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What Teaching Teaches: Mentoring and the Performance Gains of Mentors

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The effectiveness of peer mentoring and peer-led instruction has been widely studied in settings ranging from elementary school to college classes *(1–8).* In most of these studies, the primary instruction was provided by faculty lecturers and the secondary instruction (discussion, recitation, or problem-solving sessions) by peer mentors. The benefits to the mentored students have been well-documented *(9–11)* and involve self-reported heightened motivation as well as enhanced test scores and other indicators of academic success. However, few if any of these studies discuss performance gains of the mentors, and when they do, they are often anecdotal and described as an extra benefit. For example, Bruffee *(12)* states without evidence that peer mentors bring a high level of social maturity to the task, and further asserts that when, for the first time, mentors understand certain basic aspects of thought or conceptualization, this is to be regarded as a "happy by-product".

In their seminal article on passive versus active learning, Benware and Deci *(13)* discuss the performance gains from mentoring or tutoring, but ignore the actual effects of the mentoring process. In their study, a group of students (the experimental group) was told to read an article with the expectation of teaching it to others, while the control group was told to read the same article and expect an examination. After an appropriate amount of study time, both groups were given the same exam. The experimental group received a higher score than the control group on those items that required conceptualization. There were no differences between the groups on items that required rote memorization. A key feature of this study was that the group expecting to teach the article never did. The achievement benefits that might have arisen from the actual mentoring or tutoring process were not examined.

In studying the benefits of teaching, Bargh and Schul *(14)* described two types of experiments that were performed. The first, similar to Benware and Deci, gave students information to learn, with the control group expecting an examination after a suitable study period and the experimental group expecting to teach the information. No actual interaction between mentor and student occurred in the either group. Bargh and Schul found that students earned higher scores on a retention test if they expected to teach the material. In their second experiment, mentors did interact with students, but the students were restricted to comments such as "I don't understand" or "Please explain that again." These remarks could only be asked at specific time intervals. The students were also told to keep non-verbal interactions, such as smiling or nodding, to a minimum. Although there were mentor–student interactions, these interactions were limited and forced. Mentors did not work with students in ways they would most likely have done in an actual mentoring or tutoring session. Mentors in this study did show an increase in scores on a post-test in some areas of the material, but not in others.

An NSF-funded initiative, Peer-Led Team Learning (PLTL), sought to increase student achievement in the sciences by utilizing mentors to work with small groups of students outside the classroom. The mentors used instructor-provided materials and worked through problems with students in weekly meetings. The benefits to the students that participated in PLTL have been documented in several reports *(15–18).* Gafney and Varma-Nelson *(19)* surveyed former peer leaders about the performance and personal gains that resulted from their participation. When asked how activities performed in their leadership roles affected their success in other courses, the peer leaders ranked "acting as a peer-leader" and "studying assigned work alone" as leading factors. Approximately 43% of the former leaders who responded reported that acting as a leader "provided a more thorough knowledge of the discipline and made them better problem solvers". However, the depth of the leaders' knowledge of the discipline was not plumbed in this study.

Other types of studies on the benefits accruing to mentors or tutors involved personalized instruction *(20)* and reciprocal peer tutoring *(21–23).* In these approaches, both mentor and student were enrolled in the same class, learning the same material at the same time. The roles of the mentor and student were therefore fluid and interchangeable, with students functioning as both within the same class. The results showed that students who participated in these types of programs generally earned higher scores on subsequent examinations or assignments.

Studies of mentors not in reciprocal tutoring programs such as those cited above demonstrated no performance gains of the mentors. Rather, these studies tended to discuss the sociological benefits to the mentors. For example, by extracting material from Supplemental Instruction (SI) leader's journals, Lundeberg *(24)* highlighted a number of common themes. These included (i) the challenges of making a session understandable to low-achieving students while maintaining the interest of high-achieving students, (ii) the difficulties between helping students to understand concepts or suggesting rote memorization, (iii) when to cover material in greater depth, (iv) dealing with the connection between anxiety and learning, and (v) the awareness of gaps in the leaders' own knowledge. In another investigation, Bobko *(25)* found that mentors self-reported an increased knowledge of the subject material, an improved ability to speak to small groups, and a deeper satisfaction gained from helping others. However, the study did not examine quantitatively the increase in subject knowledge.

