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A Discussion Group Program Enhances the Conceptual Reasoning Skills of Students Enrolled in a Large Lecture-Format Introductory Biology Course

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It has been well-established that discussion groups enhance student learning in large lecture courses. The goal of this study was to determine the impact of a discussion group program on the development of conceptual reasoning skills of students enrolled in a large lecture-format introductory biology course. In the discussion group, students worked on problems based on topics discussed in lecture. The program was evaluated using three assessment tools. First, student responses to pre- and posttests were analyzed. The test question asked the students to demonstrate the relationships between 10 different but related terms. Use of a concept map to link the terms indicated an advanced level of conceptual reasoning skills. There was a 13.8% increase in the use of concept maps from pre- to posttest. Second, the students took a Likert-type survey to determine the perceived impact of the program on their conceptual reasoning skills. Many of the students felt that the program helped them understand and use the main course concepts to logically solve problems. Finally, average exam grades increased as the semester progressed. The average final grade in the course was 75%. Students enrolled in the course the previous year (where the lecture component of the course did not assess or reflect student learning in the discussion group) had an average final grade of 69%. The results of this study demonstrate that the discussion group program improves the conceptual reasoning skills of students enrolled in a large lecture-format introductory biology course.

Many undergraduate colleges and universities throughout the United States typically offer large freshmen-level courses due to financial constraints and high enrollment (5, 15). For a typical freshman, the first undergraduate year is a time of transition from the extremely structured learning environment that is common in high school settings to an environment which requires them to take more personal responsibility for their own learning (2). Many freshmen have difficulty taking ownership of their learning in larger classes (1, 8). This may partly be due to the fact that many first-year courses repeat materials that are covered in the high school curriculum, leading to boredom and a lack of interest in learning (2). Additionally, it is not unusual for instructors responsible for teaching freshmen-level large lecture courses to use traditional teacher-centered methods as their primary lecture style. This teaching approach emphasizes the rote memorization of facts and often promotes passive student learning, again, leading to student apathy (2). Several reports suggest that introductory courses need to introduce students to new and innovative ideas using student-centered teaching approaches that will inspire students to become more active participants in their learning (2, 16, 23). In response to these teaching techniques, students should begin to develop higher-order cognitive skills, such as conceptual reasoning, that are required for progression through the undergraduate curriculum (2, 16, 23).

Active-learning techniques such as problem-based, discovery-based, or inquiry-based learning are difficult to employ in large lecture-format courses, due to the number of students enrolled in the course and time constraints. These techniques enable students to interact with newly acquired knowledge by requiring students with different learning styles to use varying methods in order to assimilate the newly acquired knowledge in a small social setting (6, 9, 22). Active-learning strategies include such activities as small group problem solving, answering questions in real-time using classroom response systems, discussion group programs, web-based assignments, and analysis of case studies. These methods have been proven to promote the development of conceptual reasoning skills (7, 13).

In the scientific disciplines, active-learning techniques have aided in the enhancement of scientific literacy, retention of information, creativity, communication skills, self-evaluation skills, and preparedness for scientific research studies (2, 11, 19). Many undergraduate educators now support reforming science education so that it is more like “scientific teaching”—a teaching method that actively engages students in the process of science and demonstrates to them the rigor of the scientific disciplines (11). Udovic and colleagues created the Workshop Biology Project to emulate scientific teaching in their introductory biology courses. They demonstrated that using such a technique improved student performance dramatically compared to students who were enrolled in a typical lecture-style introductory biology course (21). McInerney demonstrated that adding scientific teaching techniques (using team-based projects) to his undergraduate microbial physiology course significantly improved final exam scores compared to a traditional lecture-format (14). Finally, Lyle and colleagues (12) and Tien and colleagues (20) introduced a discussion group program in their organic chemistry courses

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that used scientific teaching techniques and saw enhanced student performance as compared to traditional lecture-style courses.

