes of this magnitude to be “small” but not meaningless. Moreover, most students would not consider trivial the mean difference in posttest-pretest score between the PBL and Lecture/Discussion classes. Across all teachers, PBL classes gained .66 more than the Lecture/Discussion classes. This is equivalent to a raw score difference of 4% – or the distance between a B and a B+ in a grading system based on a maximum score of 100%.

We find these results exciting, but at the same time, they leave unanswered many important questions. A key limitation of the current study is the lack of in-depth information about what, exactly, teachers were doing in the PBL classes that distinguished them from the Lecture/Discussion classes, and how these differences were associated with increased student learning. Future research should address this lacunae with observational studies of PBL instructional environments. We believe it of special importance to develop operational concepts that document the processes of problem based learning, and distinguish its essential components. We also believe it important to develop measurement strategies that can be used to assess non-content related outcomes theoretically associated with problem based instructional approaches and espoused by PBL advocates. We are sympathetic to Norman’s (2001) argument that it is the test preparation activities engaged in by individual students – rather than the instructional approach used by the teacher – that best accounts for differences in performance on standardized, content-based tests. Well-designed research comparing the impact of PBL and traditional instruction on students' self-management skills and practices and ability to apply a problem-solving algorithm to non school-centered problems is sorely needed. We shall be turning our own research efforts in this direction.

Our next two research questions focused on whether PBL was a more effective learning environment for students with certain characteristics. Here the results displayed on Table 2 are more equivocal. While comparisons of posttest-pretest change by variable tertile within instructional condition were not statistically significant at the .05 level, the effect size differences for PBL and Lecture/Discussion students in different variable tertiles are provocative. We argue that these comparisons provide some evidence that students with different characteristics perform differently within PBL and Lecture/Discussion classes. Consider, for example, the difference in effect size for students in the high (.05), medium (.41) and low (.40) verbal ability tertiles. While there was no meaningful learning difference by instructional condition for the most verbally proficient students, students whose verbal ability was mid-range and below learned more in the PBL classes than they did in the Lecture/Discussion classes. This result can not be accounted for as an instance of "regression to the mean," as medium tertile students in the PBL classes scored slightly higher than the medium Lecture/Discussion students on the Pretest, while the relative ranking was reversed for the low tertile students. In each case, the effect size difference favoring the learning of the PBL students was approximately .40, a small, but not insignificant difference, equivalent to a raw score difference of 6-7%, or the distance between a D+ and a solid C.

Although this is hardly a ringing endorsement of the use of PBL approaches with lower-achieving students, it does, we believe, provide the first empirical evidence – rather than theoretical argument – supporting the efficacy of PBL instructional methodology for students with limited verbal skills, a key component of cognitive ability measures, and consequently, a predictor of school success (Gage, & Berliner, 1997, p. 58 – 59). Further empirical examination of the efficacy of PBL with students who typically do not succeed in school is another important avenue of future research, and we would urge that students' "at-risk" status be ascertained by multiple measures, not just verbal ability.

Instructional approach also appear to affect students differently according to their interest in learning economics. Lecture/Discussion students most interested in learning economics showed little change in mean content knowledge (-.10) between the pre-test and posttest. On the other hand, PBL students with the same level of interest in learning economics gained in content knowledge (+1.24). Although this difference is not statistically significant, it is equivalent to ½ standard deviation – a "medium" effect size according to Cohen's (1988) convention, and equivalent to a raw score gain of 8%. It is tantalizing to argue that students' with more interest in learning economics were able to capitalize on this interest to expand their personal explorations of economics in the PBL classrooms, an activity that could not occur as easily (if at all) in the Lecture/Discussion classrooms.

The effect size differences for problem solving efficacy present a curvilinear (u-shaped) profile and suggest tell another story. Whether a student was in a PBL or Lecture/Discussion classroom did not appear to make a difference for middle tertile students. On the other hand, students in the top and bottom tertile of problem solving efficacy learned more in the PBL classrooms, with the effect size difference between top tertile Lecture/Discussion and PBL students exceeding ¾ standard deviation (+.88). Again, given that this is a "black box" study with no record of student interactions, one can only speculate why this might be the case. We present the following hypothesis as a plausible explanation in hopes that it might suggest a fruitful area for future research.

