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The Effectiveness of Problem-based Instruction: A Comparative Study of Instructional Methods and Student Characteristics

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Abstract

This study compared the effectiveness of problem-based learning (PBL) and traditional instructional approaches in developing high-school students' macroeconomics knowledge and examined whether PBL was differentially effective with students demonstrating different levels of four aptitudes: verbal ability, interest in economics, preference for group work, and problem-solving efficacy. Over all, PBL was found to be a more effective instructional approach for teaching macroeconomics than traditional lecture–discussion ($p = .05$). Additional analyses provided evidence that PBL was more effective than traditional instruction with students of average verbal ability and below, students who were more interested in learning economics, and students who were most and least confident in their ability to solve problems.

Keywords: student achievement, project-based learning, problem-based learning, quasi-experimental design, student outcomes

Introduction

Problem-based learning (PBL) is an appealing instructional strategy. Rather than reading or hearing about the facts and concepts that define an academic field of study, students solve realistic (albeit, simulated) problems that reflect the decisions and dilemmas people face every day. Many argue that PBL is a powerful and engaging learning strategy that leads to sustained and transferable learning (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Hiebert et al., 1996; Jones, Rasmussen, & Moffitt, 1996; Stepien & Gallagher, 1993; Stepien, Gallagher, & Workman, 1993). PBL, it is argued, fosters the development of

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self-directed learning strategies and makes it easier for students to retain and apply knowledge and solution strategies to new and unfamiliar situations (Blumberg, 2000; Cognition and Technology Group at Vanderbilt [CTGV], 1997; Maxwell, Bellisimo, & Mergendoller, 2001).

PBL deviates from more conventional instructional strategies by restructuring traditional teacher–student interactions toward active, self-directed learning by the student (Barrows, 1988; Birch, 1986; Savery & Duffy, 1994; 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 that 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 curricular units focused on the knowledge, concepts, and principles that comprise the American high-school economics curriculum (Buck Institute for Education, n.d.). These units can take from one day to three weeks to complete, 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 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 positive and negative behavior, and watching for opportunities to direct students to specific resources or to 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 those used in traditional approaches. PBL teachers wait for teachable moments before intervening or providing needed content explanations, such as when students want to understand specific content or recognize that they must learn something.

Although the theoretical basis for the PBL argument is compelling (Norman & Schmidt, 1992; Regehr & Norman, 1990), little research has been conducted on the impact of PBL at the high-school level because most studies have occurred in medical schools (Pross, 2005), where curriculum reform is frequently based on the PBL instructional model (Armstrong, 1997; Kaufman, 1985). Reviewers who have examined PBL medical school research have reached contradictory conclusions. For example, 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), whereas Vernon and Blake (1993) reported that PBL approaches were more effective in generating student interest, sustaining

motivation, and preparing students for clinical interactions with patients. Berkson (1993) found that "the graduate of PBL is not distinguishable from his or her traditional counterpart" (p. 85).This conclusion is consistent with a number of studies that have shown no statistically significant differences in learner performance compared to students receiving lecture-based instruction (Albano et al., 1996; Blake, Hosokawa, & Riley, 2000; Farquhar, Haf, & Kotabe, 1986; Kaufman & Mann, 1988). Culver (2000) conducted a meta-analysis of studies comparing the impact of PBL and lecture–discussion instruction and concluded that there was "no convincing evidence that PBL improves knowledge base and clinical performance" (p. 259). Culver argued 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 curricular design may well make a minor contribution to exam results.

Problems abound in generalizing results from 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 they view their training as instrumental to future occupational success. Given these differences in student characteristics and learning contexts, 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, and 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 pre–post differences in learning for individual units, but there was a statistically significant pre–post difference in general economics knowledge from the beginning to the 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 yet recounting more confidence in their learning. Gallagher, Stepien, and Rosenthal (1992) compared the spontaneous problem solving of two groups of gifted high-school students: a problem-based science and society course and a comparison

group 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 a traditional lecture–discussion approach, we hypothesized that in the current study there would be no difference in learning gains 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 how individual differences *among* high-school students might make PBL a more or less effective learning environment. In a review of the implications of cognitive theory for problem-solving instruction, Frederiksen (1984) noted, "there is considerable evidence that aptitude-treatment interactions exist" (p. 397). (Note: Aptitude-treatment interactions occur when certain treatments such as PBL have differential effects on students with different aptitudes.)

