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Strategies for Improving Retention of Community College Students In the Sciences

Almost one half of U.S. students receiving B.S. and M.S. science degrees attend community colleges during their academic careers, yet for the large majority of community college students in the sciences, a four-year degree in a STEM discipline remains an unrealized goal. The authors describe methods intended to improve student learning, retention, and graduation rates of community college students in the sciences.

Introduction

Community colleges play an important role in the education and training of students in the sciences. In 2004, nearly half of the Bachelor's and Master's degrees awarded in the United States in science and engineering were granted to students who had attended community colleges at some point during their academic careers (Kincaid, et al., 2006; Tsapogas, 2004; Ryan, Wesemann, Boese, & Neuschatz, 2003). The role of these two-year institutions in science education has not been overlooked by policy-makers. The National Science Board has identified the importance of community colleges in developing a technical workforce that can allow United States companies to compete with their Chinese and Indian counterparts (National Science Board, 2006; U.S. Dept. of Education, 2000). The National Institute of Health funds a Bridge program that targets minority science students for transfer from community colleges into baccalaureate programs (Carpenter, 2008). Although there is widespread acknowledgment of the importance of community colleges in training workers, educators have made limited progress in helping the majority of students at community colleges to reach the levels of academic and economic success enjoyed by their counterparts at four-year colleges and universities. In the sciences, community colleges award associate's degrees in fields where bachelor's, master's, and doctorate degrees are increasingly becoming a requirement for employment (National Academies Press, 2007). This makes facilitating transfers from community colleges to four-year colleges an essential goal for educators and administrators.

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Socioeconomics can play a role in determining which students attend community colleges. Students enrolled in community colleges tend to be financially disadvantaged compared to students who enroll in four-year colleges directly out of high school (Government Accounting Office, 2008). High school graduates who receive diplomas with college preparatory courses and have the financial ability generally progress directly to four-year colleges. Students without the requisite high school preparation or financial ability often attend the more affordable community colleges (Phillippe & Sullivan, 2005).

Many students who begin their college studies at community colleges intend to graduate quickly and move on to more advanced degree programs (Rouse, 1999; Leigh & Gill, 2003). Despite the best intentions of community college faculty, most students leave the community colleges without obtaining degrees or transferring to four-year colleges. Estimates suggest that transfer rates for students from community colleges to four-year colleges can be as low as twenty percent for students wishing to do so (Bradburn & Hurst, 2001; Gordon, 1996). Likewise, graduation rates at community colleges are as low as thirty percent (Wild & Ebbers, 2002; Mohammadi, 1994). Because many students start their science and engineering careers at community colleges, it seems worthwhile to develop and implement strategies that improve the effectiveness of science education at these institutions in order to better prepare students to transfer to and succeed at four-year colleges.

Recent publications have studied institutional policies that affect the success rates of community colleges in preparing students for more advanced academic work (Striplin, 1999; Cohen & Brawer, 1996). Recommendations include institutional changes that affect the methods used to fund community colleges and improving counseling and advising services (Burgess & Samuels, 1999; Cohen & Brawer, 1996). It is also worthwhile to consider student performance following completion of the developmental courses and entry into college-level science courses (Long & Kurlaender, 2008). In this report, we discuss the application of methods for improving student success rates in the first two years of science education through a program called the Brooklyn Gateway. Specifically, we focus on improving student performance in a freshman-level general chemistry course. Each method is relatively inexpensive to implement. Taken as a whole, they require coordination among educators within the science curriculum. It is also necessary to consider the realities of community college students' lives, because these realities affect student utilization of support methods and student response to format of instruction.

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General Chemistry and Student Success in STEM Majors

Our institution's student retention rate is comparable to many urban community colleges. The college-wide six-year graduation and transfer rate to four-year institutions are each around thirty percent. For science and engineering majors, retention and transfer rates are similar to those of other academic areas at the College. However, unlike students in the humanities, important challenges to the success of science and engineering students include mathematics and science courses that require a high proficiency in mathematics. At our institution, only science and mathematics majors are required to take college-level math courses. Biology and engineering science are the two largest programs in the sciences at our institution. In reviewing graduation rates in these two programs, we identified general chemistry as a particularly significant stumbling block for students. Historically, pass rates in general chemistry have hovered near fifty percent. Our plan was to improve student performance in this important gateway course so that students would be more likely to progress through their academic programs, including pursuit of more advanced courses within their disciplines.

