Chemical Education Research

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Chem-2-Chem: A One-to-One Supportive Learning Environment for Chemistry

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The University of Puerto Rico at Cayey (UPR–Cayey) is a small undergraduate campus serving approximately 4000 Puerto Rican students, of which one-third are enrolled in science and mathematics programs in the natural sciences and education. In August 1997, a Chem-2-Chem Program (C2C) was designed and implemented with the objective of helping students achieve successful outcomes in the general chemistry course without sacrificing course quality, expectations, and content. In addition to providing academic assistance, the C2C offers a friendly and supportive environment for learning. Learning activities in C2C are centered on three premises: studying chemistry through collaboration, mentoring integrated with the disciplinary content, and establishing an effective learning network through teamwork. Strengthening basic science courses, such as general chemistry, is a first step towards achieving a long-range improvement in science education.

Retention problems in our general chemistry made it necessary to do something that could increase student retention. From 1995 to 1997, 42–51% of students enrolled in the general chemistry course obtained unsuccessful course outcomes: either failing ("F") or dropping ("W") the course.[1] In 1997, a study was carried out to identify student risk factors correlated with unsuccessful general chemistry course outcomes. Students with university admission index scores (IGS, Spanish language acronym for general application index) below a specific threshold were found to have an increased risk of course failure.[2] Each student's IGS is based on his or her College Board Entrance Exam score and high school grade point average.

Retention of college students is a complex issue that is affected by many factors. The transitions encountered by students during the first year, after leaving family and high school support networks, are critical. For these entering students, the intensity of academic work and their newly found independence requires an adjustment for them to feel at ease in the university environment. Providing good interaction with faculty and offering peer tutoring are highly recommended for entering students *(1).* Many models of student retention have been proposed. Tinto *(2, 3)* proposed that students' success and retention require integration between the cognitive and affective needs of the students and the academic and social environment of the institution. Tinto also emphasizes that if a strong bond is established between the students and the college, it is more probable that a student persists and eventually earns a post secondary degree. Astin *(4)* and Pace *(5)* argued that when students get actively involved in their own learning and personal growth, their opportunity for success increases.

One way for the institution to decrease attrition and increase retention is to meet these needs of the students by providing the appropriate environment. According to Vygotsky's cultural and cognitive theory of development, cognitive skills and thinking patterns are determined in the social and cultural contexts of the learning environment *(6, 7).* Based on this theory, the zone of proximal development is the difference between students' independent problem-solving capabilities and their potential with guidance or collaborative assistance. This guidance can be very effective when offered by a peer who has mastered the particular skills that are to be developed. The assistance offered by peers to peers, as in C2C, is very effective because of their similar levels of intellectual and academic development. This complements the learning achieved in the traditional classroom setting. It is important that the affective needs of the students be met to put them on the road to success.

Recent pedagogical research has also shown that students learn better through social interaction *(8).* C2C is based on two foundations: tutoring and mentoring. Tutoring gives entering students the academic help they need to complement the material covered in class while providing social interaction between peers. Mentoring offers the counseling and modeling that is useful in the development of positive attitudes and self-esteem. The affective aspect strengthened by mentoring is integrated in the learning teams with the academic development obtained by tutoring. It has been noted that, after family and love, effective mentoring can be the third most powerful relationship known for having a great impact on the life of individuals *(9).* An effective bond between the mentor and the mentored is developed to a maximum if the mentor takes an active interest in guiding the less experienced person and develops the ability to be a caring, concerned, and committed individual *(10).*

The C2C program takes advantage of an underutilized resource—undergraduate students as mentors and tutors *(11).* Peers have credibility, can communicate effectively, and are seen as role models. The C2C program stimulates the students to be actively involved in their own learning by creating a peer support network that provides a space that a traditional classroom setting does not offer for social interaction and for meeting their affective needs. The small teams of learners that characterize C2C could introduce a "small college culture" to institutions of all sizes.