Published accounts of student interaction in problem-solving groups (e.g., Anderson, et. al., 1997), as well as our own observations during the development of the PBE units suggest that group members vary considerably in the degree to which they take a leadership role. Some group members plunge in and lead the problem solving effort. Others hang back and look to others to assign tasks and monitor results. All teachers who place their students in groups confront “freeloading,” where one or two students do the majority of the work for the others. We had this (as well as other) group management problems in mind when we designed the PBE units, and followed Slavin’s dictim that maximum group learning occurs when there is individual accountability (e.g., Slavin, 1990). We therefore structured each unit to include two types of individual accountability – an individually administered multiple choice test and a procedure by which all group members are held individually accountable for justifying their problem solution and explaining their understanding the key economic concepts. For the President’s Dilemma, this procedure requires group members to explain, individually, the logic behind their economic prescriptions to an audience of interest group representatives such as the elderly and union members. We believe holding students individually accountable for their learning has a definite influence on the nature of the group interaction, and that students who are not confident in solving the problem by themselves reach out to other students for clarification and enlightenment during group research and discussion.

The review of group processes in the classroom by Webb & Palincsar (1996) identifies two individual actions associated with increased learning; 1) giving elaborated explanations to other group members, and 2) applying explanations (either received or self-generated) to solve problems or perform tasks (p. 854). We hypothesize that the PBL students who were confident in their problem-solving ability would be the one most likely to explain and clarify economic ideas for other group members. Similar opportunities for students to clarify other students’ economic understandings would not be available in Lecture/Discussion classes. At the same time, students who felt less confident in solving the economic problems by themselves could solicit help from other students and digest and apply economic explanations as they worked through the problem. Once more, similar opportunities might not be available in the Lecture/Discussion classrooms. This analysis is highly speculative, but it does point the way to important future areas of study.

The final student characteristics that merit discussion are Preference for Group Work and Gender. Here PBL-Lecture/Discussion effect size differences by Preference for Group Work tertile are too small (.15) to be meaningful. We suspect that the impact of students' preferences for a certain classroom instructional approach is outweighed by teachers' accountability systems, and the nature of the interaction that occurs in the classroom. In the abstract, students may prefer working by themselves or with others, but once they are actually in Mrs. Jones class their learning is more influenced by environmental and structural factors than their own learning group work preferences. Similarly, we did not find noteworthy differences in "PBL benefit" between female and male students. The difference in PBL – Lecture/Discussion effect size comparisons is relatively similar for both genders, reflecting a raw score difference between of 4 – 5% for each gender.

Looking ahead to further research on PBL we urge that the scope of the research endeavor be expanded. The current study examined student learning within a single, two-week unit. If problem-based instruction is to help students develop the deep, applicable knowledge and analysis skills that facilitate economic literacy, it is likely that students will need to solve multiple problems over the course of a semester or school year. Research should focus on the additive impact of multiple units, and comparisons should be made of PBL – Lecture/Discussion learning gains during initial units when students are first learning how to take advantage of the PBL approach and again when they are familiar with the working of PBL and ready to exploit the learning opportunities it offers.

In closing, we wish to point out that while PBL was more effective than Lecture/Discussion teaching in increasing academic achievement, the size of this increase, although statistically significant, was not great. PBL is not the silver bullet that will drastically increase the achievement of all students. At the same time, our data demonstrate that it did enable the majority of students in our study to learn more. This finding should be liberating to teachers, instructional designers, and researchers who seek alternatives to traditional “sage-on-the-stage” pedagogy. In this study, PBL not only “did no harm,” it did some good, and this should encourage educators to tinker with PBL to better understand the classroom conditions and social arrangements necessary to maximize its effectiveness.

This future research and development effort should include a focus on the hard to measure, learning outcomes of sustained content retention and application as well as self-management and problem-solving skills. Inventive methods need to be developed to compare whether students in the PBL classes can *apply* economic knowledge gained in the classroom to real-world situations. This is the critical test for problem-based teaching (Mayer, & Wittrock, 1996; CTGV, 1997), and the outcome that will validate its promise. Further research on this question, as well as more analysis of the optimal configuration of Problem-based teaching are needed.

References

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine*, *68*, 52 - 81.

Albano, M. G., Cavallo, F., Hoogenboom, R., Magni, F., Majoor, G., Manenti, F., Schuwirth, L., Stiegler, I., and van, d., V (1996). An international comparison of knowledge levels of medical students: the Maastricht Progress Test*. Medical Education*, 30, 239-245.

Anderson, C. W., Holland, J. W., & Palincsar, A. S. (1997, March). Canonical and sociocultural approaches to research and reform in science education: The story of Juan and his group. *Elementary School Journal, 97*(4), 359 – 384.

Armstrong, E. G. (1997). *The challenge of problem based learning (2nd ed.).* London: Kogan Page.