College-level general chemistry is, on the whole, a difficult course for many science students, including students at four-year colleges (Chambers, 2005). For many community college students, general chemistry is particularly problematic. Administrators at our institution have referred to general chemistry as a "killer course." Counselors often recommend to students that they avoid the course until their last year of school so that their grade point average won't be dramatically affected (Phillip, Brennan, & Meleties, 2005).

Preparation is a key component to success. In New York State, the majority of community college students have not completed a one-year course in high school chemistry or physics. Graduation requirements for high school students include completion of two Regents' level science courses (New York State Education Department, 2009). Although students must enroll in science courses that satisfy state graduation requirements, they are not required to complete science courses designed as college preparatory courses (Haycock, 2001; Gamoran, 1987). Consequently, many students graduate high school without the skills necessary to succeed in science and engineering disciplines. It is only when students find themselves in college that they realize that allied health fields and engineering disciplines require challenging survey courses like general chemistry and general physics.

Many students are turned off by the perception that chemistry is not a subject pertinent to their career goals.

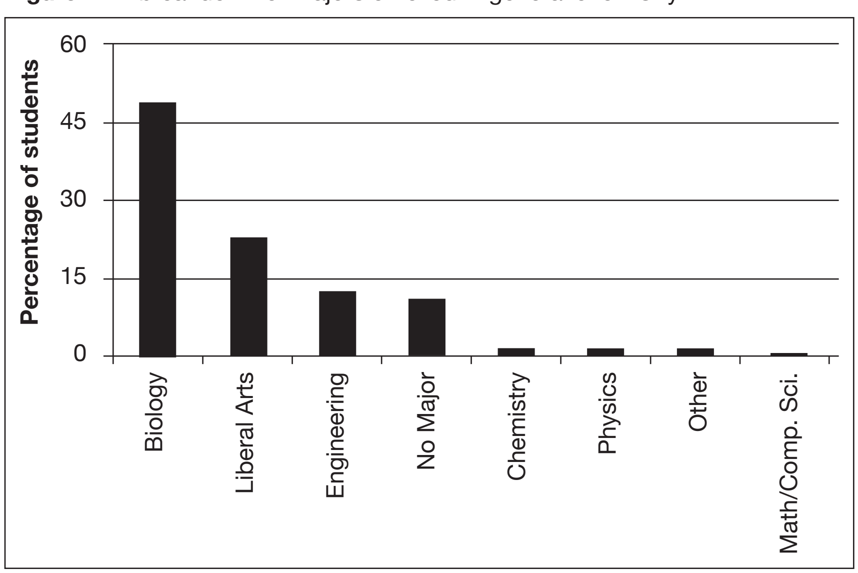
At two-year institutions, general chemistry is often the first science course required of students that involves a high level of quantitative reasoning skills. It is also often the first course in which students must connect physical theories with specific sets of calculations. The application of graphical analysis to experimental data and extraction of physical parameters are also challenging objectives for many students. These tasks are often overwhelming for students with minimal high school backgrounds in math and science. To prevent under-prepared students from enrolling, chemistry departments have generally instituted math pre-requisites for general chemistry. Others have developed preparatory courses that focus on developmental topics like scientific notation, significant figures, factor-label analysis, and rudimentary chemistry skills like equation balancing and chemical nomenclature. The effectiveness of these strategies has been the subject of some discussion (Bentley & Gellene, 2005; Jones & Gellene, 2005). Our experience suggests that preparation in quantitative reasoning is not the only, or even most important, stumbling block for students. Some of the concepts that students in freshman-level chemistry find the most difficult do not involve intensive calculations. Examples include net ionic equations, quantum chemistry, and bonding theory. Nearly all of the students at our institution enrolled in general chemistry have completed the math requirement for the course. Many have received high marks in their math courses and passed the preparatory course, but still fare miserably in general chemistry.

