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Attitudinal Effects of a Student-Centered Active Learning Environment

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Student reasons for enrollment in chemistry classes are varied but the majority of students in general chemistry are enrolled because it is a requirement for their majors. Student attitudes may be a reflection of the shift in general chemistry from a discipline-specific course taken by interested parties to a service course required by multiple majors. When this fact is added to the large enrollment in introductory chemistry classes and the diversity of student population in terms of backgrounds and learning styles, attitudinal aspects become a complex area of investigation. Under this scenario other instructional aspects such as sustaining motivation become as challenging as knowledge retention and application. This imposes a new dimension to effective instruction.

The importance of attitudes toward science has risen from widely accepted assumptions that achievement and attitude are positively interdependent *(1)* and that affective variables are as important as cognitive variables in molding student learning *(2).* Research studies have investigated the attitudinal aspects of chemistry instruction in two realms: lecture and laboratory. Both are potential grounds to excite students into the wonders of chemistry. Studies show that exclusive use of lecture methods fails to sustain student interest in the sciences *(3)* and tends to decrease student interest, attendance, and motivation as students feel little sense of responsibility or accountability *(4).* Adding aspects of cooperative learning to a lecture course showed a positive effect on student retention; however, better attitude toward science and greater enjoyment of science were attributed to individual instructors and not to cooperative techniques *(5).* On the other hand, active involvement might be the reason why students enjoy the laboratory component of chemistry more than any other part of their chemistry instruction *(6).* One study looked at the achievement–attitude relationship and the use of hands-on laboratory instruction as a means of improving student attitude toward science *(7).* Laboratory instruction seems to influence student attitudes consistently in a positive way *(7–10).*

A novel course format known as "Student-Centered Activities for Large Enrollment Undergraduate Programs" (SCALE-UP) has incorporated elements believed to positively influence student performance and attitudes toward science including cooperative learning, hands-on activities, real-world applications, and engaging technology *(11).* The most distinguished feature of this format is the blending of lecture and laboratory together into one seamless session with minimized lecture and hands-on activities as the driving force of the class time. The prevailing objective of this research is to examine whether this active learning environment that has incorporated research-based pedagogy would have an effect on student attitudes toward chemistry and learning. Anxiety towards chemistry in this environment is also investigated.

Methodology

Subjects and Setting

Two sections of the same general chemistry course, CH 101, were compared in the study. General Chemistry 101 (CH 101) is the first semester of a two-semester general chemistry sequence required for all science students. Both sections consisted primarily of freshmen students (89.1% and 91.7%) majoring in sciences, excluding chemistry. One section was a traditional lecture setting with an enrollment of 150 students while the other section was a SCALE-UP class with 51 students. Both classes have almost identical demographic populations of students majoring in physical sciences or engineering (68% and 69%), biological sciences (both 8%), and other sciences that include computer, environmental, wood and pulp, and food chemistry. These academic major groupings reflect comparable aptitudes in math and average college entrance scores within our college student population.

Treatment

CH 101 is a conceptually driven course designed to familiarize students who must fulfill a chemistry or science requirement to the most important topics in general chemistry. This course explores the principles of atomic structure, bonding, reactivity, energetics, intermolecular forces, and types of reactions as well as introductions to organic and inorganic chemistry. The course is taught with no algorithmic problems assigned in class. The lab incorporates basic mathematical manipulations. For the majority of the students this conceptual approach is different from their previous experiences in chemistry.

The same instructor (MTOH) taught both sections and the lecture section was used as the control group. Students in the traditional section attended three hours of lecture per week and three hours of lab every other week. In addition, students enrolled in one-hour problem sessions that met on alternating weeks. Students in the treatment section (SCALE-UP) attended the integrated format of lecture and lab during three two-hour sessions per week. The primary difference between the two formats was the passive versus active involvement of students in the classroom. Both sections discussed the same content but the control group (lecture section) was a teacher-centered classroom with the instructor delivering the information while the treatment section (SCALE-UP) was a student-centered environment where the instructor facilitated group work, activities, and familiarization with technology. The treatment included four elements: cooperative learning, hands-on activities, real-world applications, and engaging technology. These elements were considered for synergetic effects and not as individual contributors to the overall results.