Course and Participant Information

General Chemistry Course

The general chemistry course at UPR–Cayey is a basic course offered to first- or second-year students providing them with skills and concepts important for future courses. The course consists of approximately eight sections each with thirty natural sciences and education students per semester. In general terms, the same professors have taught the general chemistry course over the years analyzed in this study. For all sections during a semester, the method of student evaluation and the examinations were the same. The evaluations and examinations used to determine student achievement and grades were comparable over the seven semesters analyzed in this study. Each professor evaluated the chemistry exams taken by the students enrolled in their sections. During some semesters, the C2C program directors also taught general chemistry sections. The course grade for participants (P) and non-participants (NP) was handled identically and participation in C2C did not result in any additional bonus points.

Student Population Enrolled in the General Chemistry Course

The students enrolled in the general chemistry course were from the general sciences program and from the chemistry, biology, mathematics, physics, and education departments. Almost one-fourth of these students participated in the C2C Program during the seven semesters analyzed for this study. The student participants were enrolled in different sections taught by different professors. Although all of the general chemistry students were invited, participation in the C2C Program was voluntary.

C2C Program Structure and Organization

The C2C program is currently in its seventh year of continuous operation. Personnel associated with the C2C Program include directors, a student administrator, student tutors–mentors (T–Ms), and student participants. The directors are chemistry professors that are responsible for coordinating the smooth functioning of the entire program and carrying out assessment. They are also responsible for interviewing and selecting the T–Ms. The student administrator is responsible for collecting attendance data, accounting, providing clerical support, and helping in the scheduling of the learning team meetings.

The student T–Ms are advanced students, usually chemistry majors, with a cumulative grade greater than "B," who have passed the general chemistry course with an "A" or "B," and have excellent recommendations from their chemistry professors. The selection of the student T–Ms is also based on an interview. The T–Ms attend a training workshop at the beginning of the semester. The workshop includes learning strategies and theories, such as relevant aspects of Vygotsky's theory, constructivism, different learning styles, and the use of reflexive exercises. The philosophical background and the procedures that support the program are also discussed. Once the semester starts, each T–M attends a section of the general chemistry course in order to review the concepts and be part of the professor–student dynamics in the classroom. They also participate in weekly staff meetings that provide a forum for sharing tutoring–mentoring experi-

Table 1. Comparison of Participant (P) and Nonparticipant (NP) Final Grades in the General Chemistry Course

C2C Participation by Semester	A Grades/ %	B Grades/ %	C Grades/ %	A + B + C Grades/%	D Grades/ %	F Grades/ %	W Grades/ %	F + W Grades/%
F97 P (*n* = 91)	5.50	7.70	45.10	58.30	17.60	11.00	13.20	24.20
F97 NP (*n* = 308)	9.10	12.70	27.30	49.10	9.40	13.00	28.60	41.60
S98 P (*n* = 28)	10.70	10.70	64.30	85.70	3.60	10.70	0.00	10.70
S98 NP (*n* = 223)	5.40	13.90	43.50	62.80	17.00	10.30	9.90	20.20
F98 P (*n* = 103)	20.40	15.50	31.10	67.00	6.80	7.80	18.40	26.20
F98 NP (*n* = 226)	5.30	10.20	31.90	47.40	14.20	15.90	22.60	38.50
S99 P (*n* = 37)	5.40	16.20	29.70	51.30	27.00	8.10	13.50	21.60
S99 NP (*n* = 164)	8.50	10.40	24.40	43.30	15.90	18.90	22.00	40.90
F99 P (*n* = 44)	11.40	29.50	43.20	84.10	4.50	2.30	9.10	11.40
F99 NP (*n* = 170)	8.80	18.80	32.90	60.50	15.30	10.00	14.10	24.10
S00 P (*n* = 30)	10.00	23.30	53.30	86.60	6.70	3.30	3.30	6.60
S00 NP (*n* = 193)	6.70	15.00	41.50	63.20	16.60	9.80	10.40	20.20
F00 P (*n* = 91)	13.20	17.60	40.70	71.50	6.60	13.20	8.80	22.00
F00 NP (*n* = 141)	9.90	5.70	31.90	47.50	13.50	17.70	21.30	39.00
Total P (*n* = 424)	12.00	16.00	41.00	69.00	10.40	9.00	11.60	20.60
Total NP (*n* = 1425)	7.60	12.60	33.30	53.50	14.20	13.40	19.00	32.40

ences and include follow-up training in pedagogy and chemistry. The T–Ms receive a stipend for their work.