In many of the above studies, mentoring is often indistinguishable from tutoring where a one-on-one or a one-on-two relationship is established with the mentoring interaction occurring outside the classroom *(26, 27).* In the present study, peer mentors worked on problem solving during class time with small groups of students (4–6 people). We explored the relationship between mentoring and the achievement gains of the mentors using grades in subsequent subject-matter courses and the retention of the mentors in these courses. Comparison was made to students who did not participate in the mentoring program and to those who participated as students, but not later as mentors. By explicitly examining the benefits of mentoring in a classroom setting, more concrete assessments could be made about the value of a mentoring program to the mentors.

Methodology

Between the fall semester of 2002 and the summer semester of 2005, close to 10,000 students enrolled in undergraduate chemistry courses at the University of Florida. Of these, students who had taken the quantitative SAT exam and enrolled in the first semester of the mainstream general chemistry course (which we refer to as the "first-semester general chemistry course") were selected to participate in the study. The SAT score was used as a benchmark for prior proficiency in the math skills that students need in a general chemistry course. Some of the students had also enrolled in a remedial, introductory course (which we refer to as the "introductory course"). The participant group included (i) 3149 students who were deemed prepared for chemistry, who did not enroll in the introductory course and therefore did not participate in the mentoring program (called "β group"); (ii) 3186 students who were deemed under-prepared for chemistry and were required to enroll in the introductory course but did not participate later as mentors (called "γ group"); (iii) and finally 104 students who were deemed under-prepared for chemistry and were required to enroll in the introductory course but then in a subsequent semester or semesters acted as a mentor in the introductory course (called "α group"). Thus, a total of 6439 students participated in the study. The group of students that would provide the closest comparison to the α group of students would be those who were asked to mentor but were unable or declined to participate in the program. However, all data were retrieved from a warehouse without identifying markers so this group of students was placed in the γ group due to an inability to properly classify them.

The judgment about which students were prepared and which were under-prepared for general chemistry was determined by the results of an in-house online chemistry and mathematics placement exam. The exam consisted of 25 questions, of which 8 were math based and 17 were chemistry based. The math portion was split between algebra and geometry questions, while the chemistry portion covered such topics as naming, stoichiometry, dimensional analysis, isotopes, and gram-to-mole conversions. Students who did not answer a minimum number of questions correctly were determined to be under-prepared, and were required to enroll in the introductory chemistry course to prepare them for general chemistry. The introductory chemistry course was graded on a satisfactory or unsatisfactory (S or U) basis until the summer semester of 2004 and thereafter on the traditional letter grade scale.

Mentors were chosen based upon their completion of the introductory chemistry course with a satisfactory grade (S or C, or better), demonstration of good group and facilitation behaviors in the introductory course, and recommendation of an existing mentor. Potential mentors were also interviewed by the faculty member running the mentoring program. Of the 104 mentors in this study, there were 54 females and 50 males. Fifty-four self-identified as non-white, 47 as white, while 3 did not report their ethnicity. Overall, 72 of the 104 mentors were either minority or female.

Table 1. GPA Equivalents for Letter Grades

Letter Grade	GPA Equivalent
A	4.00
B+	3.50
B	3.00
C+	2.50
C	2.00
D+	1.50
D	1.00
E/W/U	0.00
S	2.00

Mentors received credit in an undergraduate chemistry teaching course in exchange for their participation in the program. Mentors were initially trained before the first day of class and then once weekly throughout the semester. The weekly sessions were used primarily to discuss specific questions or problems that arose during the week and to practice mentors' facilitation skills. Mentors participated in the program for a minimum of one semester, but many mentored for two or more semesters, whenever their schedules permitted.

Since many of the students involved in this study took the first- and second-semesters of general chemistry more than once, their average grades, their first grade, and their highest grades in the courses were tabulated. The letter grades on their transcripts were converted to the 4.00 GPA (grade point average; E is the equivalent of a failing grade) scale (Table 1). Students were generally allowed to withdraw (earning a grade of W) from a course until a week and a half before the end of each semester. However, students were only allowed to drop two courses for each 60 credit hours of instruction (i.e., two courses could be dropped in the first and second years and another two courses in the third and fourth years).

Mentors, as well as the students in the γ group, were enrolled in college for a minimum of one semester before taking first-semester general chemistry because the preparatory course was required for these students. Students in the β group, however, may have taken first-semester general chemistry in their first semester of college or may have delayed and taken it in a later semester. Because there was no way to accurately determine at what point in the college career the courses were taken, the effects of college experience were omitted from this study.