Instruments

Pre- and post-surveys were administered electronically to students during the first and last two weeks of classes. Both surveys included questions designed to monitor attitudes toward learning science (14 questions), and chemistry anxiety in learning, evaluation, and chemical handling (25 questions). The attitude portion of the surveys was adapted from surveys used to compare a modular-teaching approach to a traditional-lecture approach at Grinnell College and University of California at Berkeley *(12)*. The anxiety portion of the survey was adapted from the Derived Chemistry Anxiety Rating Scale *(13)*.

Students chose the option that best matched their feelings toward specific questions. These options included strongly agree, agree, neutral, disagree, and strongly disagree for the attitude questions. These answers were converted to numerical values with a scale ranging from 1 (strongly disagree) to 5 (strongly agree). Questions were in an affirmative mode so that the higher the values the better the attitude toward learning in science. On the other hand, the chemistry anxiety options included not at all, a little, moderately, quite a bit, and extremely, which were also converted to a scale of 1 (not at all) to 5 (extremely). Lower numbers in this scale represent less anxiety.

Raw attitude scores are obtained by adding the numerical values (from 1 to 5) assigned to each of the 14 questions on learning to obtain a total score ranging from 14 to 70. These scores were used to compute residualized gains in learning attitude. *T*-tests were used to analyze changes in student anxiety.

In addition, all students filled out a standard departmental evaluation that contained specific questions about the course and the instructor in both close-ended and open-ended formats. Scale means and standards deviations are reported for the close-ended questions. Analysis of the qualitative data will be the subject for a future manuscript. However, a summary of the most popular answers from the open-ended questions is also included in the results section.

Results and Discussion

Common Factor: Instructor

Instructors can dramatically influence student performance and attitudes in the classroom *(14, 15)*. Therefore, departmental evaluations were used to compare student perceptions of the instructor to monitor discrepancies that could jeopardize findings in the attitudinal and anxiety surveys. A total of 161 surveys were collected from the two class sections. A scale of 1 (strongly disagree) to 5 (strongly agree) was used. The averages with accompanying standard deviations are included in Table 1.

Table 1. Student Evaluations of Instructor

Question	Lecture (n = 113)	SCALE-UP (n = 48)
Instructor demonstrates enthusiasm for teaching.	4.8 (0.4)	4.6 (0.5)
Instructor is well prepared for lecture.	4.8 (0.4)	4.5 (0.7)
Instructor writes legibly.	4.6 (0.6)	4.4 (0.6)
Instructor speaks clearly.	4.1 (0.8)	3.7 (1.1)
Instructor is receptive to questions and comments.	4.6 (0.6)	4.1 (1.1)
Instructor is available during posted office hours.	4.3 (0.8)	4.4 (0.7)
Instructor is knowledgeable of subject material.	4.8 (0.4)	4.6 (0.7)
I would recommend this instructor to other students.	3.8 (1.1)	3.7 (1.2)
The overall effectiveness of this instructor as a teacher is:	4.0 (0.9)	3.8 (1.0)

Student evaluations of the same instructor in the two different formats reflect that there is no significantly different perception of the instructor in the two classes, even though the SCALE-UP class consistently gave lower markings to the same questions. Lower markings were also reported by another instructor when implementing an innovative approach where students become more responsible for their own learning *(16)*. The instructor is an important source of variation and if it were the only variable taken into consideration we could predict that parallel results would occur on student attitudes since the instructor was perceived comparably in both sections.

Analysis of Data: Residualized Gain Scores

Due to the complexity of factors affecting attitudinal responses, the use of raw difference scores raises validity concerns. Some argue that raw difference scores are inherently unreliable, especially when considering the measurement of attitudes on different occasions that may influence student responses *(17)*. Residualized gain scores, RGS, tend to attenuate some of the difficulties associated with comparison of raw scores *(17, 18)*. In RGS analysis post- versus pre-survey scores for each student in the lecture section (control section) are plotted. A regression line is obtained from this post versus pre-survey scatter plot. This regression line, or baseline, is used to compute predicted post-survey scores for each student in SCALE-UP (treatment section). The residualized gain is the difference between each predicted value and the actual post-survey value for each student, which measures real change relative to predicted change. These residualized gains are considered good estimates of the treatment effects. The post- and pre-survey scatter plot for the control group

Table 2. Chemistry Anxiety Assessed by Stress Level Response to the Following Activities