Another challenge is student motivation. Many students are turned off by the perception that chemistry is not a subject pertinent to their career goals. Unlike four-year institutions, many science majors at community colleges are not studying to enter medical or pharmacy programs. Most biology majors at our institution are interested in allied health professions like physical therapy, physician assistant, and nursing (Figure 1). Abstract concepts like electron configurations and orbital hybridization models seem irrelevant to many students. This perceived disconnectedness of subject matter to professional goals leads to low morale in the course and, consequently, lower student performance (Gillespie, 1997).

Methods for Improving Instruction

Our strategy to improve student learning and retention in general chemistry was to find a way for students to dedicate as much attention to the course as possible and to provide the support they needed to do so. The regular twelve-week semester is problematic for many students. They often enroll in four or five courses and have little time to focus on any of their classes. It is not uncommon for students to begin the semester with five courses and finish with two or three as they withdraw from the more challenging and time-consuming courses. For that reason, we enrolled students in an immersion chemistry section during the shorter six-week sessions the College offers each summer and winter (Table 1). In these

Figure 1: A breakdown of majors enrolled in general chemistry



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sections, the preparatory chemistry pre-requisite was waived. Immersion sections were enriched compared to traditional six-week summer and winter sessions by adding Peer-Led Team Learning (PLTL) sessions twice a week, daily optional drop-in tutoring, and group trips to science learning centers on off-days (Stewart, Amar, & Bruce, 2007; Gosser & Roth, 1998; Woodward, Gosser, & Weiner, 1993). Immersion sections were taught by faculty members who limited their research activities for the duration of the course in order to increase student access and foster instructor-student mentoring. Students received a three hundred dollar stipend for participation in the course as compensation for the cost of textbooks and supplies and the additional time spent on the course.

Table 1: Comparison of modes of instruction in general chemistry

	Lecture	Laboratory	PLTL Workshops	Drop-in Tutoring
12-week (traditional)	4 hours	2 hours	N/A	N/A
6-week (traditional)	8 hours	4 hours	N/A	N/A
6-week (immersion)	8 hours	4 hours	4 hours	Daily

Student Performance in Accelerated and Immersion Sections

General chemistry courses at our institution are taught by both full-time tenure-track faculty members and part-time contingent instructors. Enrollment is capped at twenty-five students per section with typical enrollments of around twenty students. We report here the results for six immersion groups for the time period between 2006 and 2008 (123 students). We offer as a comparison the students who enrolled in the regular twelve-week semester for the time period between 2001 and 2008 (1389 students) and students who enrolled in the traditional six-week semester between 2001 and 2008 (548 students).

We observed that there is a small difference in the percentage of students who received a grade of C or higher for those who enrolled in the traditional six-week sessions compared to the traditional full-length twelve-week sessions (Figure 2). Students enrolled in the shorter sessions generally have a slightly higher pass rate (C or better) than the students enrolled in the twelve-week sessions (55% compared with 50%). We also calculated a numerical score for students on a traditional four-point scale (Table 2). We then calculated an average score for each section of students which we call the course average.

The course average was found to be somewhat higher for students enrolled in the shorter six-week sessions (1.73 versus 1.46) (Figure 3). This difference is consistent with grade distributions in other chemistry and science courses, and we believe that it is a reflection of how college fits into our students' lives. The majority of students commute by way of public transportation and one-way travel times are typically one to two hours. Students often hold part-time or even full-time jobs in addition to attending college. A sizable number of students are parents or care for family members. Financial aid considerations weigh heavily on the students' academic schedules. Students are required to make regular academic progress in order to maintain access to student aid and public assistance funds. Aid agencies determine how many and into which courses students may enroll. During the six-week sessions, students are limited to enrollment in a maximum of two courses and typically enroll in one science course and one humanities course. The duration of these off-sequence courses is half that of courses during the regular twelve-week semester. Despite this acceleration, students may have a better ability to focus on their studies because they enroll in fewer courses. Another advantage of the accelerated schedule may be that faculty members are better able to dedicate time to the course and to students, because they generally teach only one section compared to three or more sections during the twelve-week sessions.