In the group sessions, the T–Ms act as tutors by reviewing the course concepts, offering different perspectives, clarifying concepts, guiding the participants in their search for answers, and developing problem-solving skills. Their role is not to give a conventional recitation or an extension of the lecture; rather, T–Ms establish a friendly and supportive learning team. They also administer practice tests and use supplementary materials from various sources including those prepared by the T–Ms under the supervision of the chemistry professors. As mentors, they promote active participation in the learning teams by providing effective communication, listening, and sharing. They also impart a positive attitude so that the students learn in an environment that instills self-confidence. A support network is established between participants, student T–Ms, and professors. The T–Ms serve as models both in the academic and personal development of the participants. The T–Ms are like big brothers and sisters to their tutored–mentored students.

All students enrolled in the general chemistry course are invited to participate in the C2C program. Student participation in C2C during the seven semesters analyzed was approximately 21% of all students registered in the general chemistry course. Students that choose to participate are assigned to the learning teams according to their available free hours. The learning teams meet for three hours a week, distributed in three sections of one hour each or two sections of one-and-one-half hours each. The participants are expected to attend and actively participate in the C2C sessions. C2C participation is defined as active involvement in the learning team sessions and activities during a semester. A support group is established that works together for the entire semester with the same T–M. Having the same T–M and belonging to the same learning team are important differences between this program and other traditional tutoring programs that have participants going to any available tutor. It is common to see the C2C learning teams meeting for more than the three minimum weekly hours due to their mutual interest in the participants' success.

Data Collection Methods and Statistical Analyses

Both groups studied, P and NP, were demonstrated to be comparable in their university admissions entrance parameters, such as IGS and mathematics aptitude scores on the College Board Exam. Comparable student populations allow us to examine the effect of participation in the C2C program on students' final grades. Analysis of the data was carried out using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL) computer program.

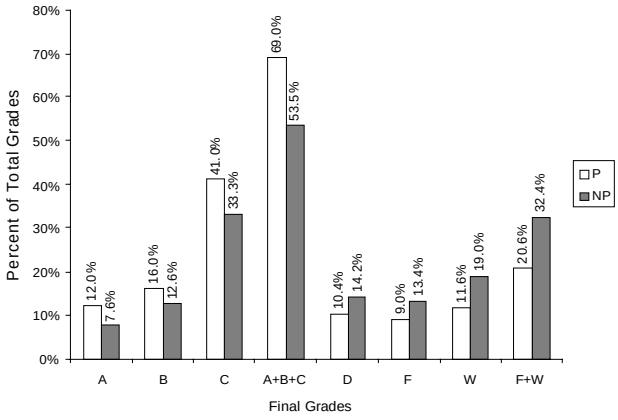

Figure 1. Distribution of general chemistry final grades over seven semesters relative to participation in the Chem-2-Chem program. Statistical parameters for these data are provided in Table 2.

The Student's *t*-test compared the average percentages of successful and unsuccessful outcomes for P and NP for all of the seven semesters studied (n = 7). A χ^2 analysis was performed using the frequencies for the non-participants as the expected value and the frequencies of participants as the observed. The χ^2 analysis was carried out using the total frequencies of all of the semesters studied of each for the six possible final grades (df = 5). A paired *t*-test was done using the successful and unsuccessful outcomes for each of the seven semesters studied (df = 6).

Results

Student Participation in the C2C Program and Final Grades in the General Chemistry Course

The college entrance parameters of both P and NP were shown to be comparable using Student's *t*-test ($p > 0.99$).[3] Table 1 shows percentages of final grades in the general chemistry course obtained by student P and NP for each of seven semesters. The successful course outcomes (defined as final grades of "A," "B," and "C") and unsuccessful course outcomes (defined as final grades of "F" and "W") are calculated and given as percentages of total students. The cumulative percentage of student P and NP during the seven-semester period that obtained each grade is presented in the bottom two rows.