	SCALE-UP			Lecture		
Questions Relating To Learning Chemistry:	Pre	Post	*p* Value (*t* Stat)	Pre	Post	*p* Value (*t* Stat)
Signing up for a chemistry course.	1.98	1.96	0.46 (0.095)	1.97	2.19	0.06 (-1.59)
Reading the word "chemistry".	1.81	1.77	0.43 (0.19)	1.70	1.90	0.03 (-1.94)
Walking into a chemistry class.	1.92	2.04	0.28 (-0.59)	1.98	2.18	0.09 (-1.35)
Looking through the pages in a chemistry text.	2.15	2.23	0.37 (-0.33)	2.34	2.57	0.06 (-1.55)
Reading a formula in chemistry.	2.27	2.23	0.44 (0.16)	2.32	2.51	0.10 (-1.30)
Picking up a chemistry textbook to begin working on a homework assignment.	2.44	2.35	0.36 (0.35)	2.43	2.58	0.14 (-1.09)
Having to use the tables in a chemistry book.	2.06	2.06	0.50 (0)	1.99	2.09	0.22 (-0.78)
Reading and interpreting graphs or charts that show the results of chemistry experiments.	2.15	2.19	0.43 (-0.19)	2.21	2.24	0.42 (-0.20)
Listening to another student explain a chemical reaction.	2.08	1.94	0.25 (0.67)	2.27	2.28	0.48 (-0.06)
Listening to a lecture in a chemistry class.	2.15	2.33	0.24 (-0.72)	2.04	2.43	0.01 (-2.57)
Total Score	21.0	21.1	0.48 (-0.06)	21.3	23.0	0.05 (-1.68)
Questions Relating To Chemistry Evaluation:						
Working on an abstract chemistry problem, such as "If *x* = grams of hydrogen and *y* = total grams of water produced, calculate the number of grams of oxygen that reacted with the hydrogen.	2.75	2.50	0.16 (1.01)	2.71	2.71	0.48 (0.06)
Waiting to get a chemistry test returned.	3.10	3.63	0.03 (-1.97)	3.29	3.50	0.09 (-1.36)
Taking a test or examination in a chemistry class.	3.56	3.65	0.37 (-0.34)	3.42	3.56	0.17 (-0.97)
Being given a homework assignment that is due the next chemistry class.	2.60	2.56	0.43 (0.17)	2.59	2.61	0.43 (-0.17)
Thinking about a chemistry test one day before.	3.15	3.52	0.09 (-1.38)	3.29	3.40	0.22 (-0.76)
Taking a final in chemistry.	3.90	4.06	0.25 (-0.67)	4.14	4.04	0.24 (0.70)
Total Score	19.1	19.9	0.24 (-0.72)	19.4	19.8	0.28 (-0.59)
Questions Relating To Chemical Handling:						
Walking into a chemistry laboratory.	1.81	1.83	0.50 (-0.11)	1.92	1.77	0.12 (1.17)
Spilling a chemical.	2.65	1.98	0.00 (2.82)	3.13	2.51	0.00 (3.77)
Listening to another student describe an accident in the chemistry lab.	1.83	2.69	0.00 (-3.47)	1.88	1.92	0.39 (-0.29)
Being told how to handle the chemicals for the laboratory experiment.	1.69	1.75	0.37 (-0.33)	1.80	1.76	0.37 (0.34)
Working with acids in the lab.	2.08	1.38	0.00 (3.61)	2.13	1.92	0.07 (1.45)
Getting chemicals on your hands during the experiment.	2.44	1.75	0.00 (3.13)	2.69	2.45	0.07 (1.50)
Working with a chemical whose identity you don't know.	2.27	2.29	0.47 (-0.08)	2.61	2.22	0.00 (2.61)
Mixing chemical reagents in the laboratory.	2.04	2.27	0.19 (-0.88)	2.15	1.93	0.06 (1.57)
Heating a chemical in the Bunsen burner flame.	2.08	1.83	0.14 (1.06)	1.97	1.97	0.50 (0)
Total Score	18.9	17.8	0.25 (0.69)	20.3	18.5	0.03 (1.83)
Overall Score	**59.0**	**58.8**	**0.48 (0.04)**	**61.0**	**61.3**	**0.43 (-0.17)**

NOTE: The following scale was used: 1–not at all, 2–a little, 3–moderately, 4–quite a bit, 5–extremely.

(n = 119) is shown in Figure 1 and the RGS graph for the treatment group (n = 48) is shown in Figure 2. Positive gains were reflected by 77.1% of the student population in the SCALE-UP section. These changes are above the baseline of lecture section responses (control section).