The first aptitude, which generally accounts for between one-third and one-half of the variance in academic achievement (Bartsch, Barton, & Cattell, 1973), is verbal ability. This relatively stable student characteristic is of interest because some authors have argued that lower ability students, who often do not thrive in traditional learning situations, are more likely to succeed in content rich, socially collaborative, contextually meaningful learning environments, such as those established in well-implemented PBL (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, the opposite may be true. One of the best known American high schools incorporating a PBL approach is the Illinois Mathematics and Science Academy (IMSA). IMSA students, however, are chosen through a highly selective admission process and demonstrate superior ability in mathematics and science (Connolly, Szczesniak, & Nayak, 2003). 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 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 other aptitudes might increase students' learning in PBL classes. The first is interest in learning economics. 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. 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). We expected that students who wanted to learn about economics would be more willing to engage in the complex cognitive and interactional tasks required by PBL and thus would learn more in this instructional condition than less interested students.

Other aptitudes include those that are more directly related to the task and interactional demands of the PBL learning environment. Meyer, Turner, and Spencer (1997) reported that individual differences in motivation and self-perception influenced mathematics attainment in investigative, activity-based group learning, an instructional approach with many characteristics in common with PBL. Ethnographic research by Anderson, Holland, and 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 wanted to explore whether students who preferred to learn in groups and who perceived themselves to be competent problem solvers would learn more in PBL learning environments than students who did not like to complete group work and who were unsure of their problem-solving ability.

To summarize, this research tested the following three hypotheses:

1. There is no difference in achievement, as measured via pretest–posttest changes in macroeconomics knowledge, between students in PBL and traditional instructional environments.
2. There is no difference in achievement, as measured via pretest–posttest changes in macroeconomics knowledge, between students with different levels of verbal ability in PBL and traditional classes.
3. There is no difference in achievement, as measured via pretest–posttest changes in macroeconomics knowledge, among students with different levels of interest in learning economics, preference for group work, or problem-solving efficacy.

Method

Sample

Five veteran teachers at four different high schools participated in this study conducted during spring semester of the 1999–2000 academic year. 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 two periods of each other. The remaining teacher's PBL and traditional classes were within three periods of each other.

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 described below. These students make up 71% of students enrolled in the classes. Some of these students did not complete one or more of the aptitude assessments. When this occurred, we substituted the population mean for the missing score. The high amount of student attrition is testament to the elevated absence rates common among graduating seniors during the second semester of the senior year (when grades do not count for college admission). Similar absence rates were found in other subjects.

Table 1 displays descriptive information about the students participating in the research. The mean verbal ability of students in different classes varied considerably, ranging from 36.67 for students in Teacher E's PBL class to 59.51 for students in Teacher C's traditional class. Independent-samples t-tests were used to examine whether students in the PBL and traditional classes showed statistically significant differences in their verbal ability, interest in learning economics, preference for group work, and problem-solving efficacy. Across instructional conditions, there were no statistically significant differences. Teacher-level analysis found two statistically significant differences ($p < .05$) between students in the PBL and traditional classes. Students in the traditional class taught by teacher A and students in the PBL class taught by teacher C had significantly higher verbal-ability scores than their peers in the contrasting classes taught by the same teacher. Students in teacher D's traditional class perceived themselves to be better problem solvers than their peers in the PBL class. These differences were not considered to affect the planned analyses.