Biology 101, the introductory biology course for science majors at Pace University—New York City, is a large lecture-format freshmen-level course. Enrollment in the course typically exceeds 100 students per semester. Based upon the information presented above, it was apparent that teaching the course using a traditional teacher-centered lecture style would not be the most effective pedagogical method to use for the students enrolled in the course. Therefore, a discussion group program, using the Peer-Led Team Learning (PLTL) model developed by Gosser and Roth (10), was added to the course. For this program, students enrolled in the Biology 101 course were broken into groups of 10 and each group met for an additional 1 hour per week with a trained peer leader. During each 1-hour session, the peer leader guided the students through problem sets (modules) that were designed by the PLTL Biology Task Force (http://www.pltl.org). The modules were related to the topics discussed in lecture. The peer leaders were students that had successfully completed the first-year biology curriculum the previous academic year and received an A or B as a final grade in Biology 101. The peer leaders were trained in how to facilitate small group discussions highlighting the thinking process, as opposed to emphasizing the answers to the problem sets, and how to work with different learning styles. The goal of this program was to engage students in the "scientific teaching" method discussed above.

The Learning Pyramid developed by the National Training Laboratories for Applied Behavioral Sciences (http://www.ntl.org) demonstrates that students only retain 5% of the materials presented to them in a traditional lecture setting. Retention rates go up to 50% upon addition of a discussion group component to a course, and they go up even further to 90% if the students are asked to teach others the materials that they have recently been taught. The National Training Laboratories assert that discussion group programs benefit students in different ways depending upon their ability levels. Weaker students receive additional inquiry-based problems to supplement the materials covered in lecture. Average students are exposed to different view points to aid them in problem solving. Stronger students are allowed to teach, which in turn, aids in the retention of the materials discussed.

The PLTL discussion group model has been effectively used in an organic chemistry course (12, 20). The hypothesis for this study is that the PLTL discussion group program will improve introductory biology students' conceptual reasoning skills. The development of conceptual reasoning skills is essential for undergraduate science majors to be successful in their given fields. These skills aid in the ability of individuals to understand concepts and see the connections between those concepts. This, in turn, enables individuals to logically and sequentially address problems and arguments. To determine if the Biology 101 discussion group program enhanced students' conceptual reasoning skills, student performance and opinions were assessed during the fall 2005 semester. A comparison of pre- and posttest results strongly suggested that the students' conceptual reasoning skills improved as the semester progressed. Student comments indicated that they benefited from the program. The enhancement of the students' conceptual reasoning skills enabled them to perform better overall on examinations as compared to students enrolled in the Biology 101 course the previous year. All of the results from this study strongly indicate that the discussion group program did indeed enhance the conceptual reasoning skills of the students enrolled in the course.

MATERIALS AND METHODS

Implementation of the Biology 101 PLTL discussion group program. Students registering for Biology 101 were required to coregister for a Biology 101 PLTL discussion group section. To guarantee that discussion groups remained small, the Registrar's Office limited enrollment to 10 students per section. Each section met once per week for 1 hour. Participation in the PLTL discussion group comprised 15% of the students' final course grade.

Peer leaders to run the discussion group sections were chosen on the basis of their outstanding performance in Biology 101; they earned a final grade of A or B. Peer leaders attended a general information session in late April and were officially hired in August. They then participated in a 2-day orientation and training session co-led by myself and the Director of the Pace University Center for Academic Excellence and Tutorial Services, Dr. Claire Berardini. During training, the peer leaders learned and practiced small group facilitation with an emphasis on promoting thinking processes and incorporating different learning styles. They also trained on how to incorporate biology study skills into their group meetings. During fall term, the peer leaders met with me on a weekly basis to prepare each module (problem set), discuss their experience as leaders, identify problems, ask questions, and ensure ongoing supervision.

The modules for the Biology 101 PLTL discussion group program were modeled after modules that are currently in use at other institutions using PLTL (developed by the PLTL Biology Task Force, http://www.pltl.org). They reinforced materials covered in lecture including topics such as the scientific method, basic and biological chemistry, metabolism, cell biology, cell cycle, meiosis, Mendelian genetics, and DNA, RNA, and proteins. The modules included activities such as concept maps, open-ended questions, reading comprehension, and case studies. Each module was designed to foster conceptual reasoning skill development using small group participation.

