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MATHEMATICS UNDERGRADUATES LEADING UNDERGRADUATES ENROLLED IN GENERAL CHEMISTRY: WHY THIS WORKS!

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New York City College of Technology is the designated college of technology of the City University of New York (CUNY). Peer-Led Team Learning (PLTL) is a structured learning method to engage students in a collaborative environment. PLTL has been used in several courses at the college, including General Chemistry and Mathematics. The implementation in Chemistry is that workshops are optional or mandatory outside of class time. The problem being addressed is the following: Is the first exam or second exam in General Chemistry II an indicator for passing the course? The approach used depends on recognizing that peer leaders with strong math problem solving skills give students insights in connecting chemistry concepts (such as kinetics and equilibrium) to math. These concepts are assessed on the second exam. Students in courses with workshop show significant improvement compared to students without workshop. The data indicate that PLTL workshops increased student retention and passing rate.

Overview of Peer-Led Learning models

Peer-Led Team Learning (PLTL), Peer Instruction Leader (PIL) and Peer-Assisted Learning (PAL) all utilize the concepts of teaching and learning. These peer-led learning models are based on students who have passed a specific course, and performed well in this course. These students are recruited and trained to be peer leaders and lead discussion and problem-solving sessions for small student groups in a designated time and place. These sessions or workshops can meet weekly or twice a week, for a period of one hour (Hockings DeAngelis, & Frey, 2008; Shaw Ticknor, & Howard, 2013; Chesney, 2011; Gosser, Cracolice, Kampmeier, Roth, Strozak, Varma-Nelson, 2001; Center for Peer-led Team Learning, n.d.). During these workshops, the peer leaders engage students in problem-solving and discussion of course concepts. Numerous terms can be used to describe this concept of peer-led learning and it has been adopted and adapted at many colleges (Tariq, 2005; Gosser et al., 2001; Center for Peer-led Team Learning, n.d.). Findings (Hockings et al., 2008; Shaw et al., 2013; Tariq, 2005) suggest that PLTL/PIL/PAL improves student active-learning. Furthermore, Parkinson (2009) found students engaged in PAL workshops showed improvement in both calculus and chemistry test scores, and lower failure rates over non-PAL participants.

PLTL and its impact on student attitudes and grades

At the nucleus of a PLTL program are students learning from other students in small groups (Hockings et al., 2008, Chesney, 2011).There are several benefits of peer-led team learning. Working in a group will give some students, who have difficulty talking in class, a more comfortable atmosphere to speak up and express their ideas and/or question in front of familiar classmates (Sarkisian, 1997). The research of Popejoy and Asala (2013) and Tariq (2005) indicate the workshops give students the control to ask and answer questions with less pressure and convey their ideas of course material. This results in students working collaboratively to build their knowledge (Popejoy & Asala, 2013).

Students in PLTL can function as a community. Working in a group, students may come up with alternative views or solutions to a problem. This enables students to solve complex questions together, which they may not be able to individually (Sarkisian, 1997). A small group learning environment can help students build up their confidence in taking and passing the course (Sarkisian, 1997; Tariq, 2005; Micari, Streitwieser, & Light, 2006; Shaw et al., 2013). And more importantly, students can implement this in methods in other courses such as engineering that will help them succeed in their college studies (Hockings et al., 2008; Micari, et al., 2006).

According to Popejoy and Asala (2013), at the midpoint mark of the semester, students change their reaction toward peer workshops from unfavorable to favorable. The attitude change comes from getting better grades and getting to know other students in the class. Students become aware that more practice improved their problem-solving skills (Hockings et al., 2008; Chesney, 2011; Quitadamo et al., 2009).