The percentages of each final grade for the total number of P and NP during seven semesters are shown in Figure 1. Successful and unsuccessful course outcomes for both P and NP are also included. In comparing the distribution of

Table 2. Statistical Parameters for General Chemistry Final Grades Data Analysis

Statistical Parameters	Final Grade = A	Final Grade = B	Final Grade = C	Final Grade = A or B or C	Final Grade = D	Final Grade = F	Final Grade = W	Final Grade = F or W
χ^2 Values	45.54	45.54	45.54	35.91	45.54	45.54	45.54	35.91
Degrees of freedom	5	5	5	1	5	5	5	1
p Values	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sample number	51	68	174	293	44	38	49	87

student grades (ABCDFW), highly statistically significant differences between P and NP were detected using the χ^2 analysis (P observed percentages compared with NP expected percentages: $\chi^2 = 45.54$; df = 5; $p < 0.0001$). For both successful and unsuccessful course outcomes, highly statistically significant differences between P and NP were detected with a 99.9 % confidence using the χ^2 analysis as shown in Table 2 (participants observed percentages compared with nonparticipant expected percentages: $\chi^2 = 35.91$; df = 1; $p < 0.0001$). Independent statistical analysis using Student's *t*-test confirmed a significant difference between P and NP for both successful outcomes ($p < 0.05$) and unsuccessful ($p < 0.05$) course outcomes.[4]

Participation in the C2C program had a significant affect on all final grades. The increases and decreases were calculated using the percent change between P and NP for each outcome. Over the seven semesters studied, participants obtained 58% more A's, 27% more B's, and 23% more C's than nonparticipants. Additionally, participants obtained 27% fewer D's, 33% fewer F's, and 39% fewer W's than nonparticipants. An increase of 29% and a decrease of 36% are observed in the percentage of successful and unsuccessful course outcomes, respectively, in the general chemistry course obtained by C2C program participants as compared with nonparticipants.

Figure 2 shows the relationship between successful outcomes in the general chemistry course and participation in the C2C program for each of the seven semesters studied. An increase was observed in the percentage of successful outcomes in the final general chemistry course grades obtained by participants as compared with nonparticipants for each semester. Statistically significant differences between participants and nonparticipants in the percent of successful course outcomes for each semester studied were detected using the paired *t*-test ($p < 0.001$) (see Figure 2 for *t-test* values).

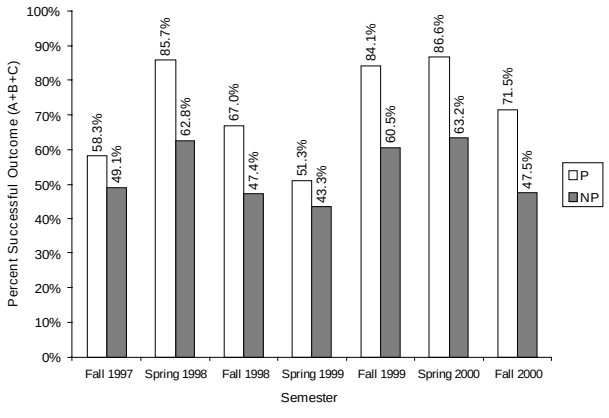

Figure 2. Successful general chemistry course outcomes (letter grades of A, B, or C) for each of seven semesters by participation in the Chem-2-Chem tutoring–mentoring program. Paired *t*-test analysis showed statistically significant differences for each of the semesters studied between successful course outcomes obtained by participants and nonparticipants ($p < 0.001$). The calculated *t* value was 7.01. The theoretical *t* value for $\alpha = 0.001$ and 6 degrees of freedom is 5.959.

Discussion

Students who participated in the Chem-2-Chem program have demonstrated significant, positive effects from their participation. Between 1995 and 1997, before the inception of Chem-2-Chem, 42–51% of students enrolled in the general chemistry course had unsuccessful outcomes. Unsuccessful outcomes after the Chem-2-Chem Program was initiated in 1997 were 33% for nonparticipants and 21% for participants (Figure 1). The significant reduction in the percentage of unsuccessful outcomes observed in the participants when compared with both nonparticipants and pre-C2C student outcomes suggests the effectiveness of the program.

While the number of successful course outcomes obtained by C2C participants increased when compared with nonparticipants, both groups were previously shown to be statistically comparable, in terms of admission index and mathematics aptitude scores obtained on the College Board Entrance Examination. The similarity between the two student populations analyzed permits us to attribute changes in successful course outcomes to the effectiveness of the C2C program.

During each of the semesters studied, the percentage of participants that obtained successful course outcomes was significantly higher than for nonparticipants (Figure 2). Also, the percentage of participants that obtained unsuccessful final grades was significantly lower than for nonparticipants. For the seven semesters studied, participants obtained 29% more successful outcomes and 36% less unsuccessful outcomes than nonparticipants.

