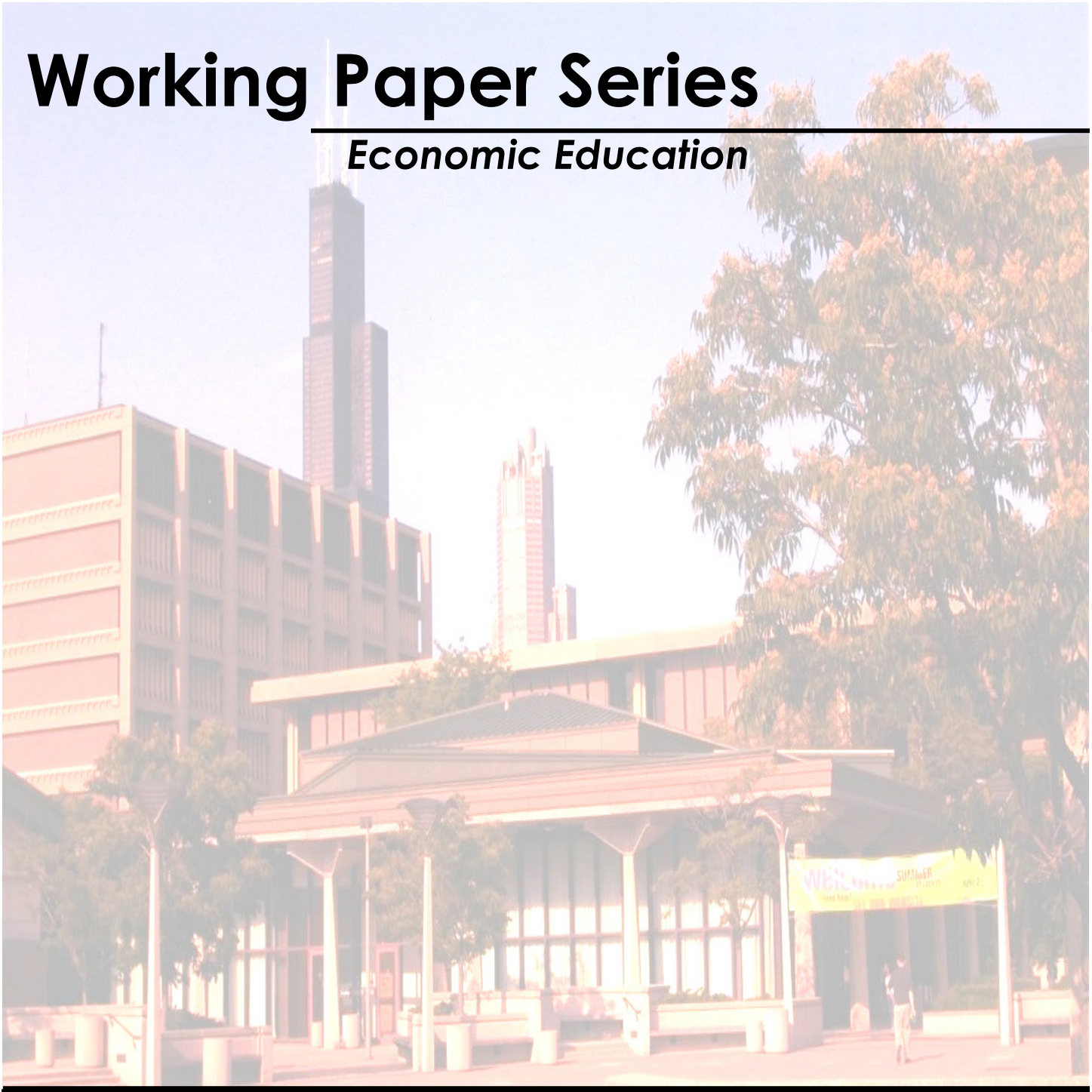
Working Paper Series

Economic Education



No. 015

Assessing the Impact of Problem-Based Learning on Student Understanding in Microeconomics Principles

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Assessing the Impact of Problem-Based Learning on Student Understanding in Microeconomics Principles

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Abstract: This paper examines the impact of using problem-based learning on the performance of students in an undergraduate microeconomics principles course. The data used in this analysis were obtained as part of an experiment with four sections of undergraduate microeconomics principles at the University of Illinois at Chicago. The two instructors alternated between the four sections and alternated between using standard curriculum and problem-based curriculum. The results indicate that the use of problem-based curriculum had significant positive impacts on student understanding and achievement in different areas of microeconomics.

Key Words: Economics, Problem-based Learning, Class-room Experiment
JEL: A22, C81, I21

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1. Introduction

Does student understanding of a subject depend on what is taught, how it is taught and who teaches it? Most certainly it does. The literature examining student outcomes—in economics and other subjects—suggests that all of these factors have a significant impact on how students learn, what they learn and how they perform in the undergraduate classroom (see, for example, Albanese and Mitchell, 1993). The aim of this paper is to assess the impact of problem-based learning in four sections of principles of microeconomics at a large, urban, public university.

The underlying model is a simple production function for economics learning outcomes. Students enter the microeconomics class with a stock of human capital. Through the inputs consisting of teaching techniques, learning resources and their own efforts, students produce the outcome measures, test scores.

This paper is organized as follows. Section 2 briefly examines problem-based learning and discuss the four problem-based economics (PBE) units used in this study. Section 3 relates the literature on undergraduate student performance and assessment in economics to the issues of this study. The data and model are outlined in section 4 and the results are discussed in section 5. Conclusions and policy implications are discussed in section 6.