At New York City College of Technology (“City Tech”), workshop participation and attendance is included as a component of the final course grade. It is suggested that increasing the percentage of workshop attendance in students’ course grade may increase attendance in workshop participation (Lewis & Lewis, 2005). In addition, Quitadamo, Brahler, Crouch (2009) found that students’ critical thinking skills are impacted positively as a result of PLTL workshops. Moreover, there are improvements in retention in STEM fields (Tenney & Houck, 2003; Chesney, 2011; Hockings et al., 2008), a decrease in the rate of D, F grades and withdrawals from STEM classes (Chesney, 2011; Hockings et al., 2008; Popejoy & Asala, 2013), and PLTL creates supportive and engaging learning opportunities (Chesney, 2011).

Chemistry Curriculum at NYC College of Technology

At the core of the Chemical Technology Associate degree at City Tech are the following STEM courses: two semesters each of general chemistry and organic chemistry, one semester of analytical chemistry or instrumental methods, two semesters of physics, calculus I, and one year of science/math electives. The remaining courses are general education requirements, which include English composition, information literacy, aesthetics, philosophy, behavioral or social science. The pre- or co-requisite course for general chemistry is college algebra and trigonometry (MATH 1275). Topics in this course include quadratic equations, exponential and logarithmic functions, which are essential to success in general chemistry 2.

From fall 2008 to fall 2011 the one-year retention rate of first-time, full-time, degree-seeking freshmen at City Tech decreased from 60% to 42%, respectively (AIR, 2013). According to Tenney & Houck (2003) and Popejoy & Asala (2013), the attrition rates in chemistry are analogous to national percentages in similar science courses.

Implementation Method

The effect of PLTL on General Chemistry 2 was compared across several terms where a) PLTL was implemented as a course component and b) PLTL was not an option in the course (non-PLTL). For non-PLTL, a total of 104 students were enrolled in three sections (fall 2010 and spring 2011) and 82 completed the course, with a ~70% passing rate (ABCD). For PLTL sections, 56 students were enrolled in two sections (spring and fall of 2012) and 49 completed the course, with a passing rate of ~84%.

The final grade comparative data (AIR, 2013) for General Chemistry 1 and General Chemistry 2 for spring 2009 to fall 2012, represented the total number of students enrolled, and includes PLTL and non-PLTL data in aggregate. For General Chemistry 1, there were 1959 students over the eight terms/semesters, whereas for General Chemistry 2, there were 833 students represented in the data.

Results and discussion

The pre- or co-requisite course for General Chemistry is college algebra and trigonometry. PLTL has been embedded in some sections of this MATH 1275 course. Figure 1 shows in the spring term of 2012, math courses with embedded PLTL workshops had passing rate (D or better) of 82.1%, which is significantly higher than the college general passing rate of 63.8%. This data indicates PLTL can improve students' performance and retention in math courses.

Final grade	PLTL-Math (n=184)	General Math (n=1355)
Pass (ABCD)	82.1%	63.8%
Withdraw	9.8%	17.7%
Fail	6.5%	16.6%

Figure 1. Pass rates of MATH 1275 in spring 2012 in NYC College of Technology, a pre- or co-requisite course for General Chemistry.

The effects of Peer Led Team Learning (PLTL) were observed and analyzed in General Chemistry 2 courses over several semesters. In General Chemistry 2 there are three chapter-based exams and one cumulative final exam. Each exam covers at least two chapters. The first exam covers intermolecular forces and properties of solutions. The second exam covers chemical kinetics and equilibrium. The third exam covers acid and bases with respect to equilibrium. Additional topics of entropy, enthalpy, Gibbs free energy, electrochemistry and/or organic chemistry are included in the final exam.

Figure 2A and 2B show the final grade distribution for General Chemistry 1 and 2 over eight semesters (AIR, 2013). On average the pass rates (ABCD) for General Chemistry 1 is 81% compared to 73% for General Chemistry 2 (Figure 3).