Measures

Verbal ability. Verbal ability was used as a proxy for general academic ability and 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 reported strong validity and reliability,

Table 1
Sample Characteristics

Classes	N	Verbal Ability *M*	*SD*	*t*	Economics Interest *M*	*SD*	*t*	Group Work Preference *M*	*SD*	*t*	Problem-Solving Efficacy *M*	*SD*	*t*
Teacher A													
PBL	44	56.61	12.18	–.045	3.16	.912	–1.10	2.49	.913	.233	3.68	.917	1.781
Traditional	19	56.78	17.34		3.42	.734		2.43	.934		3.26	.683	
Teacher B													
PBL	26	42.46	11.47	.236	3.19	.862	.568	2.26	.899	–1.46	2.85	.749	–.529
Traditional	24	41.70	11.45		3.06	.790		2.65	.990		2.96	.767	
Teacher C													
PBL	23	58.39	18.98	.237*	2.98	.842	–1.36	2.65	1.06	.605	3.39	.909	–.363
Traditional	23	59.51	12.51		3.27	.572		2.46	.974		3.49	.904	
Teacher D													
PBL	21	49.76	14.90	–.562	3.31	.620	–1.27	1.99	.696	–.955	3.12	.578	–.507*
Traditional	21	52.29	14.21		3.59	.790		2.25	1.05		3.24	.857	
Teacher E													
PBL	25	36.67	11.60	–1.10	2.99	.643	–1.44	2.06	.756	–.480	2.71	.863	–1.27
Traditional	20	40.92	14.33		3.30	.822		2.17	.786		3.04	.857	
All Teachers													
PBL	139	49.64	15.86	–.245	3.13	.805	–1.80	2.32	.901	–.700	3.22	.906	.190
Traditional	107	50.14	15.72		3.32	.752		2.40	.951		3.20	.830	

*$p < .05$.

including correlations greater than 0.80 with the verbal, total, and IQ scales of the Wechsler 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 appropriate instrument 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). Because 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 about their interest in biophysics; they may have heard the word but generally don't know enough about the concept to

express a valid opinion. As a result, we designed our own instrument asking students about their interests 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 scale ranging from 1 (Very Interested) to 5 (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 developed an instrument to measure students' preferences 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," "I learn more in the small group than I do from other class activities," and "It is an excellent way to study for tests." Students indicated their responses on a scale ranging from 1 (Strongly Agree) to 5 (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 developed an instrument to assess students' perceptions of their ability to use the problem solving, negotiation, and discussion skills required by the problem-based economics units. The instrument consisted of the stem: "I have difficulty solving problems when . . . " followed by five items: "I have to find my own resources and information," "I have to argue my own point of view," "Only some people are helped by my decision," "Other people disagree with me," and "I have to defend my choice." Students responded on a scale from 1 (Strongly Agree) to 5 (Strongly Disagree), and their scores reflect the mean of the five 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, and Krathwohl (1956) and were focused on the specific macroeconomic concepts to be covered in the classes. Several items required students to demonstrate their understanding of inflation, unemployment, and gross domestic product with reference to a graph showing changes in these indicators over time. Sample items include:

1. Gross Domestic Product is a measure of:
   A. the price level of goods and services sold
   B. total spending by federal, state, and local governments
   C. the quantity of goods and services produced by private businesses
   D. the market value of the nations' output of final goods and services

2. If your annual money income rises by 50% while prices of the things you buy rise by 100%, then your:
   A. real income has fallen
   B. real income has risen
   C. money income has fallen
   D. real income is not affected

3. The economy has stable prices, but high unemployment. Which combination of government policies is most likely to reduce unemployment?
   A. increase government spending and buy government bonds in the open market
   B. decrease government spending and sell government bonds in the open market
   C. decrease taxes and sell government bonds in the open market
   D. increase taxes and buy government bonds in the open market

Students' scores were obtained by summing the number of correct items. Inspection of histograms for both the pretests and posttests suggested a normal distribution with no outliers.