Table 2: Course scoring scale

Course grade	Point Value
A	4.0
B	3.0
C	2.0
D	1.0
F or Withdraw	0.0

The difference in academic performance of students enrolled in accelerated sections compared to twelve-week sections was one reason for considering immersion sections during the winter and summer sessions. We thought that we might be able to take advantage of the course-load limit placed on students in the shorter sessions. Improvements in the distribution of course grades were apparent when results for the first immersion group were tabulated. In the first immersion section fourteen of the fifteen students enrolled completed the course. Of those fourteen students who completed the course, all but one received a passing grade. Students in each of the subsequent immersion sections succeeded in the course with higher than normal pass rates.

In the six immersion sections studied, students completed the course with higher grades in the course than those in the twelve-week sections as well as the traditional six-week sessions (Figures 2 and 3). The average pass rate for students in six immersion groups was 81%, and the cumulative course grade-point average was 2.43. Students in the immersion sections performed better as a group than students in traditional sections offered simultaneously in each of the six sessions studied.

The percentage of students receiving a letter grade A was not significantly higher for students in the immersion groups compared to students in traditional sections. This suggests to us that the program has had a particular effect on students at risk of failing the course. In exit interviews, many students stated that the course was more difficult than they had expected. Some were aware that the "extra" support had an effect on their course outcomes. Some students offered the criticism that the support made the course time-consuming and challenging, even though they performed better than students in traditional sections. It seems possible that many students may be unaware of the time commitment necessary to succeed in the course and, consequently, become overwhelmed when taking four or five courses.

Figure 2: Pass rates in general chemistry

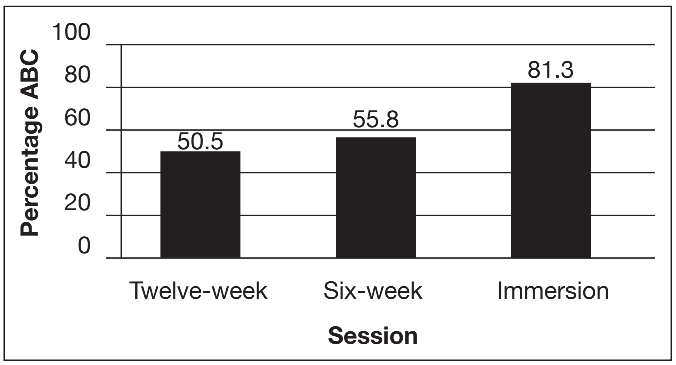
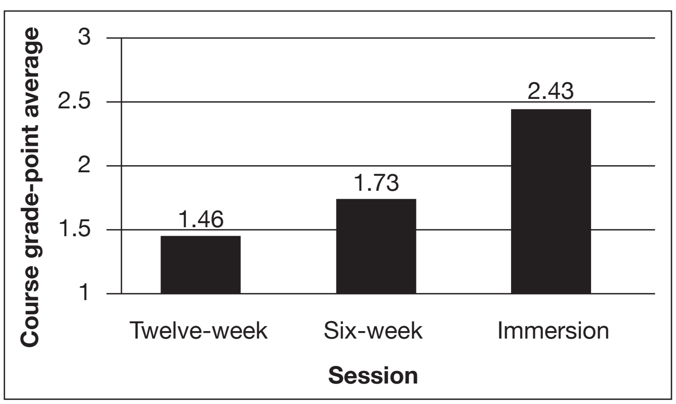