2. Problem Based Learning

Problem-based learning (PBL) is not unique to economics. In fact, this type of learning is relatively new to economics (see Maxwell et. al, 2005). Problem-based techniques have been used effectively for years to teach medicine (Borrows, 1985, 1992), education (Bridges and Hallinger, 1992; Duffy, 1994), law and social work (Boud and Feletti, 1991) and other areas of business and finance (Milter and Stinson, 1994)

Problem-based learning is an approach to teaching and presenting materials such that the student is given a 'situation' (e.g. a problem) that he or she must solve. The

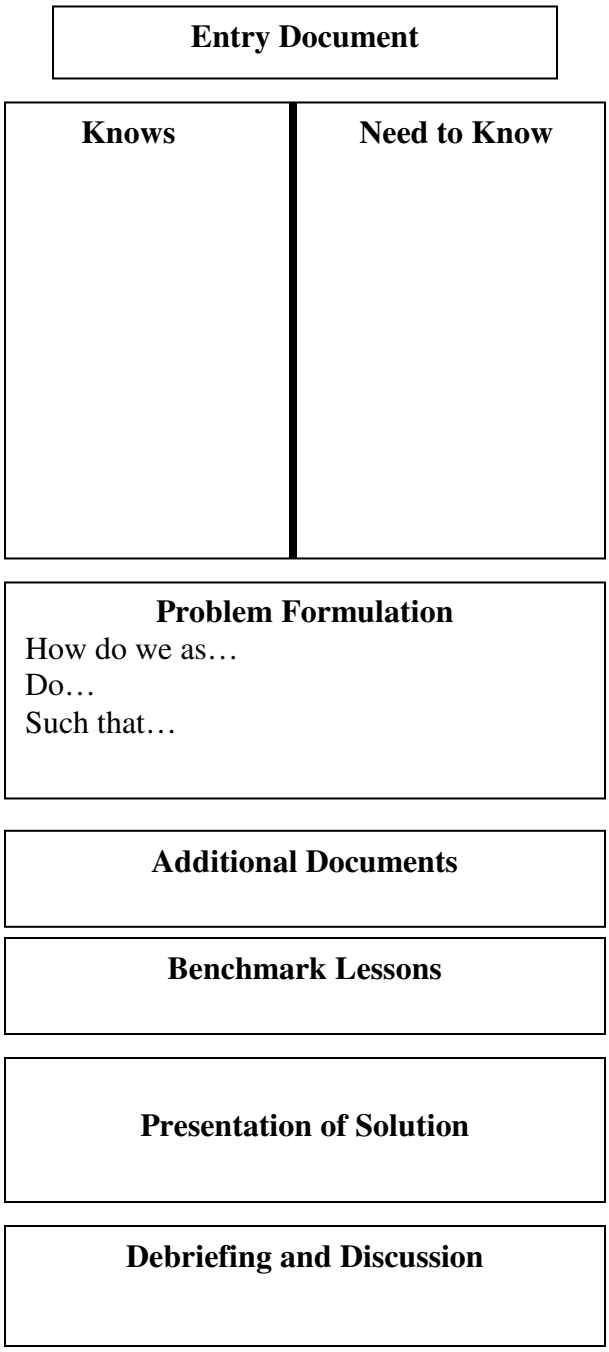
problems are framed in the context of a particular subject—economics, for example—and presented in conjunction with a set of core theories and models—supply and demand, elasticity of demand, comparative advantage, monetary and fiscal policy—depending on the problem. Each unit starts with an entry document that places the student in a position to enact policy (or advise those who will enact policy) and then presents the student with a 'problem' that they are now facing.

The students, as individuals or in groups, must then use the set of 'tools' they have been given—the core theories and models—to solve the problem. Additional documents are the given to the students as the problem progresses—usually adding constraints or identifying unforeseen consequences of following a particular solution. The best 'problems' have multiple solutions and require students to make choices and assess the costs of their choices—there are no easy answers.

The 'problems' used in these classes were provided by the Buck Institute for Education (www.bie.org) and focused on various microeconomic models: supply and demand; perfect competition; monopoly and monopolistic competition; and comparative advantage and trade. Each unit took 1 ½ to 2 weeks to complete—anywhere from four to six 50-minute class periods.

The procedure—or steps—for establishing and solving a 'problem' using PBL was established by Borrows (1985), but can and does take a number of forms. The Buck Institute for Education (BIE) problems use a series of steps that are similar in fashion (see Figure 1). Each problem starts with an entry document where the problem is addressed. The students then identify what they know about the situation and what they need to know. The students then formulate the 'problem statement' in the form : "**How do we as**… **do**… **such that**… " As students formulate solutions, additional documents are added and benchmark lessons are covered. Students then present their solutions in a written document or in an oral argument. The problem is then addressed by the instructor and students are given closing information and debriefed regarding alternative solutions.

Figure 1. BIE Problem-Based Learning Process



3. Literature

Although there is little research on the impact of PBL on student outcomes and understanding in economics--the exceptions to this are Mergendoller et al. (2000) and Maxwell et. al,(2005)--there is a large literature that examines the role of PBL in learning, the implementation of PBL and the relative impact of PBL on student learning in other disciplines..

Schmidt (1983) identified that PBL establishes several conditions that are 'optimal' for learning: it stimulates students to access their prior knowledge, it creates a context in which the students can apply their knowledge, it encourages students to apply new knowledge. Good and Brophy (1991) qualify PBL as a strong class-room tool because it provides an active role for students and incorporates a high level of peer-interaction.

Barrows and Tamblyn (1980) and then Barrows (1985, 1986) set the fundamental structure of how PBL should be used in medical classrooms and established the principle goals of effective PBL curriculum:

1. Acquiring and applying new knowledge.
2. Developing skills for self-directed learning.
3. Honing 'problem-solving' ability.
4. Identifying consequences of a course of action.
5. Building skills in 'team' construction and leadership.

Student outcomes using PBL have been reviewed in Albanese and Mitchell (1993) and Vernon and Blake (1993). Both of these studies found significant differences between students who were taught with PBL and those who were taught using traditional methods. In general, PBL students were more satisfied with the course and found the learning environment to be more 'student oriented'; PBL students studied for 'understanding', while traditional students studied for 'short-term' recall; but traditional students performed at higher levels on examinations than PBL students. Mergendoller et. al. (2000) also found that there were no significant advantages for PBL students in student outcomes. Maxwell et al. (2005), however,

found that there were some gains for PBL students as measured in gains between pre-tests and post-tests in macroeconomics. The gains for these students, however, came mostly in the form of instructional effects (instructor interaction variables). Maxwell et al.(2005) concluded that PBL was an effective tool when in the hands of trained teachers

It is clear that PBL provides the basic elements for successful student learning. It is also clear that the BIE model is very consistent with the successful structure of PBL implementation established by Borrows and Tamblyn (1980). It is not clear, however, that using PBL in the class-room consistently improves student comprehension of materials and whether that comprehension translates into higher test scores.

4. Data & Model

The sample consists of 178 students (out of 190 total registered) who registered for one of four sections of ECON 120: Principles of Microeconomics at the University of Illinois at Chicago in Fall 2005. Students were surveyed when they joined the class on their backgrounds, including age, gender, race, whether they had studied economics in high school, how many hours they planned to work per week at a job during the semester, and how many college semester credit hours they were currently taking.