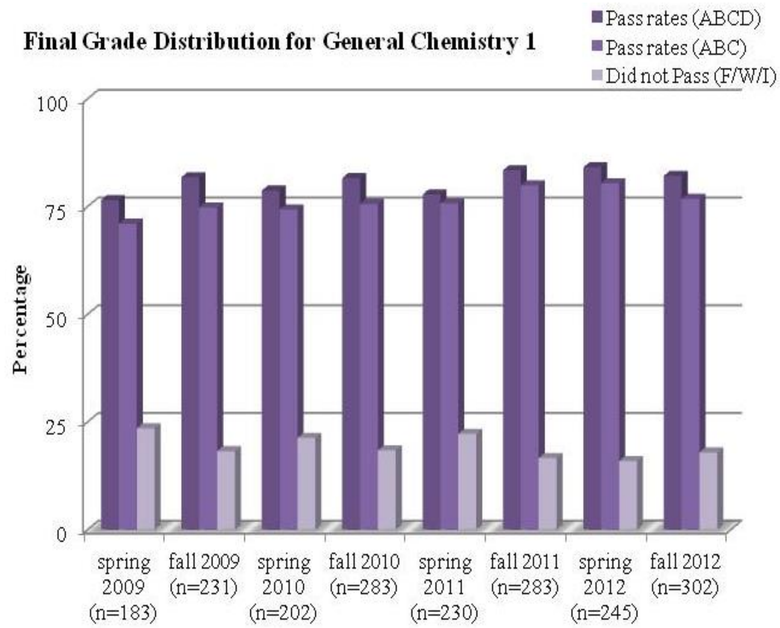

Figure 2A.Final grade distribution for General Chemistry 1, from spring 2009 to fall 2012. Data for some terms include PLTL and non-PLTL sections in the aggregate (AIR, 2013).

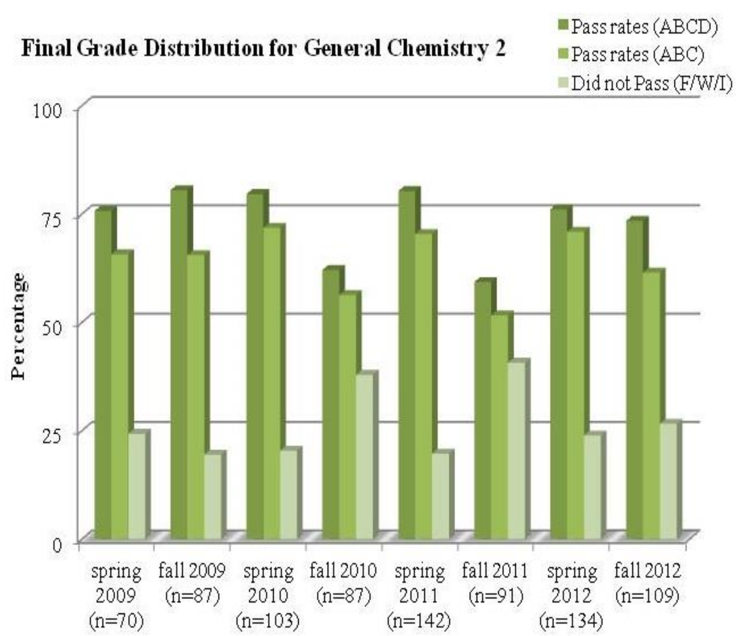

Figure 2B.Final grade distribution for General Chemistry 2, from spring 2009 to fall 2012. Data for some terms includes PLTL and non-PLTL sections in the aggregate (AIR, 2013).

Figure 3 shows that the average "Did not Pass" percentage, which includes failure, withdrawal (with and without penalty), and incompletes, is 19% for General Chemistry 1 in contrast to 27% for the second semester of the course. For the semesters evaluated, 9% of students on average, pass General Chemistry 2 with a D (Figure 3).