RGS values for the SCALE-UP class as a whole were dissected to investigate whether there were differences within academic groups. When academic groups were compared separately to the post- and pre-scatter plot, positive changes in attitude were attained by 76.9% of the physical science or engineering majors, 81.8% of the biological sciences majors, and 72.7% of the majors grouped under "other." These results are shown in Figure 3. When academic majors are compared to their counterparts in lecture, the percentage of students experiencing positive gain above the baseline of their counterparts remains the same as when compared to the lecture section as a whole (plots not shown).

Chemistry Anxiety

Research on chemistry anxiety is at an early stage but the existence of it among chemistry students is palpable *(13).* In this study changes in student anxiety levels from both classroom environments were monitored. The pre- and post-survey results are summarized in Table 2. Indication of significant differences is also reported in the form of p values resulting from t-tests performed on each specific question regarding the three factors: learning chemistry, chemistry evaluation, and chemical handling.

T-tests were used to compare the anxiety level of students in both classes. Pre-survey responses from students in both classes were first compared for each question to determine whether the two classes had similar levels of anxiety initially. The results of these t-tests (p = 0.26 and t = −0.65) reveal that there were no statistical differences between classes on pre-scores (for $p \leq 0.05$, $t_{critical}$ = 1.65). In addition, t-tests also reveal that when both classes are compared in pre- and post-scores, overall, there is no significant difference in anxiety between the students in the SCALE-UP (p = 0.48, t = 0.04) and lecture (p = 0.43, t = −0.17) sections. The overall score was computed using all questions on the anxiety rating scale. Total scores for each factor in the anxiety rating scale were computed by adding a student's responses over all questions for that factor. When t-tests were used to compare these total scores, significant changes were only noted for the lecture section in the factors of "Learning Chemistry" (p = 0.05, t = −1.68) and "Chemical Handling" (p = 0.03, t = 1.83).

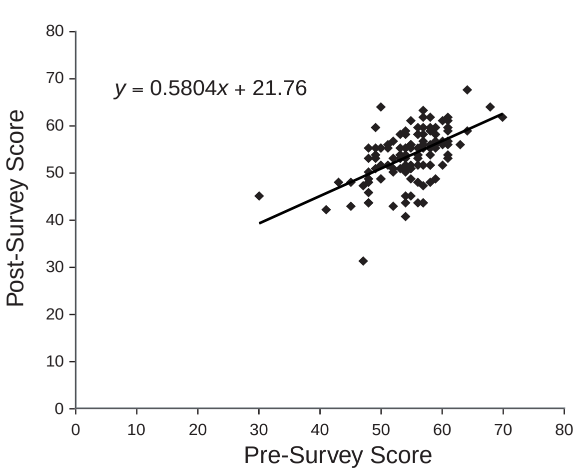

Figure 1. Post- versus pre-survey scatter plot for the control group (n = 119).

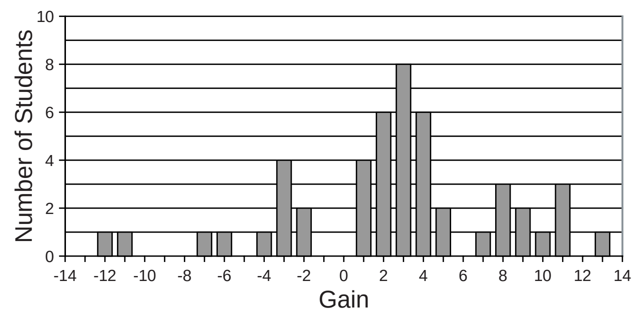

Figure 2. Residualized gains for the treatment group (n = 48).