Barrows, H. S. (1988). *The tutorial process*, Springfield Ill.: Southern Illinois University School of Medicine.

Berkson. 1993. Problem-based learning: Have the expectations been met? Invited Review, *Academic Medicine*, 10, S79 – 88.

Birch, W. (1986). Towards a model for problem-based learning. *Studies in Higher Education,* 11: 73-82.

Blake, R. L., Hosokawa, M. C., & Riley, S. L. (2000). Student performances on Step 1 and Step 2 of the United States Medical Licensing Examination following implementation of a problem-based learning curriculum. *Academic Medicine*, *75*, 66 – 70.

Bloom, B. S., Englehart, M. B., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives. *The classification of educational goals. Handbook I: Cognitive domain*. New York: Longmans Green.

Blumberg, P. (2000). Evaluating the evidence that problem-based learners are self-directed learners: A review of the Literature. *In* D. H. Evensen & C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions*. Mahwah, NH: Lawrence Earlbaum Associates.

Blumenfeld, P. C., Mergendoller, J. R., & Swarthout, D. W. (1987). Tasks as heuristics for understanding student learning and motivation. Journal of Curriculum Studies, 19(2), 135-148.

Borgatta, E.G. (1964). *Quick word test: Level 1-form cm*. New York: Harcourt, Brace and World.

Borgatta, E.G., & Corsini, R.J. (1967). *Quick word test: Supplementary report*. New York: Harcourt, Brace and World, Inc.

Borgatta, E.G., & Corsini, R.J. (1964). *Quick word test: Directions for administering, scoring, and interpreting*. New York: Harcourt, Brace and World, Inc.

Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K., & Williams, S. M. (1990). Anchored Instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Advances in computer-video technology.* Hillsdale, NJ: Erlbaum.

Brown, S. W., Johnson, P. R., Mayall, H., Boyer, M., Reis, S., Butler, M., Weir, K., & Florea, N. (2002). Gender differences in a problem-based learning environment: Do they exist? Paper presented at the 2002 American Educational Research Association Annual Meeting, April 4, 2002, New Orleans, LA.

Buck Institute for Education. (nd). *Problem Based Economics*. Novato, CA: Author.

Chang, G., Cook, D., Maguire, T., Skakun, E., Yakimets, W. W., & Warnock, G. L. (1995). Problem-based learning: its role in undergraduate surgical education. *Canadian Journal of Surgery*, *38*, 13 – 21.

Cognition and Technology Group at Vanderbilt. (1997). *The Jasper project: lessons in curriculum, instruction, assessment, and professional development.* Mahwah, NJ: Lawrence Erlbaum Associates.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Earlbaum

Culver, J. A. (2000, March). Effectiveness of Problem-based learning curricula: Research and theory. *Academic Medicine, 75*(3), 259-266

Delisle, R. (1997). *How to use* problem-*based learning in the classroom.* Alexandria, VA: Association for Supervision and Curriculum Development.

Doyle, W. (1983). Academic Work. *Review of Educational Research, 53,* 159 – 199.

Farquhar, L. J., Haf, J., & Kotabe, K. (1986). Effect of two preclinical curricula on NBME Part I examination performance. *Journal of Medical Education*, *61*, 368 – 373.

Frederiksen, N. (1984). Implications of cognitive theory for instruction in problem solving. *Review of Educational Research, 54*(3), 363 - 407.

Gage, N. L., & Berliner, D. C. (1997). *Educational Psychology 6th Edition.* Boston: Houghton Mifflin Company.

Gallagher, S., Stepien, W., & Rosenthal, H. (1992). The effects of problem-based learning on problem solving. *Gifted Child Quarterly, 36*(4), 195 – 200.

Glasgow, N., (1997). *New curriculum for new times: A guide to student-centered, problem-based learning.* Thousand Oaks, CA: Corwin Press, Inc.

Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K., Human, P., Murray, H., Alwyn, O., & Wearne, D. (1996, May). Problem solving as a basis for reform in curriculum and instruction: The case of mathematics. *Educational Researcher, 25*(4), 12-21.

Hodgin, R. F. (1984). *Attitude assessment for research in economics education.* ERIC Document Service ED 248 779.

Huberty, C. J., & Pike, C. J. (1999). On some history regarding statistical testing. In B. Thompson (Ed.), *Advances in Social Science Methodology (Vol. 5).* Stamford, CT: JAI Press, 1 – 22.