Figure 3: Course numerical average in general chemistry



Organic Chemistry as an Indication of Progress

The addition of Peer-Led Team Learning sessions, after-class tutoring, and greater faculty involvement may have helped bring about increases in course pass rates and grades-point averages. An important question is whether some of the positive effects of the program continue in future courses (Horwitz, & Rodger, 2009; Becvar, Dreyfuss, Flores, & Dickson, 2008). To study this possibility, we looked at the organic chemistry course. Organic chemistry is a sophomore-level course for chemistry, pharmacy, and pre-med students offered by our department. Enrollment in the course includes a mix of students who completed general chemistry at our institution and students from other institutions. To determine if there was a benefit to students from the immersion program in organic chemistry, we compared students who successfully completed general chemistry in one of the first four immersion sections to those who completed the course in a traditional six-week section. The number of students in each group is similar with 73 students from the immersion sections and 74 from the traditional sections (Figure 4). The success rate in organic chemistry was higher for students from the immersion sections, with fifteen immersion students passing compared to eight from the traditional sections. The number of students from immersion sections that failed organic chemistry over the same period was two, compared to five students from the traditional sections. Although the numbers being considered are small, they do suggest that, for our students, organic chemistry is not a fundamentally more challenging course than general chemistry. In fact, failure rates in organic chemistry are significantly lower at our institution than are those in general chemistry. The pedagogical approach in organic chemistry is quite different from that of general chemistry. Although organic chemistry is considered a more advanced course, the two courses possess significant conceptual overlap. The focus on calculations in general chemistry often works to filter out students who may have many of the skills needed to advance but aren't proficient in numerical and algebraic calculations. It may be that by creating a mechanism for students to succeed in general chemistry, we have opened up a potential for students to succeed in more advanced chemistry courses. We are monitoring the progress of subsequent immersions groups as well as students who return to the College to complete organic chemistry after transferring to other institutions in order to determine if this pattern continues.

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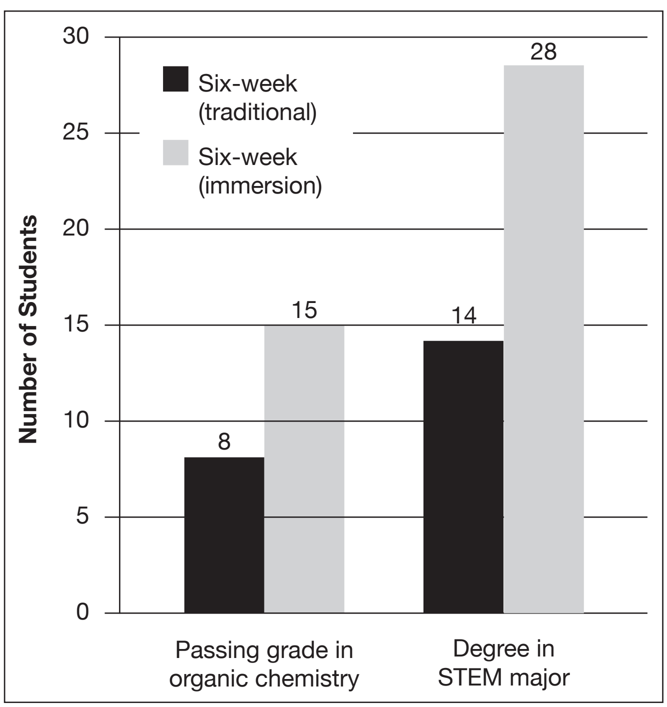
Increasing Graduation Rates in the Sciences

The three-year graduation rate at our institution has fluctuated between fifteen and twenty-five percent over the course of the past decade (CUNY Office of Institutional Research, 2005). Figure 4 shows the number of STEM degrees (science, technology, engineering, and mathematics) awarded to students who attended one of the first four immersion sections between 2006 and 2007, along with the number of graduates who attended traditional six-week sections during the same time period. The number of students initially enrolled in each of the two groups is similar, but the attainment of STEM degrees is twice as high in the immersion group (38% versus 19%). This increased graduation rate can be explained by considering the distribution of majors in our general chemistry course. Biology majors comprise the predominant group of students in our general chemistry sections (Figure 1). General chemistry is the terminal chemistry requirement at our institution for biology majors, and it is often considered by students to be their most challenging course. By increasing the pass rates in general chemistry, we may have eliminated the major barrier to graduation for the majority of those students (Reingold, 2001). We are monitoring student retention and graduation rates to determine whether the long-term number of graduates increases.

