TEACHING & LEARNING

Teaching Pre-Algebra with the Theme of Environmental Science

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Abstract

Pre-algebra is the first course of a sequence of two basic skill math courses offered at LaGuardia Community College. In order to contextualize and make the material relevant to students, the faculty of the college have integrated into the curriculum the PQL (Project Quantum Leap) projects. These projects are based on the SENCER (Science Education for New Civic Engagements and Responsibilities) approach and allow students to learn real world math in a single engaging context. This paper identifies the underlying quantitative reasoning skills embedded in these projects. I discuss the details of three projects that were piloted in my class and how effectively they supported students' learning when compared to a non-PQL class.

Introduction

Statistics indicate that about 60% of all U.S. community college students enroll in at least one remedial course in English or math, where they can get stuck studying elementary- and middle-school-level concepts; only 31% of the remedial math students ever move beyond the remedial level, according to the Community College Research Center at Columbia University's Teachers College (Redden, 2010). Nationally, pass rates in remedial math remain lower than those for remedial writing and reading (Melanie, 2005), and remedial math courses often become hurdles in the degree completion process. At LaGuardia Community College, more than half the students need basic-skills math courses, and more than 60% aspire to obtain a baccalaureate or higher degree (CUNY, 2009). Therefore, succeeding in basic math skills is important for students who want to stay in college and successfully complete their degree (Lutzer et al. 2005).

At community colleges, now the major gateway to higher education in this country, remedial classes account for approximately 57% of mathematics program

enrollments (Lutzer et al. 2005). Students in basic math courses have often had repeatedly unsuccessful experiences and view the subject as uninteresting and irrelevant. More than 35% of the students in basic-skills math courses retake the course at least once (Betne 2010), and lack of math skills proficiency has a major effect on student retention (Parker 2005).

Students can in fact learn mathematics and science with understanding, and the teachers' instructions should enhance the students' abilities to connect ideas and concepts and enable them to apply what they know to new situations and phenomena (NCISLA, 1995-2005). More than 60% of LaGuardia students specified their major to be in science or applied sciences (CUNY, 2009). Researchers at National Center for Improving Student Learning and Achievement in Mathematics and Science have found several ways to connect math with science and have reasoned that these abilities, in addition to students' mastery of basic skills, are vital for students facing an increasingly complex world. As todays' world has become technologically information-driven, students need to know more than the basics in mathematics and science to cope with accelerating changes (NCISLA, 1995-2005).

In order to engage students' interest in mathematics and enhance mathematical learning, Metropolitan State University developed a new curriculum for the Pre College Algebra course in 2009, which included real-world environmental sustainability issues, quantitative reasoning, and mathematical modeling. Six sections piloted the new curriculum and three used the traditional curriculum, and an assessment study was conducted to evaluate the effectiveness of the new curriculum. The study showed that the new curriculum integrating civic/environmental issues is at least as effective as a traditional mathematics curriculum at building students' mathematical skills, increasing students' confidence in using mathematics, and increasing students' interest in learning and applying mathematics. (Wagstrom 2010).

Similar efforts have been made at LaGuardia College for three courses, namely, Introduction to Algebra, Elementary Algebra, and College Math and Trigonometry. The Project Quantum Leap (PQL) program at LaGuardia College was established in 2007 to explore the Science Education for New Civic Engagement and Responsibilities (SENCER) approach—an interdisciplinary approach to teaching math and science that can deepen the settings and contexts and engage students. A curriculum and a pedagogy that "contextualized" the process of learning mathematics skills and concepts were developed by the LaGuardia PQL program in Fall 2012 (LaGuardia Center for Teaching and Learning 2009). Introduction to Algebra was contextualized with issues of energy, climate change, and environmental science; Elementary Algebra with issues of personal and public health; and College Algebra and Trigonometry with issues of economics and personal finance. Twenty-six PQL math courses and 13 PQL math learning communities were taught, and approximately one thousand students were served. A preliminary analysis of the students' responses to the Community College Survey of Student Engagement (CCSSE) survey data showed that students in PQL classes demonstrated more confidence, comfort, and engagement with mathematics, when compared with students in non-PQL comparison classes. This study indicated that the course pass rate in PQL classes was 54.7% compared with 47.6% in non-PQL comparison classes.

In light of the LaGuardia PQL project, I attended the professional development seminars conducted by the PQL Program leaders with support from the LaGuardia Center for Teaching and Learning (CTL), in order to develop teaching materials such as class activities and projects, and to discuss ways to implement them in the classes. I taught two sections of the Pre Algebra course in Spring 2010 and implemented PQL environmental science activities described in this report in one of these sections. The PQL section originally had twenty-eight students enrolled, while the non-PQL section had twenty-four students. Only twenty-six students from the PQL section and only eighteen from the non-PQL section completed the course. All students participated in the study, and the approval of the Institutional Review Board (IRB) was obtained in order to publish the research findings.