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1996). *Real-life problem solving: A collaborative approach to interdisciplinary learning.* Washington, DC: American Psychological Association.

Kaufman, A. (Ed.) (1985). *Implementing problem-based medical education.* New York: Springer.

Kaufman, D. M., & Mann, K. V. (1998). Comparing achievement on the Medical Council of Canada Qualifying Examination Part I of students in conventional and problem-based learning curricula. *Academic Medicine*, *73*, 1211 – 1213.

Kier, F. J. (1999). Effect size measures: What they are and how to compute them. In B. Thompson (Ed.), *Advances in Social Science Methodology (Vol. 5).* Stamford, CT: JAI Press, 87 – 100.

Login, G. R., Ransil, B. J., Meyer, M., Truong, N. T., Donoff, R. B., & McArdle, P. J. (1997). Assessment of precinlical problem-based learning versus lecture-based learning. *Journal of Dentistry Education*, *61*, 473 – 479.

Marlin, Matthew, Mings, T., & Swanson, D. (1995). *Teaching and testing from The Study of Economics: Principles, Concepts and Applications* (5th edition). Guilford, Connecticut: Dushkin Publishing Group/Brown and Benchmark Publishers.

Maxwell, N. L., Bellisimo, Y., & Mergendoller, J. (2001, March/April). Problem-based learning: Modifying the medical school model for teaching high school economics. *The Social Studies, 92*(2), 73-78.

Mayer, R. E., & Wittrock, M. C. (1996). Problem-solving transfer. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of Educational Psychology*. New York: Macmillan, 47 – 62.

Mergendoller, J., R., Maxwell, N. L., & Bellisimo, Y. (2000). Comparing problem-based learning and traditional instruction in high school economics. *Journal of Educational Research, 93*(6), 374-382.

Meyer, D. K., Turner, J. C., & Spencer, C. A. (1997). Challenge in a mathematics classroom: Students' motivation and strategies in project-based learning. *Elementary School Journal, 97*(5), 501 - 521.

Norman, G., R. (2001, April). The Cognitive perspective on learning: Problem-based learning as a facilitator of knowledge transfer. Paper presented at the Annual Meeting of the American Educational Research Association, Seattle, WA.

Norman, G. R., & Schmidt, H. G. (1992). The Psychological basis of problem-based learning: A Review of the evidence. *Academic Medicine, 67,* 557 - 565.

Regehr, G., & Norman, G. R. (1990). Issues in cognitive psychology: Implications for professional education. *Academic Medicine, 71*, 988 - 1001.

Sanders, P. , & Gilliard, J. eds. (1995). *A framework for teaching basic economic concepts: With scope and sequence guidelines, K-12.* New York: Joint Council on Economic Education.

Savery, J. R., & Duffy, T. M. (1994). Problem-based learning: An instructional model and its constructivist framework. *Educational Technology*, *35*(5), 31 – 38.

Slavin, R. E. (1990). *Cooperative Leaning: Theory, research and practice*. Englewood Cliffs, NH: Prentice Hall.

Smith, P., & Ragan, T. (1999). Instructional Design, 2nd Edition. Upper Saddle River, NJ: Merrill Publishing.

Soper, J. C., & Walstad, W. B. (1987). *Test of economic literacy (2nd edition)*. New York: Joint Council on Economic Education.

Stepien, W., & Gallagher, S. (1993). Problem-based learning: As authentic as it gets. *Educational Leadership, 50*(7), 25- 28.

Stepien, W., Gallagher, S., & Workman, D. (1993). Problem-based learning for traditional and interdisciplinary classrooms. *Journal for the Education of the Gifted*, 16 (d4), 338-357.

Torp, L., & S. Sage. (1998). *Problems as possibilities: Problem-based learning for K-12 education*. Alexandria, VA: Association for Supervision and Curriculum Development.

Vernon, D. T. A., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*, 550 - 563.

Visser, Y. L. (April, 2002). Effects of problem-based and lecture-based instructional strategies on problem solving performance and learner attitudes in a high school genetics class. Paper presented at the 2002 Annual Meeting of the American Educational Research Association, New Orleans.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of Educational Psychology*. New York: Macmillan, 841 – 876.

Notes

1. This curriculum was developed by a partnership between high school teachers, an educational research institution, and economics faculty at a university (Bellisimo et al., 1998). The *President's Dilemma* unit is part of a eight-unit PBL economics' curriculum designed for a semester-long high school course, although each of the eight units can be used in isolation. All of the units focus on the core economic concepts of scarcity, opportunity costs, and tradeoffs, as well as unit-specific concepts (e.g., Fiscal Policy, Monetary Policy, Inflation, etc.)