The participants were included only if they completed a written informed-consent form consistent with IRB guidelines. Each section met for 50 minutes three times per week for 16 weeks. The BIE problem-based curriculum units used in this study were: 1) *High School Food Court,* an analysis of supply, demand, and profits; 2) *Monopoly's Might* and 3) *The Might Strikes Back*, two units analyzing competitive markets, monopolies and monopolistic competitive markets, and 4) *Great Awakening*, an analysis of comparative advantage and trade.

The methodology called for varying the PBL units across the four sections in the following format: section A would receive all four PBL units, Section B would receive ½ of the units (Food Court and Great Awakening), Section C would receive ½ of the units (Monopoly's Might and Might Strikes Back) and Section D would receive none of the units. The four sections were then randomly assigned a letter, A, B, C or D. At

any given time, there were two sections using PBL curriculum and two sections using standard curriculum.

Background information was collected from students via an information survey (see appendix) and economics understanding and student achievement were collected in the form of the Test of Understanding College Economics (TUCE) pre-test and post test, four common midterm exams (quizzes) and a common final exam. The quizzes and exams included both multiple choice questions and graphing/problem solving/essay types of questions. The quizzes covered approximately 2 – 3 weeks of material and the final was cumulative in nature.

The midterm and final exams are 'instructor written' exams, based on information from standard microeconomics texts. The TUCE was used in this experiment for two reasons. First, the TUCE is a nationally normalized test covering areas of markets, price theory and theory of the firm, comparative advantage and other areas of microeconomics. Second, the University of Illinois at Chicago was a test sight for the newest edition of the TUCE. The use of the TUCE is important because it provides an exogenous measure of student achievement—an exam that was not written by the teachers in this experiment and is, therefore, free of any potential biases introduced by the instructors.

The instructors (Smith & Roberts) were assigned courses such that they lectured to two of the four sections each week. Each instructor changed sections throughout the semester in order to account for any instructor effects. At any given time, each instructor was teaching one PBL section and one non-PBL section.

The empirical model to test the impact of PBL curriculum and instruction on economic understanding is as follows:

$$1)\ SCORE_{kjj} = \alpha + \beta_1 Buck + \beta_2 Instructor1 + \beta_3\ Instructor1*Buck + X_i\gamma + \varepsilon$$

where $SCORE_{kjj}$ is the achievement of student *i* in test *k*: Test of College Understanding in Economics (TUCE) pre-test or post-test; midterm exams 1, 2, 3 and 4; or in economic content area *j:* supply and demand, profit maximization, monopolies and monopolistic

competition, and comparative advantage. *Buck* is a dichotomous variable identifying if the students were being taught using PBL curriculum. *Instructor1* is a dichotomous variable identifying if students were being taught by Smith, and *Instructor1*Buck* is an interaction term equal to 1 if the students were being taught by Smith using PBL curriculum. X_i is a vector of student characteristics, including gender, race, number of credits taken, number of hours per week worked at a job by the student, and a dichotomous variable identifying if the student had taken an economics course during high school. ε is a random disturbance. See Table 1 for summary statistics of the independent and dependent variables used in this analysis.

The underlying model is a simple production function for economics test scores. We take a value-added approach, using ordinary least squares (OLS) regressions to estimate production functions of the tests, with the inputs PBL and instructor variables and student characteristics as control variables. The danger of bias in this approach is well-known. For example, OLS requires that the economics course inputs and unobserved mental capacity be orthogonal, which is almost certainly violated. Also, there is a high likelihood of unobserved variables. This paper uses TUCE microeconomics test scores as a baseline to mitigate these problems.

The course was designed such that the material covered for each midterm exam is relatively independent from the previous exams. The exception is the relationship between midterm 1 covering supply and demand and markets and midterm 2 covering manipulations of those markets through taxation, quotas, price ceilings and floors. As such, the performance of the student on each exam is assumed to be independent of the other exams. The Final Exam, however, is a cumulative exam covering the materials

learned on the first four midterm exams. Excluding the midterm exams as covariates in an examination of student achievement on the final exam would almost certainly bias the results for the estimates in the final exam equation. To correct for this, the Total Points for the final exam is run as function of demographic variables and the average of the four midterm exams. For the analysis of student performance on different subject areas on the final exam—supply and demand, monopolies, and comparative advantage—the scores from the midterm exam covering that subject area is run as a covariate.

5. Results

5.1 TUCE

The results of running equation 1) using the TUCE pre-test and TUCE post-test scores is listed in table 2. The TUCE pre-test was given on the first day of class, prior to any problem-based curriculum and the TUCE post-test was given during the penultimate class session. As expected, there were no significant differences on the TUCE pre-test by class section. Also, there appears to be no impact of taking economics in high school on the performance of the TUCE pre-test. Taking economics in high school did, however, have a positive impact on the TUCE post-test score. It is a hypothesis that taking economics in high school positively influences the assimilation of economic content through the semester. Again, there was no difference in the scores of the Problem Based Economics sections compared to the non-PBE class section.

When examining the gains between the TUCE pre-test and post test (table 3), there were significant differences between the PBE sections and the non-PBE sections. Each of the problem-based sections had higher gains in both raw score and percentage, although only Class B—which received the *Food Court* and the *Great Awakening*

curriculum units—had statistically significant gains (approximately 3 points). Taking economics in high school was a significant factor in gaining points—both total and percentage—between the TUCE pre-test and TUCE post-test.

When looking at specific questions on the TUCE post-test—questions regarding supply and demand—it does not appear that the sections using problem-based curriculum scored higher than those sections using standard curriculum. Overall, the PBE sections scored slightly higher on the TUCE post-test and had significantly larger gains in raw score—approximately 3 points—compared to the non-PBE class sections.

5.2 Midterm Exam 1

The estimates of equation 1) using results from the first mid-term exam are listed in table 5. The first mid-term exam tested students on their understanding of markets, supply and demand, equilibrium price and quantity, and profit maximization--total revenue, total costs and profits.

The performance by students on the TUCE pre-test is a significant indicator of their performance on the first mid-term exam. Although the number of hours the student worked at a job per week during the semester, the number of credit hours taken during the semester and having taken economic in high school all had the anticipated signs, none were significant in predicting the score on the first midterm exam.

The problem-based unit taught during this section was *High School Food-Court*: an analysis of demand, supply, total revenue and total costs. The results indicate that students who received the problem-based curriculum scored 2.29 points higher on the first midterm than those who did not receive any problem-based curriculum. This

difference was statistically different than zero. There are not any instructor effects for the first midterm exam.