The results obtained from the previous study on the PQL program at LaGuardia focused on the overall pass rates of PQL and non-PQL sections taught by several full-time and part-time faculty. My research is a further continuation of this PQL program and focuses on the students' performance in PQL vs. non-PQL sections when taught by the same instructors; this approach minimizes the variables such as PQL activities, teaching

methodologies, tests, assessment rubric etc. The significance of this report can be summarized in the following two points: (1) The quantitative reasoning skills embedded in environmental science activities were engaging and supported students' learning. (2) The PQL approach has a positive impact on the course pass rate, which is explained by comparison between the pass rates of my PQL class and my non-PQL class.

The PQL Approach in the Classroom

The course Introduction to Algebra has a problem-solving approach that emphasizes the importance of mathematical reasoning in addressing real-world problems drawn from diverse disciplines. Topics include arithmetic (signed numbers, fractions, decimals, and percents), elementary algebra (solving first degree equations and inequalities, rules of exponents, equations of lines) and basics of geometry (area and perimeter), as well as numeracy (estimation, unit analysis).

This course is intended for students with little or no algebra background. Some of the common errors that I observed in my students' work were

- Do not understand the significance of numbers
- Do not understand the importance of units and assign them in the wrong places
- Get confused with the word problems; what is given and what is asked
- Either underestimate or overestimate the numbers in problems
- Incorrectly assign positive and negative signs
- Fail to analyze the answers or analyze the answers incorrectly

Objectives and Design of Projects

I designed classroom activities and piloted them in my PQL course with four goals. These goals in systematic order are as follows: *First goal*— the activities had to address causes and consequences of global warming and the impact of our living habits on earth's resources, on both the individual and global levels. *Second goal*—the projects had to involve students in the regular practice of skills common to both math and critical thinking, such as decision-making, problem-solving logic, and argument building. *Third goal*—the projects must address the above-mentioned common math errors. *Fourth goal*—the sustainability and environmental science content for the activities must be designed specifically for each math topic.

The activities listed in Table 1 consisted of both in-class discussions and homework assignments designed to motivate the students (Ande and Kothari 2009). The in-class discussions involved my introduction of environmental issues to the class followed by the students' participation in discussing these issues. The homework

TABLE 1. PQL activities designed for the course Introduction to Algebra

Syllabus Topic	Activities	Learning Objectives
Whole numbers. Place value. Rounding whole numbers.	Greenhouse gas: carbon dioxide (CO_2) emissions	1. Understand what numbers mean in terms of CO_2 emissions 2. Be able to successfully write numbers in words and vice versa 3. Be able to round numbers 4. Rank each country with respect to CO_2 emissions
Solving equations	Greenhouse effect and global warming	1. Understand what greenhouse effect and global warming are 2. Be able to calculate the amounts of carbon dioxide released and absorbed 3. Be able to write and solve one-step equations 4. Analyze the answer and write a reflection
Average. Understanding rates. Adding and dividing decimals. Converting decimal to percent	Ecological footprint: How much do we consume?	1. Be able to compute average acres 2. Be able to find the difference between the world average and the average computed 3. Be able to calculate percent 4. Analyze the answer 5. Reflect on how our consumption habits impact our environment and climate and contribute to global warming

assignments involved reading, finding numerical results using basic computations, and subsequently reflecting on their responses and views on environmental issues based on the knowledge gained. After completion of each activity, a quiz based on the math topic learned was given to the class in order to assess their knowledge.

Greenhouse Gas: Carbon Dioxide (CO_2) Emissions

The activity, Greenhouse gas: carbon dioxide emissions, was developed not only to help students overcome the common errors (explained above) in the first week but to see the connection between math and a global problem. A definition of greenhouse gases along with references and a list of carbon dioxide emissions by each country were given as a handout to students after instruction on whole numbers and rounding whole numbers. Students were asked to read the handout first and then complete a table by writing the emissions in word form or in scientific form and rounding the numbers to the nearest thousands, hundreds, tens, or ones, and ranking them in ascending order. This assignment was conducted in class in order to observe students' perception of global problems and their response to the assignment. Students did well in completing the table. However, some students were confused about whether to rank the countries after rounding or before rounding.