Results

The benefits of mentoring were determined by comparing the mentors' performance in chemistry to the β and γ groups of students (students who were prepared for general chemistry and those who were under-prepared for general chemistry, respectively). The influence of previously acquired mathematical prowess on the grade attained in the mainstream chemistry course was determined by a linear regression analysis of the quantitative SAT scores versus course grade. Neither the average, first, or highest course grades were found to correlate with quantitative SAT scores. Both the mentors and the students in the γ group had enrolled in a minimum of one semester of chemistry prior to their enrollment in the first-semester general chemistry course, while first-semester general chemistry course was the first chemistry course for the students in the β group.

To ensure that the three groups of students held to a normal distribution of grades, a skewness and kurtosis were run on the data. Since the skewness and the kurtosis coefficients were found to be more than twice their corresponding errors, the data were considered to be non-normalized. This precluded an ANOVA analysis, so instead a Kruskal–Wallis analysis of variance was performed, which, although similar to an ANOVA, does not need normalized data. If the Kruskal–Wallis asymptotic significance (AS) value is less than or equal to 0.05, the difference between the means of the sample populations can be considered significant, and any value above 0.05 is considered insignificant. All statistical tests were run with the SPSS 15.0 program for Windows.

The academic levels of the three groups of students were compared to determine whether differences existed among them. The Kruskal–Wallis analysis showed a significant difference between the groups (AS = 0.000). The β group had a significantly higher quantitative SAT score than both the α group and the γ group (Table 2). There was no difference in the quantitative SAT scores of the γ group students and the α group ($p = 0.126$). Thus the β group of students was more academically ready for chemistry than their peers.

The Kruskal–Wallis analysis of the highest, average, and first grades showed significant differences in the first-semester mainstream general chemistry course for the three groups of students (Figure 1). The α group, initially under-prepared upon entering the University, had average and first grades that were half a letter grade higher than the β group (deemed prepared for chemistry) and a full letter grade higher than the γ group who were mentored (AS = 0.000) When highest grades were compared, the α group earned a full letter grade higher than the β group and one and a half times greater than the γ group (AS = 0.000).

The number of times these three groups of students enrolled in the course and the number of times they withdrew were also compared (Table 3). A Kruskal–Wallis analysis showed that the α group withdrew from general chemistry at a much lower rate (5%) compared to the γ group (19%) and the β group (12%, AS = 0.000). The α group, γ group, and β group all took the course slightly more than one time (1.06, 1.11, and 1.09 times, respectively), with no significant difference between the three groups (AS = 0.113).

The number of courses taken beyond general chemistry (not including the mentoring course) was also compared for these three groups of students (Table 3). The Kruskal–Wallis test showed a significant difference in the number of courses taken by each group (AS = 0.000). The α group took an average of 1.31 courses beyond general chemistry, while the γ group took an average of 0.69 courses, and the β group an average of 0.95 courses.

To examine the influence of gender or ethnicity of the mentors on their retention in chemistry, the number of courses the α group took after general chemistry were further dissected and compared using a Student's *t* test. No significant difference in number of courses taken by mentors was found based on either gender or ethnicity (Table 4). (The small number, 3, of students who did not indicate ethnicity were excluded from this analysis.)

The number of students who enrolled in second-semester general chemistry was fewer than those enrolled in the first-semester general chemistry. However, all three samples were still considered large enough for statistical comparisons. The average grade, first grade, and the highest grade received in second-semester general chemistry by the three groups of students were compared using a Kruskal–Wallis analysis, again used because of the non-normalized data.

Significant differences were found for the three groups of students when the highest grades (AS = 0.000), the first grades (AS = 0.000), and the average grades (AS = 0.000) were compared (Figure 2). All three groups had average and highest

Table 2. Quantitative SAT Scores

Group	N	Mean	Standard Error
γ Group	3186	606	1
β Group	3149	662	1
α Group	104	616	7

Table 3. Withdrawal Rates and Number of Courses Taken after First-Semester General Chemistry

Group	N	Withdrawal Rate		Courses Taken	
		Mean	Standard Error	Mean	Standard Error
γ Group	3186	0.19	0.01	0.69	0.02
β Group	3149	0.12	0.01	0.95	0.02
α Group	104	0.05	0.02	1.31	0.12

Table 4. Number of Courses Taken by α Group by Gender and Ethnicity

Group	N	Courses Taken	Standard Error
White	47	1.30	0.16
Minority	54	1.26	0.19
Female	53	1.30	0.18
Male	50	1.30	0.16