It is evident that students attain better grades in General Chemistry 1 in comparison to the second semester of the course. The questions are "why" and what indicators can be used to determine success in General Chemistry 2. Based on our observations, the second exam in General Chemistry 2 appears to be an indicator of success in the course – as this is where the most mathematically challenging problems are evaluated. There was no significant difference in the average grade for exam 1 (excluded are students who withdrew or did not take the exam), for PLTL (n=49) and non-PLTL (n=82) sections. This comparison takes into consideration only students who completed the course. This lack of difference can be ascribed to (i) the course material at this point is not math intensive, and (ii) few PLTL workshops are scheduled before exam 1. Exam 1 includes topics such as intermolecular forces and properties of solutions. There is however a noteworthy difference for exam 2. The averages of exam 2 for non-PLTL are not only lower than PLTL sections, but also lower than the average of the first exam. PLTL sections' grades average higher than non-PLTL sections for exams 2, 3 and the final. This suggests that after the first exam, attendance at peer-led workshops becomes a positive factor for the second exam as well as toward the final grade distribution. Research by Mills and Sweeney (2009) has linked student performance on the first exam in General Chemistry 1 to their success in the course and final grade.

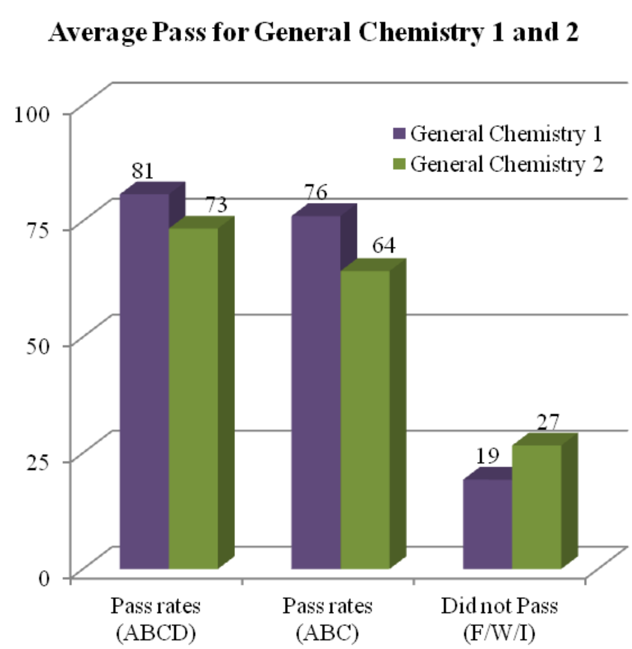

Figure 3. Average final grade distribution for General Chemistry 1 (n=1959) and General Chemistry 2 (n=823) from spring 2009 to fall 2012 (AIR, 2013).

A typical second exam problem in General Chemistry 2 is presented in Figure 4. Problems of this type explore the concept of equilibrium. Students must be able to critically think about how to approach these problems. Unmistakable in this process are the numbers of mathematical steps used to solve these problems. Core concepts such as quadratic equations, encountered in MATH 1275, are used to solve these chemical equilibrium problems. Our approach to PLTL is two-fold – to have a peer-led learning approach, but also employ the skills and knowledge of a peer leader with a strong mathematics foundation. Hence, undergraduates majoring in mathematics peer lead undergraduates enrolled in General Chemistry 2. We have seen success in this approach because math peer leaders possess both chemistry knowledge (having previously taken the course) and the math knowledge (majoring in this discipline).

For the following problem, the objective is to determine equilibrium concentration of all species present based on the given data: at 727 °C, the equilibrium constant (K_c) is 3.8×10^{-5} for the dissociation reaction of I_2. The initial concentrations of all species are: $[I_2]_0 = 0.063\ M$; $[I]_0 = 0.012\ M$.