Equation 1) is also tested for two subject areas covered in midterm exam 1: a) supply and demand, and b) profits. The results for the questions covering supply and demand indicated that students who received problem-based curriculum out-performed other students by approximately 4 points. The instructor effects for these questions are negative and in-significant.

The results for the questions covering profits—total revenue, total costs and profit maximization—indicate that students who had taken economics in high school performed slightly better than those who had not had economics in high school. It is likely that this result reflects that high school instruction in economics covers some topics more thoroughly—or with greater emphasis—than other areas. It is not un-reasonable to assume that some high-school instruction/knowledge carries over into the college class-room and certainly a likely outcome that economics instruction in high school would compliment the learning of some economics concepts in the college classroom.

With respect to the different groups, the problem-based learning students scored 1.42 points higher on the profit questions than the non-problem based students. The instructor effects for this area are also positive and significant—1.33 points. The different impacts of PBL on the understanding of supply and demand and profits suggests that the presentation and formulation of the problem and the emphasis the instructor puts on different parts of the problem will have varying impacts on the student understanding across content areas

5.3 Midterm Exam 2

The concept areas of taxation, quotas, price ceilings and price floors were taught during the fifth and sixth weeks of the semester and tested on the second midterm exam. This section of the semester was the only period where there were no problem-based units taught. As such, the estimation of student outcomes was examined as a function of demographic characteristics and whether the individual had been exposed to a problem-based unit during the first 4 weeks. Because the concept areas listed above are continuations of markets, it is hypothesized that students who were exposed to the Buck problem-based curriculum on supply, demand and markets in the first four weeks would have a stronger understanding of the implication of restrictive policy on markets.

The results of running equation 1 for the point totals for the second midterm exam, listed in table 7, show many of the same relationships seen in the first midterm exam: students who scored higher on the TUCE pre-test also scored higher on the second midterm exam; students who work more hours per week in a job outside of school scored lower on the second midterm exam. The results also indicate that there were considerable differences between racial groups: Blacks and Asians scored lower than Whites (although not statistically significantly so), while Hispanics scored significantly higher than Whites.

The results also indicate that there were significant differences in outcomes by class section—class sections B and A (the sections that received the Buck problem-based curriculum units) scored approximately 7.5 points higher than class sections C and D. The model for this exam does not include teacher effects because Instructor 1(Smith) taught all four class sections during week 5 and half of the sections during week 6.

5.4 Midterm Exam 3

The third midterm exam covered topics of perfect competition, monopolistic competition, and monopolies. The analysis of the student scores for this exam show that having taken economics in high school results in much stronger understanding of firm types and behavior: students who had some economics in high school scored between 2.5 and 3.2 points higher than those who had not taken economics in high school. This area of microeconomics is often very difficult for students and requires a great deal of preparation and study time. Because of this, it is not surprising that the number of hours worked had a significant negative effect on student test scores. It is also important to note that Black students scored much lower—between 9.7 and 12.1—points lower than white students.

For this exam, the students who were given PBL curriculum scored slightly lower—between 0.71 and 2.9 points—than the non-PBL students. This result is better understood by examining the PBL curriculum given during this three-week period in the semester. For the content areas of perfect competition, monopolistic competition and monopolies, students were given two BIE units: *The Monopolies Might* and *TheMight Strikes Back*. Both units cover similar themes: the impact on the market when there are changes in the number of firms providing a specific good. The first unit—*The Monopolies Might*—addresses the firm's perspective and identifies how profits change when the market moves from a Monopoly to a Duopoly and Oligopoly. Additionally, this unit covers other business angles, such as capital expenditure and venture capitalism. These latter areas are probably better suited for a general course in business rather than a course covering the basic principles of microeconomics. As such, the students who went

through the activities of 'pitching an idea' to venture capitalists probably had a better understanding of how businesses raise capital, but might have been a bit behind other students in understanding pricing and output decisions of the monopolist.

The second unit—*The Might Strikes Back*—examines the profitability of a firm that gains monopolistic control of a market through a patent. The students are asked to defend the profits of the firm and examine the ethical issues associated with earning large profits and the impact of the firm's policies on factors of production—land, labor and capital. Students are taught the difference between monopolies, monopolistic competitive firms and perfect competitive firms. However, students are also asked to address the role of the firm in society and the obligations that a firm has to those that are impacted—not only on the consumer side, but on the factor market side. Again, these latter areas are very helpful in a general business course where students must discuss business ethics and the societal impact of policy decisions. For a principles course, however, these areas do not match-up very well with the content of the usual text books.

There are, however, considerable instructor effects for this unit. Students who were given PBL by SMITH scored between 3.77 and 5.1 points higher than other PBL students. This is likely a result of SMITH having more training[1] in these specific PBL units and being able to tailor the problem to cover both the venture capitalist angle as well as the more traditional 'graphs' associated with monopolies, monopolistic competitive firms and perfectly competitive firms.

The analysis of the outcomes of students for specific areas from this exam—monopolies, perfect competition and monopolistic competition—show similar patterns:

[1] Smith attended a three-day training with the Buck Institute for Education and practiced each of the units under the guidance of other teachers and those who wrote the problems.

students who had some economics in high school scored higher and students who worked more scored lower. The students in the PBL sections performed a bit lower than the non-PBL students—the PBL students did not score significantly different than the non-PBL students in one model and scored 1.9 points lower in another model. In both models there were large positive and significant instructor effects—between 3.9 and 4.6 points.

5.5 Midterm Exam 4

The fourth mid-term exam covered comparative advantage, absolute advantage, international trade, exchange and exchange rates. The analysis of the student outcomes for exam 4 show similar results as the other exams: students who had economics in high school scored higher and students who worked more hours per week scored lower. The students who were in the PBL sections for this unit—*The Great Awakening*—scored higher than the non-PBL students by 2.0 to 2.7 points. These differences, however, were not statistically significant at $p < 0.10$. For this unit, the students who were taught by SMITH—both PBL and non-PBL—scored lower, although not significantly.

The use of the PBL unit during this section appeared beneficial, although the results do not show any statistically significant increase in understanding or test scores. The traditional way of teaching comparative advantage is to take a 2 x 2 matrix that identifies the total output for two individuals or countries given similar inputs. The following figure is a typical example from a principles text.