Procedures

The focus of the units in both the PBL and traditional classes consisted of the macroeconomics content defined by the *National Voluntary Content Standards in Economics* (National Council on Economics Education, 1997), *A Framework for Teaching Basic Economic Concepts* (Sanders & Gilliard, 1995), and the *History-Social Science Content Standards for California Public Schools* (Commission for the Establishment of Academic Content and Performance Standards, 2000). The PBL unit under study, *The President's Dilemma,* was developed by a partnership among high-school teachers, an educational research and development organization, and economics faculty at a university. It is one of eight units designed for a semester-long high-school economics course, although each of the 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 concepts specific to each unit. More extensive information on the problem-based economics units can be found at http://www.bie.org/pbe/unitsoverview.php.

The problem-based unit under study, *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 prepackaged but exists in a variety of places. Students' judgments of relevant and irrelevant information and their definitions of the problem change 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, clarify the nature of the problem, determine what economic concepts and relationships are necessary to solve it, and undertake the research and reading necessary to understand the relevant economic theories. The problem concludes with a presentation of each group's solution to an audience of interest-group representatives (e.g., the elderly, labor unions, business owners). 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 all group members. This procedure, with its 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 to address the same concepts in both the traditional and PBL classes. In the traditional classes, teachers used a combination of textbook assignments and whole-class lectures punctuated by whole-class discussions. Throughout the traditional class sessions, teachers took responsibility for transmitting an understanding of the key economic concepts to students. They rarely (if at all) asked students to teach other students or explain a concept to a small working group—something that consistently occurred during the PBL class sessions. Although teachers gave examples of the working of economic concepts to make sense of a situation ("Why do tickets to a Stones concert get more expensive the closer you get to the concert?), they did not pose problems for students to solve. Finally, during the traditional class sessions, teachers did not delay their content lectures until students realized they needed to understand a concept but rather presented them daily, organized topically according to the content covered in the previous night's textbook assignment.

All teachers had attended at least one week-long training workshop (under the guidance of a university economics professor and codeveloper of the problem) to prepare them to use the PBL unit in their classes. Two of the five participating teachers 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 traditional approaches were implemented as intended.

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 the multiple choice content test.

Results

To determine if there was a statistically significant difference in the learning of macroeconomic concepts between students in the PBL and traditional classes, we calculated independent-samples t-tests on the pretest–posttest change on the macroeconomics tests (see Table 2). For PBL students, the average pretest–posttest change was +1.48 ($SD = 2.52$); for students in the traditional classes it was +.82 ($SD = 2.81$). This difference was 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 traditional approach. When pretest–posttest changes in macroeconomics knowledge for students in the PBL and traditional classes are analyzed at the teacher level, PBL class gains were greater than traditional class gains for four of the five teachers, although this comparison reached statistical significance only for teachers A ($p < .05$) and D ($p < .01$). Students in teacher C's traditional class gained more in macroeconomics knowledge than students in the PBL class, although this difference was not statistically significant at the .05 level. These data led us to reject our first hypothesis and indicated that the PBL instructional approach was more effective than the traditional approach in helping students learn basic macroeconomic concepts.

To test whether there was a difference in gains in macroeconomics knowledge between students with different aptitude levels in PBL and traditional classes, we conducted three analyses. First, we examined whether the correlations between aptitude and pretest–posttest change in macroeconomics knowledge were the same for students in the PBL and traditional classes. After correlating each of the four aptitudes with pretest–posttest change on the macroeconomics tests, we used Fisher's z-transformation (Fisher, 1921) to transform the r values for the PBL and traditional classes so they would be normally distributed. We then calculated z scores, which ranged from 0.15 to 1.15, depending upon the aptitude. None were statistically significant at the .05 level.

