

Preparation for High School Chemistry: The Effects of a Summer School Course on Student Achievement

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A novel summer school course was created to prepare students for high school chemistry at an all-girls independent school in California. A study was conducted to quantify any differences in class rankings in the subsequent chemistry class of the students who took the summer course compared to a control group. The summer course was designed to address several of the difficulties that students face when taking high school chemistry. In particular, chemistry class is usually the first time that students are expected to apply mathematics to scientific systems, and the material builds on itself so that students who struggle in the first couple of weeks often struggle throughout the year. Additionally, chemistry concepts are abstract, and most high school students have not yet fully developed their formal reasoning skills (1). This results in many students memorizing, rather than conceptually understanding, the material in high school chemistry (2). The summer course aimed to provide students with the time and facilities necessary to reflect on the material so that they could learn it in a meaningful way, rather than relying on rote learning (3).

An all-girls school was chosen for this study. Women continue to be underrepresented in the chemistry profession, particularly in faculty positions (4, 5). Many studies have documented differences between boys and girls in attitude and self-confidence in science (6–14). A goal of the summer course was to engage girls in learning fundamental chemistry concepts and developing laboratory skills so that they could approach high school chemistry with the background and confidence necessary to succeed.

Previous studies have tracked the effect of science summer camps on student interest in science, and these studies suggest that students who attend science summer camps may increase their interest in science (15)—or that their interest remains constant—while other students' interest in science decreases (16). Our goal was to track quantitatively the progress of students who took the summer course by comparing their rankings in the subsequent high school chemistry course to the rankings of students who did not take the summer course. The small school size provided the advantage that the students who enrolled in chemistry immediately after taking the summer course all had the same teacher for high school chemistry, providing an important control element for the study.

Description of the Course

The name of the summer course was Preparation for High School Chemistry. The course met for two hours a day, five days a week (except for a holiday on July 4), for four weeks, for a total of thirty-eight hours of instruction during the summer of 2003. Student enrollment was voluntary, and there were no formal student evaluations or feedback provided to parents of the students' progress. The students included both strong and weak performers from a ninth-grade general science course. Students enrolled in the summer school course with the primary objective of increasing their chances of doing well in high school chemistry.

Students were told the goals of the course on the first day of class. The goals, as enunciated, were to:

1. Introduce the principles of chemistry and familiarize students with chemical terminology
2. Illustrate the relevance of chemistry in students' daily lives
3. Present strategies for solving problems, and to practice problem-solving skills with one-on-one instructor assistance
4. Use demonstrations and hands-on laboratories for visual reinforcement of chemical principles
5. Introduce effective skills for working collaboratively in small groups to solve complex problems
6. Prepare students to approach high school chemistry with the confidence and skills necessary to succeed

A general syllabus was also presented to the students and is outlined in List 1.

List 1. Topics Taught in the Preparatory Course, by Week

Week 1	Matter, Atomic Structure, Periodic Table, Ions, Chemical Reactions
Week 2	Numerical Analysis, Conversion Factors, Measurement, Significant Figures
Week 3	Moles, Reaction Yield, Stoichiometry
Week 4	States of Matter, Gases, Thermochemistry

In-class assessments were given at the end of each week so that students could practice taking chemistry tests under conditions similar to the actual testing conditions they would experience in their high school chemistry courses. Students were expected to study for the assessments as if they were actual tests, and the assessments were graded numerically; however, no letter grades were assigned.

Overview of the Class

The framework of the course aimed to emphasize understanding over memorization, to help students discover ways in which chemistry relates to real life, and to incorporate pedagogies that have been shown to be particularly effective for educating girls in science, such as emphasizing collaboration and relating the material to the students' personal experiences. Memorization was minimal, as students could refer to their notes for all worksheet and laboratory activities, and the assessments focused on testing conceptual understanding. During class discussions, students were directed to reflect on the relevance of the material in their lives. Typically, these discussions continued during the latter portion of the class, as students related the laboratories to their own life experiences.

Particular emphasis was placed on activities involving both the whole group (class discussions) and small groups (worksheet completion and laboratories), consistent with collaborative pedagogy (17). The small group collaborative efforts accounted for approximately 75% of the class time each day.

List 2. Typical Daily Course Elements and Their Duration

20 min.	Introduction: Brief description of a new topic
30 min.	Student Work: Students tested their understanding of the topic by completing worksheets individually and in small groups
10 min.	Break (also an opportunity to ask questions)
60 min.	Laboratory Experiments: Students performed a laboratory and wrote a laboratory report

List 3. Laboratory Experiments Undertaken, by Week

Week 1	1-1: Evidence for Chemical Change 1-2: Preparation and Formula Determination of Iron Compounds 1-3: Types of Chemical Reactions (Synthesis, Decomposition, Displacement)
Week 2	2-1: Systems of Measurement (Conversion Factors) 2-2: The Amount of Oxygen in Air
Week 3	3-1: Synthesis of Alum 3-2: Preparation and Reactions of Carbon Dioxide
Week 4	4-1: Endothermic and Exothermic Reactions 4-2: Heat of Fusion

In contrast to conventional instruction in which the teacher is the focal-point of the class, the students used each other as primary resources for assimilating knowledge and applying it to hypothetical situations (worksheets) and actual situations (labs). Actively engaging students throughout the class aimed to instill them with a sense of accomplishment and empowerment (18), goals that underlie feminist pedagogy (19, 20).