Figure 2

Country	Number of Cars produced in 8 hours	Pails of Milk produced in 8 hours
Big-Sky	***36***	**120**
Little-Land	***23***	**90**

This table reveals that although Big-sky has an absolute advantage in the production of both cars and milk, Big-Sky only has a comparative advantage in the production of cars—a lower opportunity cost—and Little-Land has a comparative advantage in the production of milk. For the PBL units, the students were given a series of 20 different products produced, rather than the standard 2 units. The students find the product for which the country has an absolute advantage in production and then calculate the opportunity cost of all other goods in terms of that one product/service. The students have a rank-order for all goods produced in the country in terms of opportunity cost of the one service for which the country excels. Given this information, students can quickly identify which goods they should produce in-country and which goods they should trade other countries for. It is much more realistic and the informal feedback from students during in-class exercises identified that they had a good grasp of the subject. However, the test was more standard and took the form of figure 2.

5.6 Final Exam

The final exam for this course was cumulative in nature—the exam covered the materials presented in the previous 15 weeks and tested through the four mid-term exams. The analysis of the student performance on the final test (final exam total) shows many of the same results as the mid-term exams—the total score decreases with number of credit hours and number of hours spent at a job. The total score was run as a function of the amount of problem based curriculum the students had been exposed to—either ½ of the units or all of the units. The class sections that received half of the PBL curriculum outperformed the no-PBL class section by 4.42 points and the 'all PBL' class section scored approximately 5.5 points higher than the no-PBL section. However, neither of these estimates are statistically significant.

Because the final exam covers the different content areas touched on during the semester, we ran a separate analysis of performance on areas of supply & demand, monopolies & monopolistic competition, and comparative advantage and trade. The students who received the first Buck unit "High School Food Court" scored 7 points higher on the supply and demand questions than those students who received standard curriculum. This coefficient is significantly different than zero. Students who received training through "The Monopolies Might" and "The Might Strikes Back"—Buck 3—scored slightly lower than other students, although not significantly so. Those students who went through the "The Great Awakening"—the Buck unit (Buck 4) on comparative advantage and trade—scored 1 point higher than other students. Again, this was not statistically significant.

6. Conclusion

The aim of this paper is to assess the impact of problem-based learning (PBL) in four sections of principles of microeconomics at a large, urban, public university. The problem-based curriculum units adopted for this study were developed by the Buck Institute for Education and cover specific subject areas: supply and demand and profit maximization; monopolies, monopolistic competition and perfect competition; absolute and comparative advantage and trade. The authors ran an experiment in which the PBL curriculum was introduced to two of the four classes while standard curriculum was used in the other two class sections. In addition, the two instructors changed sections during the semester, always teaching at least one PBL section and one non-PBL section.

On the first day of the semester, each student was given the Test of Understanding College Economics (TUCE)--microeconomics version as a pre-test. On the penultimate class, the same students were given the Test of Understanding College Economics (TUCE)—microeconomics version as a post test. The student outcomes in the gains between the pre-test and post test (both raw score and percentage gains), were regressed against demographic characteristics and dichotomous variables identifying if the students had received some PBL curriculum (class sections B and C) or all the PBL curriculum (class section A). The results indicate that the class sections that had received PBL curriculum posted slightly higher gains in raw score compared to the class section that had received no PBL curriculum.

The student outcomes on each midterm exam (total points) were also regressed against demographic characteristics and dichotomous variables identifying if they were given PBL curriculum and which instructor had taught them during that unit. In addition, the student performance on subject-specific questions for each midterm exam was regressed against those same covariates.

The results for the analyses of the performance on the midterms are a bit more robust. Students who received the first PBL unit, “High School Food Court” performed higher on both the first midterm exam and on the second midterm exam. Additionally, these students performed better on questions specifically relating to supply and demand

and profit maximization. There are positive teacher effects for the first midterm exam in the subject area of profit maximization.

On the third midterm, the students who were given PBL curriculum units "The Monopoly's Might" and "The Might Strikes Back" performed slightly worse than students who received standard non-PBL curriculum. The teacher effects for this midterm, however, were very strong. Students who received instruction from the teacher who had trained at the Buck Institute for Education—the organization that developed the PBL units—scored significantly better than students receiving the PBL curriculum from the teacher who did not train. The teacher effects were also present in the analysis of performance on specific questions on the third midterm exam. For the forth midterm exam, there were no significant PBL or teacher effects.

The analysis of student performance on the final exam shows similar results. There are positive, but statistically insignificant, relationships between the total score on the final exam and students receiving any (some or all) PBL curriculum. When examined by subject area, students who received the PBL curriculum on supply and demand scored 7 points higher than the non-PBL students.

These results suggest several important aspects of PBL curriculum and student outcomes. First, there is much greater impact of Problem Based Learning curriculum when the problem is aligned with how the material is 'typically' presented. As one of the first Buck Problem Based Economic Units, the "High School Food Court" serves its purpose very well. The 'problem' is well defined and the exercises are focused on students plotting demand curves, calculating total revenue and profits and making decisions regarding scarce resources—all the concepts that are ordinarily taught at the start of a microeconomics principles course and are instrumental in other aspects of microeconomics. The other units used in this experiment—"Monopolies Might" and the "Might Strikes Back" and "Great Awakening"—have elements that are less directly aligned to standard economics delivery. The "Monopolies Might" and "Might Strikes Back" focus on investment capital, entrepreneurs and government intervention. These units focus on questions of 'fairness' and 'ethics' that might be better suited for a class in 'business'. The "Great Awakening" has terrific elements and a unique approach to the calculation of opportunity costs. However, the method for computing comparative

advantage is unlike the typical methods introduced in principles texts (although considerably more realistic).

Additionally, the results identify that teacher training in PBL has considerable effects on the impact of the PBL. For the unit on monopolies, the students who were taught by the instructor who had trained at the Buck Institute for Economics scored much higher than the other students. The presence of these teacher effects points to the important role of both the curriculum and the teacher in student understanding.