Second, we created tertiles containing students with high, medium, and low levels of each aptitude within the PBL and traditional classes. We then conducted ANOVAS for each aptitude with tertile as the grouping variable and pretest–posttest change in

Table 2

Verbal Ability, Pretest, and Pretest–Posttest Change in Macroeconomics Knowledge by Teacher and Instructional Condition

Classes	N	Verbal Ability *M*	*SD*	*t*	Knowledge Pretest *M*	*SD*	*t*	Pretest-Posttest Change *M*	*SD*	*t*	Pretest-Posttest Effect Size
Teacher A											
PBL	44	56.61	12.18	.045*	7.68	2.61	–.608	1.36	2.18	2.36*	.50
Traditional	19	56.78	17.34		3.42	.734		2.43	.934		–.06
Teacher B											
PBL	26	42.46	11.47	–.236	4.42	1.78.	1.10	1.42	2.86	.48	.70
Traditional	24	41.70	11.45		3.06	.790		5.65	.990		.35
Teacher C											
PBL	23	53.89	18.98	.237*	7.78	2.61	1.04	1.09	2.39	–1.57	.44
Traditional	23	59.51	12.51		8.57	2.48		2.35	3.02		.95
Teacher D											
PBL	21	49.76	14.94	.562	5.10	2.61	2.43*	2.43	2.40	3.38**	.93
Traditional	21	52.29	14.21		7.14	2.78		–.19	2.62		–.06
Teacher E											
PBL	25	36.67	11.60	1.10	5.88	2.33	–1.159	1.32	2.88	.616	.57
Traditional	20	40.92	14.33		5.10	2.13		.85	2.03		.38
All Teachers											
PBL	139	49.64	15.86	.245	6.37	2.77	.687	1.48	2.52	1.94*	.59
Traditional	107	50.14	15.72		6.63	2.97		.82	2.81		.29

*$p < .05$ **$p < .01$

macroeconomics as the dependent variable. Post-hoc comparisons with Bonferroni corrections were used to evaluate whether the pretest–posttest scores differed between students in any of the tertiles. We found no statistically significant differences within either the PBL or traditional classes.

Finally, we conducted independent-samples t-tests within tertiles comparing mean pretest–posttest change scores in macroeconomics knowledge for students in the PBL and lecture–discussion classes. Table 3 displays the data used in this analysis, the t-tests results, and the effect size for each comparison. Except for students whose scores on the interest-in-learning-economics aptitude measure placed them in the high tertile, there were no statistically significant differences at the .05 level. These analyses allowed us to accept our second hypothesis of no differences in pretest–posttest change in macroeconomics knowledge between students with different levels of verbal ability in PBL and traditional classes, and to reject our third hypothesis, indicating a difference in pretest–posttest change in macroeconomics knowledge among students with different

levels of the following aptitudes: interest in learning economics, preference for group work, and problem-solving efficacy.

Table 3

Mean Pretest and Pretest–Posttest Change in Macroeconomics Knowledge in PBL and Traditional Classes by Aptitude

Aptitude	Tertile	Class Type	N	Pretest-Posttest Change	*SD*	*t*	PBL-Traditional Effect Size
Verbal Ability	High						
		PBL	44	1.45	2.25	.24	.05
		L/D	39	1.31	3.30		
	Medium						
		PBL	43	1.84	2.54	1.67	.41
		L/D	24	.67	3.10		
	Low						
		PBL	49	1.22	2.71	1.66	.40
		L/D	31	.26	2.08		
Interest in Learning Economics	High						
		PBL	55	1.24	2.68	2.21*	.50
		L/D	31	–.10	2.70		
	Medium						
		PBL	43	1.67	2.59	.92	.21
		L/D	34	1.12	2.68		
	Low						
		PBL	41	1.61	2.22	.61	.14
		L/D	42	1.26	2.90		
Problem Solving Efficacy	High						
		PBL	52	1.48	2.33	1.73	.88
		L/D	33	–.58	2.37		
	Medium						
		PBL	38	1.37	2.47	.05	–.01
		L/D	40	1.40	2.79		
	Low						
		PBL	49	1.57	2.78	1.81	.40
		L/D	34	.38	3.17		
Preference for Group Work	High						
		PBL	48	1.10	2.60	1.29	.32
		L/D	28	.36	2.09		
	Medium						
		PBL	47	1.53	2.23	.84	.17
		L/D	44	1.14	2.26		
	Low						
		PBL	44	1.84	2.70	1.42	.32
		L/D	35	.80	3.80		

** = $p < .05$*

Discussion

We believe the rejection of our first hypothesis concerning the equivalent learning of macroeconomic concepts in PBL and traditional classes to be a compelling finding because statistically significant differences at the .05 level (or lower) were found for the population and for two of the five teachers. Across all teachers, the average effect size difference for PBL-Lecture–Discussion comparisons was .25, or one-fourth, 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. Most students would not consider the mean difference in pretest–posttest score between the PBL and traditional classes to be trivial. Across all teachers, PBL classes gained .66 more than the traditional 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%.