Step 1: Identify initial concentrations and determine direction of shift to attain equilibrium

$$Q_c = \frac{[I]^2}{[I_2]} = \frac{(0.012)^2}{(0.063)} = 2.3 \times 10^{-3} \quad Q_c > K \text{ implies shift to reactants}$$

Step 2: Set up ICE table

	$I_2\,(g)$	$\rightleftharpoons$ $2I\,(g)$
Initial	$0.063\,M$	$0.012\,M$
Change	$+x$	$-2x$
Equilibrium	$0.063\ M + x$	$0.012\ M - 2x$

Step 3: Write equilibrium expression and solve for x

$$K_c = \frac{[I]^2}{[I_2]} = \frac{(0.012 - 2x)^2}{0.063 + x} = 3.8 \times 10^{-5}$$

Step 4: Complete algebraic expression and use quadratic form

$4x^2 - 0.048x + 1.44 \times 10^{-4} = 2.39 \times 10^{-6} + 3.8 \times 10^{-5}x$

$4x^2 - 0.048\,x + 1.42 \times 10^{-4} = 0$

$ax^2 + bx + c = 0$

Step 5: Solve for x, using quadratic equation

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$x_1 = 6.71 \times 10^{-3}$ and $x_2 = 5.29 \times 10^{-3}$

Step 6: Evaluate both values of x to determine equilibrium concentrations of all species. Rule out x_1

$[I_2] = 0.063 + x_1 = 0.063 + 6.71 \times 10^{-3} = 0.070\ M$ or $0.063 + x_2 = 0.068\ M$

$[I] = 0.012 - 2x_1 = 0.012 - 2(6.71 \times 10^{-3}) = -0.00142\ M$ or $0.012 - 2x_1 = 0.00142\ M$

$[I_2]_{eq} = 0.068\ M$

$[I]_{eq} = 8.44 \times 10^{-3}\ M$

Figure 4. Typical mathematically challenging equilibrium problem (with solution) encountered in General Chemistry 2 and the step-by-step method used by peer leaders (adapted from Chang, Goldsby, 2013).

From a peer leader point of view, the factor that makes math difficult for many students is that it takes time, energy, patience and persistence. For many students, math is not something that can be understood easily, with little effort. It consumes a lot of a student's time and energy to practice in order to become familiar with the material. Math knowledge is cumulative, as is knowledge in science courses. Students who do not have a solid foundation in math will have difficulty in moving on. Similarly, when students study chemistry, a new subject for some students at City Tech, it consumes students' time, energy, patience and persistence to manage the course materials. A multitude of calculations in General Chemistry 2 will strike at students' confidence to pass the class. Peer leaders having a strong mathematics background will help students not only understand chemical reactions, but also assist them with the ability to perform complex calculations and critical thinking in solving problems. A student who has a solid mathematics foundation will perform better in General Chemistry than one who does not.

During the workshop, students are expected to interact with their classmates and discuss the workshop questions and express their ideas. All through this process, they may come up with two or more solutions (alternative approaches to the same problem), which may improve the students' problem-solving skills.

The PLTL model of learning can be reinforced in the classroom by using group work. Students will have more practice in order to understand course concepts. In addition, we have used online homework problems to supplement PLTL workshops by giving students more opportunities to practice. Students gain confidence when working with math peer leaders and favor this learning method. In the future, we can consider the correlation of the students enrolled in embedded math PLTL courses with the students enrolled in General Chemistry with PLTL, to assess the pass rates compared to non-PLTL sections.

Conclusions

Currently, the peer leaders for General Chemistry are Applied Mathematics majors. They not only have a solid foundation in math, but are familiar with the chemistry course materials as well. There is consistent and weekly communication between peer leaders and instructors. The peer workshop format is modeled in classroom as well, where students work in small groups to tackle a mathematically challenging chemistry problem. This reinforces knowledge from other disciplines and mirrors a learning community.

The multitude of calculations in General Chemistry inherently brings some students fear. Since MAT1275 is pre- or co-requisite course for General Chemistry, by having peer leaders with strong mathematics background, it will help students not only understand chemistry concepts, but also assist them with the ability to perform complex calculations and critical thinking in solving problems. Consequently, it may help students improve their performance in mathematics classes as well.

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