Figure 4: Pass rates in organic chemistry and achievement of STEM degrees within two years for students in immersion sections and traditional six-week sections



Peer-Led Team Learning

Increases in course grades and graduation rates are encouraging, and this suggests that there are students who may progress academically if we use some well-known methods for improving instruction. For example, PLTL is a method designed to introduce constructivist approaches to science education and has been used in the physical sciences since the 1990's (Fosnot, 2005; Vykotsky, 1978). In PLTL, a student peer who has previously succeeded in the course leads a group of six to eight students through faculty-designed workshops. Workshops are designed to promote exploration of the course material outside the traditional lecture environment. In PLTL workshops, the course instructor is absent as are answer keys to the workshop materials. Important goals include shifting the focus of education away from lecturing and toward active student learning, developing student leadership skills, and democratizing learning. We used PLTL as a method of instruction in order to help students develop a deeper understanding of the material and as a way to discourage memorizing algorithms as a method of solving problems. These are particularly important goals, because many of the students transferring from our institution suffer from a "transfer shock" when they arrive at four-year institutions (Diaz, 1992; Cejda, 1997). Class sizes in the sciences are often much larger at senior colleges. Students there are often more competitive compared with students in community colleges. Faculty members are also often less available to students than those at community colleges. These differences are factors in the decisions of large numbers of students to leave the sciences shortly after reaching the four-year colleges. One role of PLTL is to help students to develop their own reasoning and critical-thinking skills through practice in a social environment and to promote a sense of independence that allows them to be less dependent on instructors.

The Role of Tutoring

The number of students who used after-class tutoring fluctuated between four and eight students out of twenty in each of the immersion sections. Although these numbers seem low, they are higher than we have observed for students in traditional tutoring services offered by the College. Because many of our students work after class, they were often unable to take advantage of tutoring. However, the number of students who used tutoring spiked near midterm and final examinations. This suggests that providing flexible student support is an important component in connecting students to support. The amount of academic support students receive outside the classroom at our institution is limited. Traditional tutoring at the institution takes place through semester-long scheduled appointments. If students miss a total of two sessions for any reason, they are dropped from tutoring for the remainder of the semester. Conversely, during the immersion sessions, we offered more flexible, drop-in tutoring, and this was found to be an important contribution to the program. The highest attendance in tutoring sessions was found when tutors also served as peer leaders from the PLTL workshops. We believe that student attendance in tutoring sessions may have acted as a measure of their confidence in the tutors. Successful workshops often led to working relationships between leaders and student participants that expanded beyond the time constraints of the workshops and into tutoring sessions. We also offered drop-in tutoring to students who were in the traditional sections. With few exceptions, those students did not make use of tutoring. We believe that this shows that tutoring is more important to students when it is connected to other components of the course.

Student-Faculty Interactions

As part of the immersion program, we invited students to join their instructors at science institutions like the American Museum of Natural History and the New York City Hall of Science. Attendance among students ranged between twenty-five percent and fifty percent. Just as in tutoring, one of the challenges is the large number of students who work during the times we were able to schedule the trips. For the students who did attend, there was a tendency for them to become more connected to the other students in the course, peer leaders, and faculty members. Some students became peer leaders in future PLTL sessions, leading to continuity of the program. A few others became involved in laboratory research projects with faculty members, leading to even greater connection to their academic disciplines (Gafney & Varma-Nelson, 2007).

Future Directions

Based on the successes of the immersion program, we have implemented some of the same methods for the twelve-week semester. Students were enrolled in sections that included PLTL workshops and after-class drop-in tutoring. We found a slight improvement in the course pass rates and grade distributions compared to historical groups, with pass rates slightly above sixty percent. However, these increases in student retention and grade performance were lower than those observed for students in the six-week immersion groups. We believe that enrollment in four to five courses per semester is a challenge for many students due to the realities of their lives. One strategy we are considering is a schedule that involves two six-week chemistry courses, taken serially during the traditional twelve-week semester. Under this plan, students would be limited to enrolling in one non-chemistry course during the twelve-week semester.

Important goals include shifting the focus of education away from lecturing and toward active student learning, developing student leadership skills, and democratizing learning.

We have yet to determine the effectiveness of the immersion program on student academic performance following transfer to four-year institutions. We are monitoring the academic progress of students who have transferred to local four-year public colleges and have implemented PLTL in two courses at a local four-year sister campus. We chose advanced physiology as well as first-semester organic chemistry, because these are courses in which biology majors commonly enroll during the transition from their sophomore to junior year. Our goal is to provide a bridge for students once they enter a four-year program by promoting learning environments that are similar to those they experienced during their years in community college.

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