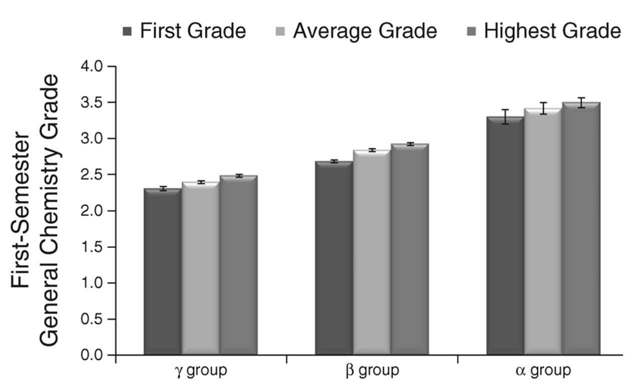

Figure 1. First, average, and highest grades in first-semester general chemistry for α, β, and γ groups: α group are students who entered the university under-prepared for chemistry, took the preparatory course and mentored in it; β group are students who entered the university prepared for chemistry and did not need the preparatory course; and γ group are students who entered the university under-prepared for chemistry and took the preparatory course.

grades in the C+ range, but the α group's grade point was 2.9, while the γ group's was 2.5 and the β group's was 2.7. For highest grades received, the α group just crossed the line into the B range (3.05), while the γ group and the β group remained in the C+ range, with grades of 2.69 and 2.84, respectively.

When the number of times the students withdrew from the course (AS = 0.36) and the number of times they took second-semester general chemistry (AS = 0.15) were compared, no significant differences were seen between the groups.

Conclusions

The introductory chemistry course covered material from the beginning of general chemistry through stoichiometry and limiting reagents, material usually considered to be a review of high school chemistry. This material is only briefly discussed in first-semester general chemistry. Therefore, the material that the mentors helped teach other students deemed initially under-prepared for chemistry was a minor component of the curriculum in first-semester general chemistry. With this in mind, and considering that the mentors were also classified as under-prepared for chemistry when entering university, the performance increases found for the mentors participating in the program are deemed to be extraordinary.

Students who mentored had higher average (and first and highest) grades in first-semester general chemistry than either of the other two groups of students. The mentors also needed fewer attempts at the course and were less likely to withdraw than students deemed initially under-prepared for chemistry and the students deemed initially prepared. Furthermore, the mentors also took more chemistry courses beyond the first-semester general chemistry course, not including the course in mentoring. These gains continued into the second-semester general chemistry course. Again, the mentors had higher average (and first and highest) grades than either of the other two groups.

The success and retention of under-prepared students who mentored in our study argues strongly that programs that encourage student leadership should be considered an important aspect of any undergraduate science curriculum. Additionally, the fact that approximately three-quarters of the mentors were either female or minorities demonstrates the potential of leadership programs to promote diversity in the STEM (science, technology, engineering and mathematics) disciplines. This program falls into Steele's "Wise Schooling" practices *(28)* that utilize optimistic teacher–student relationships to promote minority achievement in college. A program of this type could benefit many students in a wide range of disciplines and its adoption in any program concerned with performance of under-prepared students is thus highly encouraged.

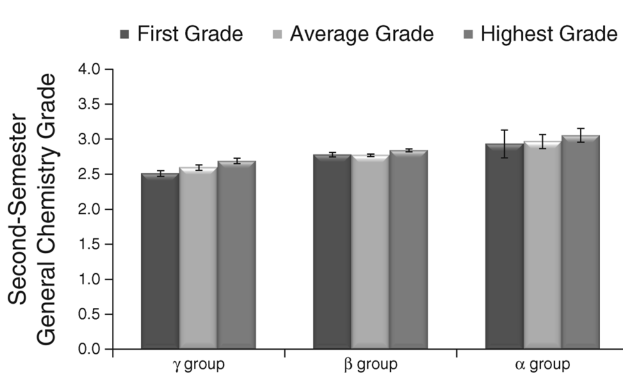

Figure 2. First, average, and highest grades in second-semester general chemistry for α, β, and γ groups: α group are students who entered the university under-prepared for chemistry, took the preparatory course and mentored in it; β group are students who entered the university prepared for chemistry and did not need the preparatory course; and γ group are students who entered the university under-prepared for chemistry and took the preparatory course.

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