Greenhouse Effect and Global Warming

The original activity was developed by Dr. Prabha Betne. I tailored the activity to suit the students' need and to emphasize quantitative learning. This activity targeted word problems based on fractions, decimals, and forming and solving one-step equations. It was introduced to students using a short PowerPoint presentation on the greenhouse effect, global warming, and the contribution of carbon dioxide (CO_2) to global warming. Graphs depicting the trends in atmospheric concentrations, anthropogenic emissions of CO_2, and prospects for future CO_2 emissions were shown, followed by in-class discussion. A picture depicting the global carbon cycle was displayed, and as a part of an in-class activity, students were asked to recognize the sources that release and absorb CO_2. They were asked to formulate the one step equation showing the imbalance between the amount of carbon dioxide that is released into the atmosphere and the amount that is absorbed by various sources, and the effects of the imbalance. As an assignment, they solved the equation. They were also asked to estimate the amount of CO_2 that would be released in next 15 years if the same trend continued, and to analyze and reflect on how they would contribute towards a safer environment by minimizing emissions.

Ecological Footprint

This activity was originally developed by Dr. Betne. I tailored the activity to suit the students' need and to emphasize quantitative learning. Average, rates, addition and division with decimals and conversion from decimal to percent were the topics covered through this activity. The ecological footprint assignment required students to calculate their own ecological footprint (acres of land required to support the lifestyle) and compare that value with the available land space, countrywide and worldwide. Students were given sample data in acres for 15 students in the age group 16-20 years that was obtained from an online survey conducted to study the consumption habits (food, mobility, shelter, and goods and services) of students in the college. Calculations were performed to find the ecological footprints (equivalent earth resources as the number of acres) required per person to support such living habits, and to find the total acres required for each student.

Students calculated the average total acres required for a student, and the difference between the average they computed and the given 4.5 biologically productive acres per person (world average). As part of an assignment, students were asked to convert the difference found as a percentage (above or below the world average value) and estimate the number of planet earths we need to live the way we are living. They were required to review their calculations, analyze their answers, and write reflection on their learning from this exercise, for example the role of math in understanding the environmental issues and how math helped them find a solution for these problems.

Conclusions

The Greenhouse gas: carbon dioxide (CO_2) emissions assignment was well received by the students. About 90% of students completed the table in class, which showed that they are interested in real world problems. About 82% of students rounded the numbers correctly. It was interesting to observe that about 87% of students were confused and asked questions whether to rank the countries after rounding or before rounding. Students answered this question themselves, after being asked to rank the countries before and after rounding. The ranks were then compared and discussed. Students clearly understood that rounding emissions did not affect the ranks, as the emissions are large numbers and emissions released by each country are far apart. When the same quiz was given to both sections, the quiz average on whole numbers for a PQL class was 76.8%, compared to a non PQL class quiz average of 65.3%. This indicated clearly that the PQL approach was effective in helping the students to understand the topic.

The Global warming assignment graphs drew students' attention with respect to the seriousness of global warming and the sources that impact emissions. Most of the time in class was spent on discussing the graphs, the importance of units, and analysis of data. About 81% of students were able to correctly formulate an equation using the global carbon cycle picture. The interaction with individual students revealed that they liked this topic and the class discussion. About 85% of students completed the assignment and the class average on the assignment was 70.7%. When the same quiz was given to both sections, the quiz average on word problems, forming and solving equations was 67.2% for a PQL class, which was higher than the quiz average of 62% for a non-PQL class. The above results indicate that these PQL assignments improved student understanding, learning and remembering the quantitative skills, and applying them effectively in various scenarios.

Approximately 87% of students were able to correctly compute their own ecological footprint and compare that value with the available land space worldwide and countrywide. 74% of students were able to successfully convert decimals to percentages and interpret their results. About 84% of student responses on the reflection assignment indicated that the students were intrigued and fascinated with ecological footprint facts and that their understanding of the environmental issues increased.

These PQL assignments allowed students to read the facts on environmental science topics and clearly showed them the connection of math with science. The mathematical part of the assignment helped students to develop the appropriate number sense and enhance their knowledge of numeracy and calculations, and, in turn, improved their quantitative reasoning skills. Moreover, the use of PQL projects, a student-centered approach, engaged students in critical thinking and reasoning, and supported them in becoming independent learners. In particular, the activities described above gave them a sense of civic and social responsibilities of the real world they live in. The research study that I undertook indicated a 61.3% course pass rate in my PQL section as compared to 55.7% in my non-PQL section.

Future Study

The LaGuardia PQL program internally published a collection of PQL activities as a sampler, available through the LaGuardia CTL website. This collection serves as a teaching resource for faculty. My research as an environmental engineer working in the fields of water and air pollution, environmental health, toxicology, and hazardous waste management will help me to develop new PQL activities and revise the current ones in order to keep up with the most current real-world data on environmental issues.

I am in the process of incorporating more PQL-type activities for math topics listed in the Introduction to Algebra syllabus. I also plan to administer SENCER math SALG pre-course and post-course surveys in order to collect demographic information about the students and evaluate changes in students' interest and confidence in learning mathematics. The activities I have developed and the ones that are in the developmental stage will be shared with other faculty members, so that they can implement them in their classes to assess student performance.

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