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Table 1. Summary Statistics

Variable	Description	N	Mean	Standard Deviation	Minimum	Maximum
DEPENDENT VARIABLES						
TUCE PRE score	The total score on the TUCE pre-test	167	10.59	3.64	3.00	21.00
TUCE POST score	The total score on the TUCE post-test	178	13.72	7.42	5.00	28.00
TUCE POST: Supply and Demand	The score on the TUCE post test on supply and demand questions: 2,3,12,13,18 & 23	147	5.04	1.58	3	15.00
Midterm 1 Total	The total score on the midterm exam #1 (covering the first 4 weeks in class: supply, demand, markets, equilibrium)	137	45.73	5.74	27.0	57.5
Mid 1: Supply & Demand Total	The score of midterm exam #1 questions on supply and demand: multiple choice questions # 1,2,4 & 6 and essay questions # 2, 3 & 4	177	21.74	7.41	0	33
Mid 1: Profit Questions Total	The score of midterm exam #1 questions on calculating profit (TR, TC and Π): multiple choice questions # 5, 8 & 11 and essay questions # 5 & 6	178	14.60	5.50	0	22
Midterm 2 Total	The score of midterm exam #2 (covering weeks 5 & 6 on price floors, price ceiling, quotas, impact of taxation)	178	38.80	14.33	19	57
Midterm 3 Total	The score of midterm exam #3 (covering weeks 7 – 9 on consumer behavior, perfect competition, monopoly, monopolistic competition, and government involvement)	158	49.78	8.08	23	63
Mid3: Monopoly Questions	The score of midterm exam # 3 questions on monopolies, monopolistic competitive markets and perfect competition: multiple choice questions 2, 3, 6 & 6 and Essay Questions	158	24.11	5.59	4.50	33
Midterm 4 Total	The score of midterm exam #4 (covering weeks 10-12 comparative advantage, absolute advantage, gains	163	35.50	8.21	12	53

	from trade)					
Mid 4: Comparative Advantage	The score of midterm exam #4 questions on comparative advantage: Questions #	163	10.78	6.17	0	22
INDEPENDENT VARIABLES						
Age	The age of the student (continuous)	152	20.53	3.20	16	37
Male	Gender of Student Male = 1	178	0.47	0.50	0	1
Black[a]	Dichotomous variable Black = 1 if student identified as Black	178	0.03	0.17	0	1
Hispanic	Dichotomous variable Hispanic = 1 if student identified as Hispanic	178	0.10	0.30	0	1
Asian	Dichotomous variable Asian = 1 if student identified as Asian (Benchmark is White)	178	0.29	0.45	0	1
Economics HS	Dichotomous variable HS= 1 if student took any economics in high school	178	0.34	0.47	0	1
Class D (Class 9)	Dichotomous variable = 1 if student was in class D (NO PBL)	178	0.1799	0.38	0	1
Class C (Class 10)	Dichotomous variable = 1 if student was in class C ½ PBL	178	0.2528	0.43	0	1
Class B (Class 12)	Dichotomous variable =1 if student was in class B ½ PBL	178	0.2302	0.42	0	1
Class A (Class 1)	Dichotomous variable =1 if student was in class A (ALL PBL)	178	0.2078	0.40	0	1
Credit Hours	The number of credit hours the student is taking Fall Semester 2005	154	14.36	2.57	3	19
Hours Worked	The average number of hours the student was working per week the first week of Fall Semester 2005	140	10.34	12.22	0	50

a: Benchmark race is White

Table 2. Impact of PBL on Student Achievement: TUCE
Dependent Variable: Total Score on TUCE pre-test and TUCE post-test
OLS Estimates (standard errors in parenthesis)

Variable	Pre-TUCE	Post-TUCE
Intercept	7.691	4.658
	(4.974)	(7.290)
Age	0.197	0.261
	(0.121)	(0.190)
Male	0.220	-0.038
	(0.697)	(1.117)
Black[a]	-2.930	0.763
	(1.834)	(2.991)
Hispanic	0.066	1.738
	(1.169)	(1.907)
Asian	0.249	0.384
	(0.827)	(1.309)
Economics HS	0.813	5.733**
	(0.694)	(1.110)
Credit Hours	-0.138	0.494*
	(0.200)	(0.279)
Hours Worked	-0.010	-0.169
	(0.030)	(0.049)
Class C[b]	0.034	2.522
	(1.048)	(1.656)
Class B	-1.555	2.361
	(1.047)	(1.658)
Class A: ALL PBL	-0.559	1.887
	(1.069)	(1.673)
N	153	153
R^2	0.1051	0.1104

Notes:

1. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

a. benchmark race is white; b: benchmark is Class D— NO PBL

Table 3. Impact of PBL on Student Achievement: TUCE
Dependent Variable: TUCE GAIN RAW (Post − Pre) and TUCE GAIN % (Post – Pre)/Pre
OLS Estimates (standard errors in parenthesis)

Variable	TUCE Gain (raw)	TUCE Gain (percent)
Intercept	2.683	1.267
	(7.095)	(0.962)
Age	0.023	-0.015
	(0.185)	(0.023)
Male	0.066	-0.164
	(1.087)	(0.135)
Black[a]	2.511	0.267
	(1.857)	(0.354)
Hispanic	1.280	0.258
	(1.169)	(0.226)
Asian	-0.249	-0.144
	(1.274)	(0.160)
Economics H.S.	4.236**	0.412**
	(1.081)	(0.134)
Credit Hours	0.274	0.026
	(0.271)	(0.039)
Hours Worked	-0.178**	-0.024**
	(0.048)	(0.006)
Class C[b]	1.693	-0.044
	(1.612)	(0.203)
Class B	2.803*	0.230
	(1.613)	(0.202)
Class A: ALL PBL	2.012	0.013
	(1.628)	(0.207)
N	138	138
R^2	0.1125	0.1145

Notes:

1. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

a. benchmark race is white; b: benchmark is Class D— NO PBL

Table 4. Impact of PBL on Student Achievement: TUCE
Dependent Variable: Total Score on TUCE pre-test and TUCE post-test
OLS Estimates (standard errors in parenthesis)

Variable	Post-TUCE: Supply & Demand	Post-TUCE: Supply & Demand
Intercept	3.333**	3.178**
	(1.588)	(1.597)
TUCE PRE	0.4228**	0.4018**
	(0.1175)	(0.1159)
Age	0.0047	0.0076
	(0.0419)	(0.0420)
Male	-0.0184	-0.0426
	(0.2582)	(0.2584)
Black[a]	0.2250	0.2561
	(0.6294)	(0.6284)
Hispanic	0.7834*	0.6572
	(0.4644)	(0.4742)
Asian	0.1660	0.1226
	(0.2984)	(0.2962)
Economics HS	0.0695	0.0642
	(0.2541)	(0.2536)
Credit Hours	0.0260	0.0286
	(0.0763)	(0.0762)
Hours Worked	0.0145	0.0143
	(0.0118)	(0.0118)
BUCK 1: S & D, Profit	0.1416	0.0747
	(0.309)	(0.2623)
SMITH TEACH	--	0.2351
		(0.2597)
BUCK * SMITH	-0.1836	--
	(0.3386)	
N	114	114
R^2	0.0745	0.0792