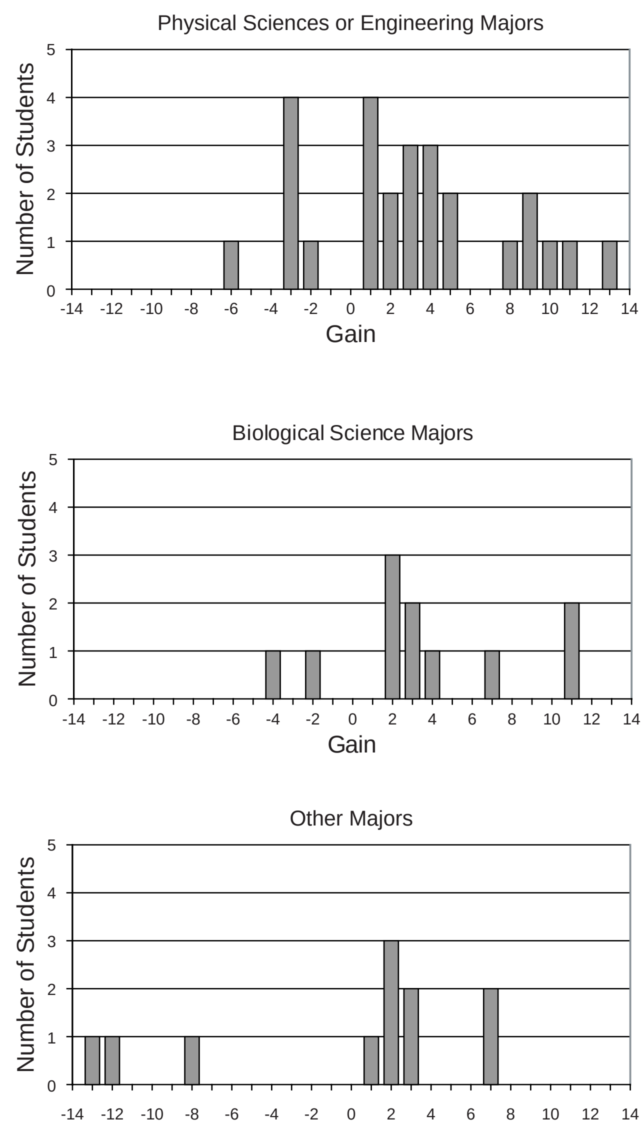

Figure 3. Residualized gains by academic groups.

Table 3. Chemistry Anxiety Ratings by Majors

	Rating	Pre-Survey			Post-Survey		
		P	B	O	P	B	O
SCALE-UP	Total Derived Chemistry Anxiety Rating	2.06	2.83	2.59	2.13	2.76	2.47
	Factor 1, Learning-Chemistry Anxiety	1.71	2.81	2.31	1.82	2.74	2.18
	Factor 2, Chemistry-Evaluation Anxiety	2.78	3.79	3.50	3.00	3.97	3.42
	Factor 3, Handling-Chemicals Anxiety	1.97	2.21	2.29	1.89	1.99	2.15
Lecture	Total Derived Chemistry Anxiety Rating	2.45	2.39	2.46	2.44	2.42	2.53
	Factor 1, Learning-Chemistry Anxiety	2.10	2.09	2.23	2.26	2.25	2.46
	Factor 2, Chemistry-Evaluation Anxiety	3.34	3.13	3.10	3.31	3.22	3.36
	Factor 3, Handling-Chemicals Anxiety	2.24	2.24	2.29	2.05	2.06	2.04

NOTE: P indicates the physical sciences or engineering majors, B indicates the biological sciences majors, and O represents the other science majors.

Anxiety significantly decreased for chemical handling, while anxiety significantly increased for learning chemistry in the lecture section.

T-tests were also used to compare pre- and post-responses within a class in order to look for significant changes occurring over the course of the semester. These tests reveal that anxiety for SCALE-UP students was lowered in four areas of the chemical handling section: "spilling a chemical", "listening to a description of an accident", "working with acids in the lab", and "getting chemicals on your hands during the experiment." Anxiety for students in the lecture section was also lowered in the area of "spilling a chemical", as well as in "working with a chemical whose identity you don't know." Significant decreases or improvement in anxiety levels were only observed for the chemical handling factor for both classes. Although students in SCALE-UP completed the same labs as the lecture students, SCALE-UP labs involved microscale techniques only. Additional activities conducted by the SCALE-UP students also used microscale techniques and nonhazardous materials. This may explain the significant overall decrease in chemical handling anxiety for the lecture students while students in SCALE-UP experienced only a slight overall decrease (not significant).

Even though there were no significant changes for SCALE-UP in the learning chemistry factor, the averages for each area in this factor show increase in anxiety of learning chemistry in only 4 of the 10 questions, while those in the lecture show increase in anxiety in all 10 questions. Two of those questions increased significantly in the lecture section, "Reading the word 'chemistry'" (p = 0.03, t = −1.94) and "Listening to a lecture in the chemistry class" (p = 0.01, t = −2.57). Under the "Chemistry Evaluation" factor, only one question showed a significant increase in anxiety and it was found in the SCALE-UP section, "Waiting to get a chemistry test returned" (p = 0.03, t = −1.97).