Assessment of the impact of the PLTL discussion group program on the development of conceptual reasoning skills: evaluation of pre- and posttest answers. At the beginning of the fall 2005 semester, students in Biology 101 were asked to take a pretest to evaluate their conceptual reasoning skills prior to participating in the discussion group program. A posttest was given to the students at the end of the Biology 101 course to assess the impact of the discussion group program on their conceptual reasoning skills. The question on both the pre- and posttest was, "Demonstrate the relationship between the following terms in a way that you feel is most appropriate." On the pretest, the terms were, "bright colors, pot of gold, fantasy, prism, sun, rainbow, Somewhere Over the Rainbow, rain clouds, leprechauns." The terms on the posttest were, "stapler, pencil, pen, computer, printer, paper, desk, lamp, push pins, chair". Nonbiological terms were chosen for the pre- and posttests because the students enrolled in the course had different levels of biology preparedness. I did not want the different levels of preparedness to affect their answers to the questions. It was assumed that the terms used for the pre- and posttests were familiar to all of the students. Although not traditionally done, different terms for the pre- and posttests were used because I did not want the students to recall and use their pretest answers on their posttests. Finally, upon asking the peer leaders to answer both the pre- and posttest questions, there was little difference in the types of responses between the two tests. This suggests that the terms on the tests did not influence the types of answers (data not shown).

A total of 115 students took the pretest and 85 students took the posttest. Among the pre- and posttests, I was able to obtain 61 matched pretest-posttest pairs. I was unable to match the remaining tests because the students either forgot the ID number that they used on the pretest when they took the posttest or they dropped or added the course after the pretest was given.

Assessment of the impact of the PLTL discussion group program on the development of conceptual reasoning skills: evaluation of student perceptions. In order to assess the perceived impact of the discussion group program on the development of the students' conceptual reasoning skills, students were asked to fill out a web-based questionnaire with Likert-type questions. This questionnaire was a modified version of a Student Assessment of Learning Gains (SALG) survey designed by Dr. Victor Strozak of the PLTL Biology Task Force. Likert-type questions require that students respond to a statement by choosing whether they strongly agree, agree, disagree, strongly disagree, or are neutral with respect to the statement. Survey questions were designed to evaluate the perceived impact of: (i) the discussion group's organization and materials on student learning; (ii) the content of the modules on the student's ability to learn the different topics in the course; (iii) the program on student enthusiasm, confidence, and communication; and (iv) the program on the student's abilities to understand concepts and solve problems in Biology 101 and other courses at the University. For every question on the survey, 50% or more of the students strongly agreed or agreed that the discussion group program helped them.

Students received two points of extra credit on their final exam for completing the survey. Ninety-seven students filled out the survey but not every student answered every question. In this manuscript, the responses to 4 of the 37 questions are presented. These four questions directly assessed the students' opinions about the impact of the discussion group program on their conceptual reasoning skills.

Assessment of the impact of the PLTL discussion group program on the development of conceptual reasoning skills: evaluation of student performance. During the fall 2005 semester, students enrolled in the Biology 101 course took four pop quizzes, three lecture examinations, and one cumulative final examination. The quizzes had five questions each, and each question was similar to the questions that appeared in the discussion group modules. The students were permitted to work in groups to answer the questions on the quizzes. Each quiz was worth 0.6% of the final Biology 101 grade and did not significantly impact final student grades. The lecture exams had 50 questions each. Approximately 50% of the exam questions were designed to test knowledge retention, and 50% were designed to test the conceptual reasoning skills of the students. Finally, the lecture final examination had 100 questions and contained only knowledge retention questions that were similar to the ones used on the lecture examinations.

Fall 2005 grades were compared to the grades obtained by students in the fall 2004 Biology 101 course. Students in the fall 2004 course did participate in the discussion group program, but they did not receive quizzes in lecture with questions reflecting the modules and the lecture exams only contained knowledge retention questions. In essence, no connection was made between the modules and the tools used to assess student performance in fall 2004. Additionally, although lecture content was the same both semesters, I was more conscious of ensuring that students saw connections between the different topics covered by using examples from the discussion group modules in the fall 2005 class. The lecture final examinations were identical for the fall 2004 and fall 2005 Biology 101 courses. One hundred seventeen students were enrolled in the fall 2004 Biology 101 course, and 115 students were enrolled in the fall 2005 Biology 101 course. I was the lecture instructor for both courses.