2. More extensive information on the Problem Based Economics units can be found at http://www.bie.org/pbss/pbe/index.php

Table 1: Means and Standard Deviations of Verbal Ability, Pretest, and Posttest-Pretest Change by Teacher and Instructional Condition

Teacher		N Students	Verbal Ability	Pretest	Posttest-Pretest Change	Effect Size
A	**PBL**	44 (2 classes)	56.61 (12.18)	7.68 (2.61)	1.36 (2.18)	.50
	Lecture/Discussion	19	56.78 (17.35)	7.21 (3.28)	-.21 (2.96)	-.06
	Difference		-.17	.55	***1.57****	.61
B	**PBL**	26	42.46 (11.47)	4.42 (1.78)	1.42 (2.86)	.70
	Lecture/Discussion	24	41.70 (11.45)	5.13 (2.69)	1.04 (2.69)	.35
	Difference		.77	-.70	.38	.14
C	**PBL**	23	58.39 (18.98)	7.78 (2.61)	1.09 (2.39)	.44
	Lecture/Discussion	23	59.51 (12.51)	8.57 (2.48)	2.35 (3.02)	.95
	Difference		-1.12	-.78	-1.26	-.46
D	**PBL**	21	49.76 (14.91)	5.10 (2.61)	2.43 (2.40)	.93
	Lecture/Discussion	21	52.29 (14.21)	7.14 (2.78)	-.19 (2.62)	-.06
	Difference		-2.52	***-2.05****	***2.62*****	1.04
E	**PBL**	25	36.67 (11.60)	5.88 (2.33)	1.32 (2.88)	.57
	Lecture/Discussion	20	40.92 (14.33)	5.10 (2.13)	.85 (2.03)	.38
	Difference		-4.25	.78	.47	.19
ALL TEACHERS						
	PBL	139	49.64 (15.86)	6.37 (2.77)	1.48 (2.52)	.59
	Lecture/Discussion	107	50.14 (15.72)	6.63 (2.97)	.82 (2.81)	.29
	Difference		-.50	-.25	***.66****	.25

NOTE: * = $p < .05$, ** = $p < .01$

Table 2: Mean Pretest and Posttest-Pretest Change within Instructional Condition by Verbal Ability, Interest in Learning Economics, Problem Solving Efficacy, Preference for Group Work Tertiles

Variable	Tertile / Condition	N	Pretest	Posttest-Pretest Change	SD	*t*	Effect Size
Verbal Ability							
	High					.24	.05
	PBL	44	8.16	1.45	2.25		
	L/D	39	8.38	1.31	3.30		
	Medium					1.67	.41
	PBL	43	6.12	1.84	2.54		
	L/D	24	5.83	.67	3.10		
	Low					1.66	.40
	PBL	49	4.92	1.22	2.71		
	L/D	31	5.45	.26	2.08		
Interest in Learning Economics							
	High					***2.21****	.50
	PBL	55	6.56	1.24	2.68		
	L/D	31	7.39	-.10	2.70		
	Medium					.92	.21
	PBL	43	6.56	1.67	2.59		
	L/D	34	5.94	1.12	2.68		
	Low					.61	.14
	PBL	41	5.93	1.61	2.22		
	L/D	42	6.62	1.26	2.90		
Problem Solving Efficacy							
	High					1.73	.88
	PBL	52	7.62	1.48	2.33		
	L/D	33	7.48	-.58	2.37		
	Medium					.05	-.01
	PBL	38	6.13	1.37	2.47		
	L/D	40	6.18	1.40	2.79		
	Low					1.81	.40
	PBL	49	5.24	1.57	2.78		
	L/D	34	6.32	.38	3.17		
Preference for Group Work							
	High					1.29	.32
	PBL	48	5.73	1.10	2.60		
	L/D	28	6.43	.36	2.09		
	Medium					.84	.17
	PBL	47	6.57	1.53	2.23		
	L/D	44	6.07	1.14	2.26		
	Low					1.42	.32
	PBL	44	6.86	1.84	2.70		
	L/D	35	7.49	.80	3.80		

NOTE: * = $p < .05$

Table 3: Mean Posttest-Pretest Change by Gender

Gender Condition	N	Mean Change	SD	*t*	Effect Size
Female				1.70	.32
PBL	69	1.86	2.08		
L/D	46	1.04	3.05		
Male				.95	.17
PBL	70	1.11	2.85		
L/D	61	.66	2.63		