Dissecting this information into the three academic majors revealed that physical sciences or engineering (P) students had higher levels of anxiety in the lecture setting both initially (comparing averages on pre-scores for both sections) and at the end of the semester (comparing averages on post-scores for both sections) while the biological sciences (B) majors showed more anxiety in the SCALE-UP section for factors 1 and 2 initially and with the end results. When comparing changes of these two majors within each class setting there were no significant differences on pre- and post-survey results. The academic grouping of all other sciences (O) did not show a consistent pattern when comparing lecture to SCALE-UP. However, this group (O) showed a decrease in anxiety on all three factors for SCALE-UP and only a decrease in the laboratory factor in the lecture setting. Table 3 includes these results.

Student Opinions

Departmental evaluation questions that refer specifically to the course do not show differences between lecture and SCALE-UP sections. These results are shown in Table 4. The neutrality shown in these quantitative results does not match the strong opinionated responses given to the open-ended questions that asked, "How would you describe this course?" and "Elaborate on any other aspects of this course, especially those rated very positively or negatively in the multiple-choice section." Both classes felt they had to work hard, yet the SCALE-UP class used adjectives like "in-depth" and "stimulating" more often than the lecture class. In almost every instance that the SCALE-UP class referred to the course as "hard" it was accompanied by phrases like "rewarding", "worth it", "better", and "teaches you a lot" or "you get more

Table 4. Course Specific Questions

Question	Lecture (n = 113)	SCALE-UP (n = 48)
The course is challenging and stimulates independent thinking.	4.7 (0.7)	4.5 (0.6)
The knowledge gained in previous courses prepared me sufficiently for this one.	3.4 (1.1)	3.4 (1.1)
The degree of difficulty associated with this course is: very difficult (5), difficult, average, easy, trivial (1).	4.3 (0.8)	4.2 (0.7)
The numbers of hours required outside of class per week is: less than: 2 (5), 2–5, 5–8, 8–12, more than 12 (1).	3.4 (0.8)	3.4 (0.8)

out of it". That was not the case in lecture where "hard" was often accompanied by adjectives like "extremely" and "too" or phrases like "too much work", "must put lots of effort", and "requires too much time". In the SCALE-UP class words like "fun" and "interesting" were used more often.

A phenomena not encountered with the lecture class was the aftermath of emails expressing gratitude for the opportunity to learn chemistry. The reason for this effect might lie in the fact that students in the SCALE-UP section are familiar with the lecture format but not vice versa. Students in SCALE-UP consistently referred to their active class as a better way to learn and they recognized their roles and responsibilities in learning. In the lecture setting the "responsibility" for not doing well in class was more often blamed on the instructor rather than the student.

Conclusions

The active environment integrated four elements believed to positively influence student attitudes. It was expected that the synergy of these elements would show markedly positive changes in students familiarized with this format. Clear changes were recorded that could help others in their action research. In addition, the chemistry anxiety results are shared in the hopes they will contribute to a better understanding of anxiety in chemistry. Our findings can be summarized as follows:

- Evaluations by students on the instructor's performance and capability showed comparable perceptions from both classes but the SCALE-UP class evaluation was a bit lower in every survey question. Instructors need to be aware that this is a real effect encountered in implementation of new approaches.
- Positive changes were markedly obtained in student attitudes toward learning as 77.1% of the student population in the SCALE-UP class showed positive RGS. These changes represent gains above projected changes in the lecture (control section).
- No significant differences in anxiety were obtained for the SCALE-UP classes when total (for each factor) and overall scores (factors combined) were taken into consideration for this class. Significant differences were found for the lecture section in "Learning Chemistry" (p = 0.05, t = −1.68) and "Chemical Handling" (p = 0.03, t = 1.83) total scores. A closer look at individual questions revealed significant differences in only five (SCALE-UP) and four questions (lecture) out of 25 questions distributed in three factors.
- Quantitative results of student opinions from departmental evaluation surveys were comparable for both classes. However, the feedback received by instructors in SCALE-UP was numerous, positive, and inspiring. This feedback came from both informal and formal sources including the open-ended questions on departmental surveys, emails received both during and after the course of the semester, interviews, and entries on reflective journals obtained during in-class assignments. Analysis of these qualitative data is in preparation.

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