Statistical analyses. The answers to all of the pre- and posttests that were matched pairs (n = 61) were marked as either correct or incorrect. The most complex answer and, therefore, the "correct" answer to the pre- and posttests was a concept map. A concept map is a graphical tool that links concepts in a hierarchal fashion with the most general concepts at the top of the map and the less general concepts linked to them in a hierarchy below (17). All other student answers were considered incorrect. Using a paired *t* test, I was able to assess the students' conceptual reasoning skills based on their responses to the pre- and posttest question. The results are reported as the percentage of students that got the pre- and posttest questions correct. The *P* value from a paired *t* test analysis comparing the pre- and posttest scores was also determined. A *P* value of ≤ 0.05 was considered statistically significant.

For the SALG survey, the student responses to four representative questions are reported as the averages of the responses for each question (Table 1). Student grades on exams and quizzes are given as averages with the corresponding standard deviations (Table 2). Finally, unpaired *t* tests were used to compare the fall 2004 Biology 101 average

TABLE 1. Responses to four questions on the Student Assessment of Learning Gains (SALG) Likert survey

Question	Answer				
	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)
The discussion group helped me to make gains in my ability to understand the main concepts in Biology 101.	14	51	20	10	3
The discussion group helped me to make gains in my ability to understand the relationships between the concepts in Biology 101.	14	51	18	15	1
The discussion group made me feel comfortable with some of the complex ideas in Biology 101.	11	53	19	13	3
The discussion group helped me to make gains in my ability to logically and sequentially think through a problem or argument in Biology 101.	8	44	30	14	2

TABLE 2. Biology 101 average student lecture and final examination grades and final course grades

Item	Fall 2005	Fall 2004	*P* value[a]
Lecture exam 1	66.0% ± 16.1	85.0% ± 18.0	NA
Lecture exam 2	66.0% ± 20.5	72.5% ± 21.3	NA
Lecture exam 3	71.2% ± 16.0	74.0% ± 20.0	NA
Lecture exam 4	NA	63.0% ± 23.3	NA
Cumulative final examination	74.0% ± 16.6	66.0% ± 20.0	0.0003[b]
Final grade	75.0% ± 13.8	69.0% ± 17.5	0.004[b]

[a] Unpaired *t* test analysis comparing pre- and posttest scores (fall 2004, n = 117; fall 2005, n = 115).
[b] A *P* value of $\leq$ 0.05 was considered significant.

cumulative final examination scores and average final grades (n = 117) with those from fall 2005 Biology 101 (n = 115; Table 2). Again, a *P* value of $\leq$0.05 was considered statistically significant.

Pace University Institutional Review Board approval for these studies was granted in August 2005.

RESULTS

Evaluation of pretest-posttest results. Students enrolled in the fall 2005 Biology 101 course were required to participate in the PLTL discussion group program. Those students also elected to participate in this study to assess the impact of the discussion group program on the development of their conceptual reasoning skills. On the first day of lecture, the students were asked to answer a pretest question in order to supply a set of baseline answers for this study. The pretest question asked the students to demonstrate the relationships between related, but nonbiological, terms in the best way that they could. On the last day of lecture, they were asked to answer the same question on a posttest with different related, but non-biological, terms. One hundred fifteen students took the pretest, and 85 students took the posttest.

The answers given on both tests were separated into four categories: (i) formation of a concept map to link the terms, (ii) use of all the terms in a paragraph, (iii) use of a one-to-three word phrase to describe what the terms reminded the student of (in this case, none of the words given were used by the student), and (iv) other assorted answers (e.g., relisting the terms, no response, or “I don’t know”). The percentages of students that answered the pre- and posttest questions using answers from one of these four categories are depicted in Fig. 1. In the first category (formation of a concept map), there was a 13.8% increase in the number of students that used this answer on the posttest versus the pretest. Representative examples of concept maps prepared by the students are depicted in Fig. 2. There was no significant difference in the number of students that answered the question by using the terms in a paragraph (22% and 20% on the pre- and posttest,