It is interesting to compare results for teachers A and C. Both teachers taught at the same high school with a population of generally upper-income students whose verbal ability and macroeconomic knowledge pretest scores were higher than those of students in the other schools. One teacher (A) was more effective using the problem-based approach. The second teacher (C) was more effective with a traditional approach. Although a PBL instructional approach may not be suited for all teachers, our results should be encouraging to teachers, instructional designers, and researchers who seek alternatives to the traditional "sage-on-the-stage" pedagogy. In this study, PBL not only "did no harm," but it did some good. This may prompt educators to experiment with PBL to better understand the classroom conditions and social arrangements necessary to maximize its effectiveness.

Our next two research questions focused on whether PBL was a more effective learning environment for students with certain characteristics. Here the results displayed in Table 3 are more equivocal. Although comparisons of pretest–posttest change by variable tertile within instructional condition were not statistically significant at the .05 level, the trends in effect size differences for PBL and traditional students in different variable tertiles are worth discussing. 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 midrange and below learned more in the PBL classes than they did in the lecture–discussion classes. This result cannot be accounted for as an instance of regression to the mean because 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 may not be considered 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). 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 at-risk students be assessed by multiple measures, not just verbal ability.

Instructional approach also appears 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 pretest and posttest. On the other hand, PBL students with the same level of interest in learning economics showed a statistically significant ($p < .05$) gain in content knowledge (+1.24). This is equivalent to one half of a standard deviation—a medium effect size according to Cohen's (1988) convention and equivalent to a raw score gain of 8%. It appears 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 traditional classrooms.

The effect size differences for problem solving efficacy present a curvilinear (U-shaped) profile and suggest another story. Whether a student was in a PBL or lecture–discussion classroom did not appear to make a big difference for middle tertile students. On the other hand, students in the top and bottom tertiles of problem solving efficacy learned more in the PBL classrooms, with the effect size difference between top tertile traditional and PBL students exceeding three-fourths of a 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 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 problem in mind when we designed the PBE units and followed Slavin's (1990) dictum that maximum group learning occurs when there is individual accountability. 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 were held individually accountable for justifying their problem solution and explaining their understanding of the key economic concepts. For the macroeconomics unit under study, this procedure required 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 that holding students individually accountable for their learning has a definite influence on the nature of the group interactions 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 and Palincsar (1996) identified 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. We hypothesize that the PBL students who were confident in their problem-solving ability would be the ones 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 traditional classrooms. Although this analysis is speculative, it does point the way to future areas of study.

The final student characteristic that merits discussion is preference for group work. 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 interactions that occur in the classrooms. In the abstract, students may prefer working by themselves or with others, but once they are actually in Mrs. Jones's class, their learning is more influenced by environmental and structural factors than by their own learning-group work preferences.

Future Research

The current study examined student learning within a single, two-week unit. If problem-based instruction is to help students develop deep, applicable knowledge and analysis skills, 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 between PBL–traditional 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 addition, future research should include a focus on the hard-to-measure learning outcomes of deep understanding, sustained content retention, and knowledge application, as well as self-management and problem-solving skills. We believe the attainment of these complex outcomes—rather than performance on a multiple-choice content assessment—is the standard by which problem-based instruction should be measured (CTGV, 1997; Mayer & Wittrock, 1996;). We agree with 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 account for differences in performance on standardized content-based tests.

Our results leave many important questions unanswered. 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 include observational studies of PBL instructional environments, document the essential components of problem-based learning, and assess the extra-content outcomes theoretically associated with problem-based instructional approaches and espoused by PBL advocates.

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