Notes:

2. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

a. benchmark race is white; b: benchmark is Class D— NO PBL

Table 5. Impact of PBL on Student Achievement: Midterm 1
Dependent Variable: Midterm Total Score
OLS Estimates (standard errors in parenthesis)

Variable	Midterm 1 Total (1)	Midterm 1 Total (2)
Intercept	37.76**	38.03**
	(2.120)	(6.570)
TUCE PRE	0.557**	0.6044**
	(0.139)	(0.1406)
male	0.560	0.3803
	(1.064)	(1.100)
Black	1.396	0.7647
	(3.201)	(3.246)
Hispanic	0.466	0.9566
	(1.773)	(1.791)
Asian	0.198	0.0577
	(1.197)	(1.248)
Economics HS	1.582	1.606
	(1.040)	(1.060)
Credit Hours	0.015	0.1797
	(0.254)	(0.3119)
Hours worked	-0.024	-0.0320
	(0.048)	(0.0491)
BUCK 1	2.293**	2.627**
	(1.084)	(1.259)
SMITH TEACH	0.161	--
	(1.049)	
SMITH * BUCK 1	--	-1.095
		(1.431)
N	106	104
R^2	0.1118	0.1212

Notes:

1. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

Table 6. Impact of PBL on Student Achievement: Concept Areas Supply and Demand, Profit
Dependent Variable: Total Score on Supply and Demand, Profit Questions
OLS Estimates (standard errors in parenthesis)

Variable	Supply and Demand Total	Supply and Demand Total	Profit Total	Profit Total
Intercept	12.43**	13.06**	7.742**	6.643
	(3.829)	(5.733)	(2.899)	(4.49)
TUCE PRE	0.384**	0.4492**	0.379**	0.4001**
	(0.127)	(0.124)	(0.096)	(0.097)
Age	-0.2994*	-0.2885*	-0.080	-0.0869
	(0.186)	(0.1601)	(0.070)	(0.124)
Male	0.684	0.5766	0.747	0.774
	(0.959)	(0.934)	(0.724)	(0.729)
Black	3.027	2.286	-1.188	-1.238
	(2.846)	(2.774)	(1.929)	(1.936)
Hispanic	2.949*	3.691*	1.590	1.972
	(1.595)	(1.554)	(1.207)	(1.219)
Asian	-0.670	-0.8617	-0.691	-0.7048
	(1.102)	(1.099)	(0.834)	(0.848)
Economics H.S.	0.688	0.6473	2.057**	2.125**
	(0.954)	(0.931)	(0.718)	(0.720)
Credit Hours	0.308	0.6241*	0.145	0.325
	(0.225)	(0.261)	(0.170)	(0.203)
Hours Worked	-0.093**	-0.1030**	-0.093**	-0.097**
	(0.041)	(0.0393)	(0.031)	(0.030)
BUCK 1	3.991**	4.338**	1.431*	1.412*
	(0.977)	(1.11)	(0.740)	(0.7422)
SMITH TEACH	-0.036	--	1.480**	--
	(0.957)		(0.721)	
SMITH*BUCK 1	--	-0.9366	--	1.322*
		(1.266)		(0.724)
N	130	130	130	130
R^2	0.1725	0.2344	0.1919	0.2303

Notes:

1. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

Table 7. Impact of PBL on Student Achievement: Midterm Exam 2
Dependent Variable: Total Score on Midterm Exam 2
OLS Estimates (standard errors in parenthesis)

Variable	Midterm 2 Total (1)	Midterm 2 Total (2)
Intercept	37.12**	35.75**
	(12.03)	(11.64)
TUCE PRE	1.182**	1.181**
	(0.254)	(0.252)
Age	-0.906**	-0.929**
	(0.330)	(0.324)
Male	-0.426	-0.380
	(1.921)	(1.896)
Black	-2.474	-2.571
	(5.090)	(5.040)
Hispanic	6.079**	6.155**
	(3.201)	(3.151)
Asian	-1.665	-1.776
	(2.259)	(2.213)
Economics H.S.	1.848	1.915
	(1.905)	(1.881)
Credit Hours	0.7108	0.693
	(0.535)	(0.529)
Hours Worked	-0.298**	-0.299**
	(0.080)	(0.079)
Class C	0.933	--
	(2.826)	
Class B	8.325**	--
	(2.843)	
Class A	7.852**	--
	(2.902)	
BUCK 1	--	7.551**
		(1.923)
N	131	130
R^2	0.2820	0.

Notes:

2. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

Table 8. Impact of PBL on Student Achievement: Midterm Exam 3
Dependent Variable: Total Score on Midterm Exam 3: Exam Covering Perfect Competition, Monopolies, Monopolistic Competition, dead-weight loss, inefficient behavior, pricing by firm, output decision by firm.

OLS Estimates (standard errors in parenthesis)

Variable	Midterm 3 Total (3)	Midterm 3 Total (4)	Midterm 3 Total (6)	Midterm 3 Total (8)
Intercept	44.43**	41.44**	51.55**	50.07**
	(2.642)	(6.730)	(1.920)	(6.545)
TUCE PRE	0.761**	0.843**	_	_
	(0.190)	(0.187)		
Male	-1.977	-2.037	-1.290	-1.445
	(1.483)	(1.439)	(1.564)	(1.552)
Black	-9.743*	-7.236	-12.11**	-9.864
	(5.536)	(5.422)	(5.960)	(5.954)
Hispanic	0.652	1.450	0.103	0.742
	(2.408)	(2.365)	(2.591)	(2.589)
Asian	-1.940	-2.593	-2.104	-2.697
	(1.662)	(1.616)	(1.738)	(1.725)
Economics H.S.	2.569*	2.920**	2.937*	3.234**
	(1.479)	(1.437)	(1.557)	(1.542)
Credit Hours	_	0.150	_	0.091
		(0.395)		(0.412)
Hours Worked	-0.228**	-0.237**	-0.205**	-0.213**
	(0.066)	(0.064)	(0.070)	(0.070)
BUCK 2 & 3	-0.172	-2.913*	1.444	-0.713*
	(1.516)	(1.853)	(1.571)	(1.961)
SMITH TEACH	0.146	_	-0.813	_
	(1.520)		(1.588)	
SMITH * BUCK 2 & 3	_	5.199**	_	3.778*
		(2.042)		(2.170)
N	130	130	130	130
R^2	0.2084	0.2055	0.1831	0.1850

** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

Table 9. Impact of PBL on Student Achievement: Concept Areas Monopoly
Dependent Variable: Total Score on Questions Covering Perfect Competition, Monopolies, Monopolistic Competition

OLS Estimates (standard errors in parenthesis)

Variable	Monopoly Total (1)	Monopoly Total (2)	Monopoly Total (3)	Monopoly Total (4)
Intercept	22.51**	21.89**	25.63**	25.52**
	(1.631)	(1.500)	(1.120)	(1.012)
TUCE PRE	0.311**	0.363**	_	_
	(0.117)	(0.111)		
Male	-1.253	-1.105	-1.222	-1.170
	(0.894)	(0.838)	(0.896)	(0.858)
Black	-7.308**	-6.488**	-8.149**	-7.553**
	(2.281)	(2.150)	(2.309)	(2.220)
Hispanic	-0.379	0.165	-0.601	-0.076
	(1.483)	(1.397)	(1.513)	(1.455)
Asian	-0.698	-1.431	-0.884	-1.489
	(1.033)	(0.974)	(1.025)	(0.987)
Economics H.S.	1.806**	2.148**	1.852**	2.144**
	(0.899)	(0.841)	(0.902)	(0.861)
Credit Hours	-0.002	0.000	-0.003	-0.001
	(0.005)	(0.005)	(0.005)	(0.005)
Hours Worked	-0.105**	-0.115**	-0.098**	-0.106**
	(0.040)	(0.038)	(0.041)	(0.039)
BUCK 2 & 3	0.321	-1.910*	0.972	-0.955
	(0.895)	(1.013)	(0.888)	(1.029)
SMITH TEACH	-0.101	_	-0.336	_
	(0.905)		(0.900)	
SMITH * BUCK 2 & 3	_	4.630**	_	3.917**
		(1.187)		(1.197)
N	130	130	130	130
R^2	0.1702	0.1711	0.1654	0.1623

Notes:

1. ** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

Table 10. Impact of PBL on Student Achievement: Midterm Exam 4 & Comparative Advantage
Dependent Variable: Total Score Midterm 4 Covering Comparative Advantage, Absolute Advantage, International Trade, Exchange, Exchange Rates
OLS Estimates (standard errors in parenthesis)

Variable	Midterm 4 Total (1)	Midterm 4 Total (2)	Comparative Advantage (3)	Comparative Advantage (4)
Intercept	7.133	7.485	0.332	0.462
	(12.97)	(13.00)	(5.531)	(5.547)
TUCE PRE	1.417**	1.415**	0.600**	0.600**
	(0.282)	(0.282)	(0.1203)	(0.120)
Age	-0.168	-0.193	-0.148	-0.160
	(0.363)	(0.361)	(0.154)	(0.154)
Male	0.6621	0.722	0.159	0.193
	(2.12)	(2.114)	(0.904)	(0.902)
Black	-1.191	-1.313	0.681	0.618
	(5.631)	(5.625)	(2.401)	(2.400)
Hispanic	1.381	1.478	0.711	0.773
	(3.544)	(3.525)	(1.511)	(1.504)
Asian	0.116	-0.007	0.199	0.154
	(2.466)	(2.490)	(1.051)	(1.062)
Economics H.S.	5.251**	5.327**	2.220**	2.254**
	(2.095)	(2.097)	(0.893)	(0.894)
Credit Hours	0.857	0.836	0.490*	0.481*
	(0.590)	(0.590)	(0.251)	(0.252)
Hours Worked	-0.2302**	-0.230**	-0.074**	-0.074**
	(0.0881)	(0.088)	(0.037)	(0.0379)
BUCK 4	2.048	2.776	1.095	1.393
	(2.158)	(2.637)	(0.920)	(1.125)
SMITH TEACH	-1.137	--	-0.584	--
	(2.107)		(0.898)	
SMITH * BUCK 4	--	-1.629	--	-0.695
		(2.873)		(1.226)
N	131	131	131	131
R^2	0.2188	0.2190	0.2120	0.2113

** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).

Table 11. Impact of PBL on Student Achievement: Final Exam & Concept Areas
Dependent Variable: Total Score Final Exam; Concept Areas : Supply and Demand, Monopolies, Comparative and Absolute Advantage.
OLS Estimates (standard errors in parenthesis)

Variable	Final Exam Total (1)	Final: Supply and Demand (2)	Final: Monopolies (3)	Final: Comparative Advantage (4)
Intercept	49.61	11.43	-4.52	-0.461
	(12.07)	(9.94)	(7.06)	(6.50)
TUCE PRE	-0.4366	-0.088	-0.276	-0.181
	(0.5942)	(0.350)	(0.182)	(0.176)
Male	-2.86	-0.002	-0.428	1.166
	(6.75)	(2.45)	(1.303)	(1.22)
Black	-24.97	-9.502	-4.523	-7.26
	(17.24)	(7.25)	(4.77)	(5.67)
Hispanic	12.80	8.85**	0.975	2.48
	(11.85)	(4.37)	(2.23)	(2.16)
Asian	0.250	0.067	0.287	-0.390
	(7.643)	(2.75)	(1.44)	(1.32)
Economics H.S.	-2.512	-0.447	-0.231	-0.245
	(7.17)	(2.44)	(1.310)	(1.231)
Credit Hours	-0.0443	-0.009	0.428	0.347
	(0.037)	(0.012)	(0.350)	(0.317)
Hours Worked	-0.0398	-0.050	-0.046	-0.0468
	(0.306)	(0.116)	(0.061)	(0.0576)
Midterm Exam Score 1	---	0.0156	---	---
		(0.235)		
Midterm Exam Score 3	---	---	0.178**	---
			(0.090)	
Midterm Exam Score 4	---	---	---	3.994
				(6.53)
Buck Half[a]	4.42	---	---	---
	(8.97)			
Buck Whole[b]	5.57	---	---	---
	(10.08)			
Buck 1	---	7.12**	---	---
		(2.97)		
Buck 2 & 3	---	---	-1.41	---
			(1.67)	
Buck 4	---	---	---	1.02
				(1.57)
N	125	125	125	125
R^2	0.055	0.1316	0.1244	0.1120

** indicates a statistically significant estimate ($p < 0.05$); * indicates a statistically significant estimate ($0.05 \leq p < 0.10$).
a: Buck Half =1 for class sections B and C
b: Buck Whole = 1 for class section A
Benchmark for Buck Half & Buck Whole is Class D = No Buck