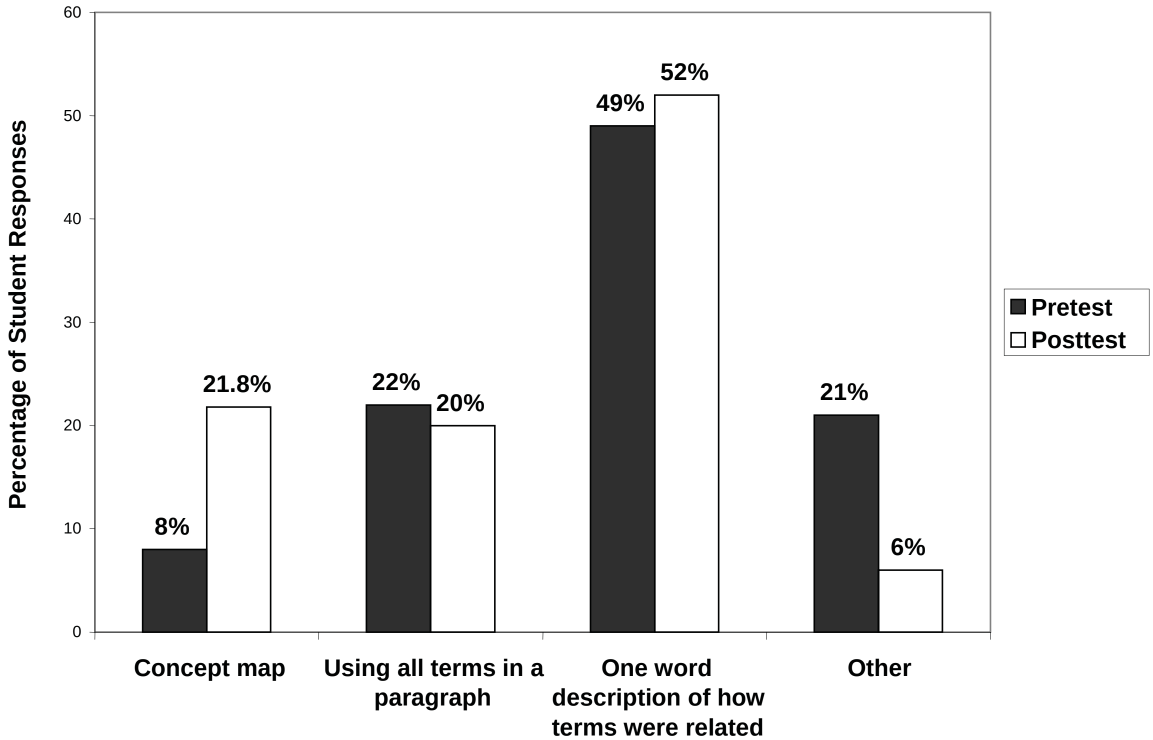

FIG. 1. Responses to pre- and posttest questions. Percentage of students that responded to the question on the pretest (black bars) and posttest (white bars) using the different answer categories (listed on the x axis). Actual percentage values are listed above each bar. One hundred fifteen of the fall 2005 Biology 101 students took the pretest while 85 of them took the posttest.

respectively) or by answering the question by using a one word phrase to describe what the terms reminded the student of (49% and 52% on the pre- and posttest, respectively). Finally, there was a 15% decrease in the number of students that gave some other answer to the question on the posttest versus the pretest. Taken together, these results suggest that there was a shift in the types of responses the students used to answer the questions between the pre- and posttest. This shift resulted in an increase in the number of students that used a concept map on the posttest and a corresponding decrease in the number of students that used some other response on the posttest.

Sixty-one of the pretest-posttest answers were matched to form pretest-posttest pairs. Matching the pretest-posttest pairs enabled a more detailed statistical analysis of the student answers. In reviewing answers from the matched pairs, 16.4% of the students used a concept map on the pretest, and 27.9% used a concept map on the posttest. This shows an 11.5% increase in the number of students that used the concept map on the posttest versus the pretest. A paired *t* test analysis of these results demonstrated that the increase in concept map usage on the posttest versus the pretest was statistically significant ($P = 0.034$).