One dramatic effect of the C2C program during each of the seven semesters studied is shown in the percentage of participants that obtained W (withdrawal from the course) as final grades. A course withdrawal decrease of almost 40% by C2C participants as compared with nonparticipants was observed. This decrease in the W grade shows that the students at risk of not completing the course can benefit significantly from the C2C program. Based upon these numerical results and C2C participation, it seems that the support network offered by the program helps students persevere in the course and achieve successful outcomes. Students doing better in the course and persisting in obtaining their goals early in their academic life are important objectives of the C2C Program. These results also reduce the institutional cost incurred by student repetition of courses due to failures and withdrawals.

A questionnaire was developed and administered each semester to students enrolled in the C2C program to ascertain student perception of their study habits, the difficulties they have encountered, and the C2C program.[5] In general, C2C participants perceived the program in a positive way. More than 90% of students surveyed rated the T–Ms as excellent. Greater than 95% of the students surveyed also indicated a continued interest in future participation in the C2C program. Some participants' comments about the C2C program include: "I learned the value of not quitting"; "The T–Ms offered me personalized attention"; and "Chem-2-Chem helped maintain and improve my study habits". The participants say that the emotional aspects emphasized in the mentoring component in C2C are very important in developing persistence, and motivation to succeed, fostered by the deep mutual commitment of the participants, T–Ms, and faculty.

Based upon a variety of assessment tools, such as questionnaires, group discussions, and open-ended questions, we conclude that the C2C Program also had a significant impact on T–Ms. In their preparation for the tutoring sessions and during the contact hours shared with the participants they were constantly reviewing basic chemistry concepts needed for professional exams and graduate studies. In advanced chemistry courses the T–Ms expressed that they felt more secure in their knowledge of the basic concepts that otherwise may have been forgotten. They developed communication skills and teaching experiences important for their future careers and improved their own study habits while receiving payment for an on-campus experience.

Independent pedagogical research at a number of universities is in agreement with the results obtained in the C2C program. The "Workshop Chemistry Project: Peer-Led Team Learning" (PLTL), a program established in many universities based on tutoring by advanced chemistry students, has shown a "statistically significant improvement in grades, retention, and levels of student satisfaction" *(12).* Approximately one year after the inception of C2C at UPR–Cayey, our group attended a presentation at an ACS meeting about the PLTL Project and subsequently established a working collaboration with the project leaders. C2C shares the six critical components of the PLTL model: tutoring sessions integral to the course, faculty closely involved, leaders closely supervised, collaborative learning groups and challenging materials, organizational arrangements, and support from the institution. Some of the academic materials used in C2C were obtained from the PLTL group. Another example of peer-assisted learning was reported at the University of Manchester Chemistry Department in the United Kingdom. Their results also indicate that participating students achieve higher chemistry exams scores than nonparticipants *(13).*

C2C provides students with a supportive learning environment and the opportunity to develop positive study attitudes and self-confidence by offering a peer-led personalized and individualized learning experience to address their academic and emotional needs in a holistic way. The C2C program offers an interactive approach that reaches out to students and successfully meets their needs with dramatic results. This research supports recent trends in chemical education to provide a social context for learning experiences. This strategy can serve as a model for educational excellence and extend to other science courses at UPR–Cayey and other institutions.

Acknowledgments

The Office of the President of the University of Puerto Rico, The Office of the Chancellor, Dean of Academic Affairs, the Planning and Development Office, and the Title III Program of UPR–Cayey provided support for this project. We thank the National Science Foundation and the Alliance for Minority Participation of the Puerto Rico Resource Center for Science and Engineering for support during the initial work on this manuscript. We thank Jairo Pardo for providing results from unpublished studies identifying student risk factors, and Carlos Ricart for assistance in the statistical analyses of the data obtained in this study. We thank the Workshop Chemistry Project: Peer-Led Team Learning (PLTL) group, especially Pratibha Varma-Nelson, Jack Kampmeier, and David Gosser for their support. We also thank the student tutors–mentors and participants of C2C. Finally we thank Jack Kampmeier and Kenneth Takeuchi for reviewing a preliminary version of this paper.

Notes

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