Upon comparing the pretest-posttest responses, it was determined that the concept map was the most complex answer to the question because there was an increase in the number of students that used a concept map on the posttest. Supporting this decision, the literature suggests that one of the most advanced answers to questions such as the one on our pre- and posttests is the development of a concept map linking the terms together. Experts commonly make connections using concept maps to organize information (4). Additionally, Rebich and Gautier (18) used concept map pre- and posttests to analyze changes in their students' conceptual reasoning skills. The results from their studies demonstrated that their students displayed evidence of significant learning and an increase in conceptual reasoning skills as determined by an increase in the complexity of the concept maps created on the posttests compared to the pretests.

Students choosing to link the terms using a paragraph demonstrated that they were indeed able to link the terms but their linkages were linear—with a distinct start point and end point. Concept mapping enables students to make connections between concepts in any order. Cohen (3) suggested that concept mapping requires more metacognitive reflection than paragraph writing. Metacognitive reflection results in enhanced conceptual reasoning. These data suggest that the shift detected in the number of students that answered the posttest question with a concept map may reflect an increase in the ability of the students to make connections between terms in ways that are not necessarily linear and are similar

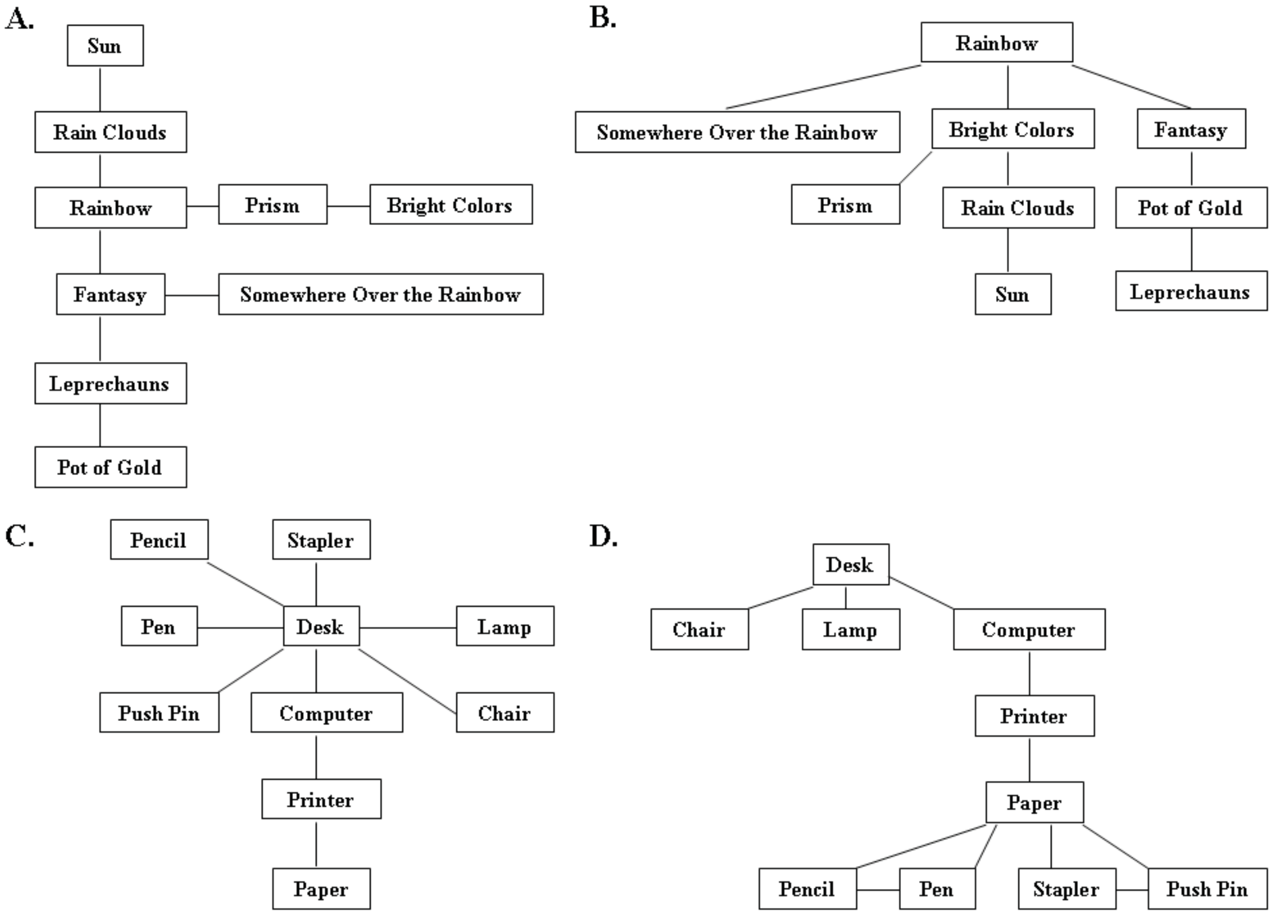

FIG. 2. Representative examples of student-prepared concept maps in response to the (A and B) pretest question and (C and D) posttest question.

to how experts work (4).

During the first discussion group session (which followed the first lecture and administration of the pretest), students were introduced to concept maps. They were asked to fill in a preconstructed concept map using supplied basic chemistry terms. Along with introducing the concept map, the peer leaders instructed the students on how to prepare the maps on their own and suggested to the students that the construction of concept maps would help ensure that they understood the materials covered during the course. The students were never asked to construct concept maps on their own as an assignment or requirement for the course, and the peer leaders did not discuss their usefulness as study tools after the initial discussion group session. Because of the students' limited encounter with concept mapping during the discussion group, the posttest answers were not influenced by concept map exposure.

Evaluation of Student Assessment of Learning Gains (SALG) survey results. At the end of the fall 2005 semester, students were asked to complete a Likert survey to describe their perceptions of whether or not the Biology 101 PLTL discussion group program enhanced the development of their conceptual reasoning skills. The results from the four most pertinent survey questions are depicted in Table 1. Of the 97 students that took the survey, 65% of them strongly agreed or agreed that the discussion group program helped them to understand the main concepts in Biology 101 and the relationships between those concepts. Sixty-four percent of the students strongly agreed or agreed that the program made them feel more comfortable with the complex ideas presented to them. Finally, 52% of the students strongly agreed or agreed that the discussion group program helped them to make gains in their ability to logically and sequentially think through problems or arguments addressed during Biology 101. The student responses to the survey questions indicate that, overall, the students found the discussion group program beneficial and that it helped them to improve their conceptual reasoning skills.

Evaluation of student performance on quizzes, lecture exams, and cumulative final exams and comparison of average final course grades. Throughout the fall 2005 semester, several methods were used to evaluate student performance in the Biology 101 course. The students were responsible for taking four pop lecture quizzes with questions based on materials from the discussion group modules, three lecture examinations, and one cumulative final examination.

All of the questions on the lecture and final examinations were multiple choice. On the lecture examinations, 50% of the questions were knowledge retention questions and 50% assessed the conceptual reasoning skills of the students. Although the questions on the lecture examinations varied from year to year, the questions on the final examination are identical every year. The final examination included only knowledge retention questions.

Students were permitted to work in groups to answer the questions on the pop lecture quizzes. This enabled them to discuss answers with their peers in an active fashion that highlighted different learning styles and thinking processes. The average quiz grades, as expected, were high and increased as the semester progressed (89%, 94%, 97%, and 100%, respectively). Student performance on lecture examinations and cumulative final examinations and final grades is depicted in Table 2. During the fall 2005 semester, student examination grades increased as the semester progressed (66%, 66%, and 71.2%, respectively). In contrast, during the fall 2004 semester, as the course progressed and the concepts covered became more difficult, examination grades decreased (85%, 72.5%, 74%, and 63%, respectively). The questions on the fall 2004 lecture examinations were all knowledge retention questions. On the cumulative lecture final examination, students in the fall 2005 course received an average grade of 74% while those in the fall 2004 course received an average grade of 66% ($P = 0.0003$). This shows an 8% increase in the average final examination grade for the fall 2005 semester compared to fall 2004. Finally, the average final grade in the fall 2004 course was 69%, while in the fall 2005 course it was 75% ($P = 0.004$). This represents a final grade increase of 6% for the fall 2005 semester compared to fall 2004. Taken together, these data demonstrate that the Biology 101 PLTL discussion group program did indeed impact the students' performance on their quizzes, examinations, and overall (as evidenced by their final grades) in a positive fashion.

DISCUSSION

The goal of these studies was to demonstrate that the Biology 101 PLTL discussion group program would improve introductory biology students' conceptual reasoning skills. The development of conceptual reasoning skills is essential for undergraduate science majors in order for them to be successful in their given fields (11). These skills aid in the ability of individuals to understand concepts and see the connections between those concepts. This in turn, enables individuals to logically and sequentially address problems and arguments in their discipline. The data obtained from these studies strongly suggests that the Biology 101 PLTL discussion group program does indeed enhance the conceptual reasoning skills of students enrolled in the course.

The pre- and posttest results demonstrated that the students improved in their ability to make connections between different concepts. These gains were shown by the 11.5% increase in the number of students that answered the question using a concept map on the posttest versus the pretest (Fig. 1). The shift detected in the number of students that answered the question with a concept map reflects an increase in the ability of the students to make connections between terms in ways that are similar to how experts work (4). According to the literature, expert knowledge is organized around important ideas or concepts. Experts have a thorough knowledge of their discipline and can use that knowledge to aid them with conceptual reasoning in response to questions such as the one posed on the pre- and posttests (4). Additionally, Rebich and Gautier (18) demonstrated that pre- and posttest concept maps enabled them to detect increases in students' conceptual reasoning skills. They reasoned that the metacognitive reflection required for concept mapping enabled their students to better demonstrate the relationships between terms and enhanced their learning. The students that used a concept map to answer the pre- and posttest questions in Biology 101 responded in an expert-like fashion suggesting that the discussion group program enabled them to better develop their conceptual reasoning skills.

The student comments, as determined by the SALG Likert survey, clearly indicated that the students felt that they benefited from the discussion group program. The students felt very strongly that the program enabled them to better understand the concepts introduced in Biology 101. They also concurred that the discussion group program helped them to make connections between the different concepts in the course. This is supported by the increase in the number of students that used concept maps to answer the posttest question. The survey also indicated that the discussion group program made the students feel more comfortable with the materials covered in the course. As suggested by the Learning Pyramid (http://www.ntl.org), retention of course materials is enhanced by 50% upon the addition of a discussion group program to a course. It is logical to assume that one of the reasons for the increase in retention rates upon addition of a discussion group is that the materials covered in the lecture are repeated in the discussion group. Repetition of new and complex materials increases student comfort when they are asked questions about the materials. Finally, according to the survey, the students felt that the PLTL discussion group program helped them to make gains in their abilities to answer questions more logically and sequentially than prior to taking the course. This indicates that the students felt they had grasped the concepts presented to them in the course and were comfortable enough to use the knowledge they had obtained to logically reason answers to questions posed to them about the subject matter.

The enhancement of the students' abilities to make connections between the different topics covered in the course enabled them to perform better overall as indicated by the increase in the fall 2005 Biology 101 student grades. The average grades that the students received on the pop lecture quizzes and lecture examinations increased as the fall 2005 semester progressed (Table 2). In contrast, during the fall 2004 semester, the average lecture examination grades decreased as the semester progressed (Table 2)—even though the types of questions (knowledge retention) on the fall 2004 lecture examinations were less challenging than the types of questions (knowledge retention and conceptual reasoning) on the fall 2005 lecture examinations. Upon comparison of the average cumulative final examination and average final grades between the fall 2004 and fall 2005 semesters, it was determined that students in the fall 2005 semester did significantly better on an identical cumulative final examination and received significantly higher final grades (Table 2). Students in the fall 2004 course did participate in the discussion group program, but they did not receive quizzes in lecture with questions reflecting the modules and the lecture exams only contained knowledge retention questions. No connection was made between the modules and the tools used to assess student performance in fall 2004. Taken together, the performance of the fall 2005 students on their quizzes, examinations, and final grades indicates that the enhancement of the students' conceptual reasoning skills due to the discussion group program did enable the students to achieve higher grades compared to those in the fall 2004 course.

The Biology 101 PLTL discussion group program was designed to engage the students in a small group setting. The modules developed for the program require active participation, highlight the process required to answer problem sets, and aim to develop strong critical thinking skills. The results from this study strongly indicate that the discussion group program implemented for the Biology 101 course at Pace University—New York City does enhance the conceptual reasoning skills and overall performance of the students enrolled in the course.

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