Teacher preparation time was approximately two hours each day. Preparation consisted of writing and photocopying skeleton notes, worksheets, and assessments; preparing chemicals; cleaning the laboratory; and grading laboratory reports and assessments.

A typical class proceeded as outlined in List 2 and discussed below.

Introduction to New Topics

The instructor spent 20 minutes at the beginning of class each day by engaging students in a discussion about their conceptions of a topic. For example, questions such as "What is chemistry?", "What is matter?", and "What is the difference between heat and temperature?" were posed to the class so that the students could share and reflect on their understanding of the material and on how the topics related to their lives. All students were expected to contribute actively in the discussion; if a student was not participating, the instructor would involve her by posing an open-ended question. As the instructor shaped the discussion, students were given "skeleton notes" in which many of the terms and concepts used in the discussion were already written out. These skeleton notes enabled students to focus on the discussion, rather than rushing to write notes on all of the material that was covered. Students were encouraged to make notations on the skeleton notes that they could refer to for the remainder of the course, which reduced the amount of memorization involved.

Student Work

After being introduced to a new topic, students were given 30 minutes to test their understanding of that topic by completing worksheets. These worksheets began with several definition-based questions to ensure students had an accurate understanding of the concepts. Students were typically able to complete the initial sections of the worksheets independently within several minutes. The remaining portion of the worksheets posed questions that required students to apply the concepts covered in the discussion to real-life situations. For example, after a discussion of the properties of gases, students were challenged with questions such as "Why does a hot air balloon rise?". Students worked together to answer these more involved questions, and although the instructor was available for guidance, the students were ultimately responsible for formulating responses. Students routinely expressed surprise, and then exuded a sense of self-confidence, when they were able to solve problems that they initially claimed they "couldn't get".

Break

We found that even the 10 minute breaks were pedagogically important. Many students used this time to ask the instructor further questions about the topic.

Laboratory Experiments

Approximately half of every class period was devoted to laboratory experiments (List 3). The rationale of placing such a heavy emphasis on the hands-on application of chemistry was for students to “do” what they had discussed earlier in the class with a new understanding of the intricacies of the topics, to practice formulating and testing hypotheses, to present their results and analysis in an organized fashion, and to learn to use laboratory equipment and technology. Students performed a laboratory on the day’s topic or continued a laboratory from the previous day and wrote and turned in a one-page laboratory report consisting of the experimental results and answers to post-laboratory questions. The instructor provided written feedback on the laboratory reports and returned them the next day.

Statistical Analysis

Enrollment in Preparation for High School Chemistry during the summer of 2003 consisted of thirteen female students. Of these, eight students took the same high school chemistry course during the 2003–2004 school year. All of these students were taught by the same instructor, who was a different instructor than the summer school instructor. The rankings of these eight students were compared to the rankings of a control group of 22 students who were enrolled in the same chemistry course during the 2003–2004 school year and who did not take the summer course.

For the 30 students in the study, we tabulated the numerical grades (on a scale of 0–100) that each student received in her first and second semesters of high school chemistry. The students’ final scores in high school chemistry were based on the following (with approximate percentages): homework (5%), quiz scores (15%), chapter test scores (40%), laboratories (30%), class notebook (5%), and a class PowerPoint presentation (5%). We then ranked the students in each semester with a 1 indicating the student with the highest numerical grade for the semester, and a 30 indicating the student with the lowest numerical grade.

Our objective was to determine whether the students who took the summer preparatory course ranked significantly higher than the students who had not taken the summer course. We did this separately for each of the two semesters following the summer course.

We also wanted to investigate whether any differences we might find could be attributed to self-selection. If the experimental group outperformed their peers, for example, it might be because the summer program attracted more higher-performing students. On the other hand, perhaps the summer program attracted lower-performing students who historically had difficulty in science classes, and felt a need to obtain further preparation. Of the 30 students in this study, 27 took the same ninth-grade integrated science course, including six of the eight students who took the summer preparatory course.

The statistical method we used to test our hypotheses was the Wilcoxon Rank Sum Test (21). This test uses ranked data to test for significant differences in the median. An advantage of testing for differences in the median grade rather than the mean grade (e.g., with the Student’s *t*-test) is that it

is not necessary to assume that the grade distribution is normal. Another advantage is that the test is less influenced by outliers (22).

Formally, we performed three statistical tests, and evaluated the results at the $p < 0.05$ significance level:

1. For the second semester of the ninth-grade science course, the null hypothesis was that the median grade of the students who subsequently took the summer preparatory course was equal to that of the students who did not. The alternative hypothesis was that the median grade of the students who subsequently took the summer preparatory course was not equal to that of the students who did not take the summer course (a two-tailed test).
2. For the first semester of high school chemistry the null hypothesis was that the median ranking of the students who had taken the preparatory course was equal to that of the students who had not. The alternative hypothesis was that the students who took the summer course had a higher median ranking (a one-tailed test).
3. For the second semester of high school chemistry the null hypothesis was that the median ranking of the students who had taken the preparatory course was equal to that of the students who had not. The alternative hypothesis was that the students who took the summer course had a higher median ranking (a one-tailed test).

Results

The second-semester grade distribution for the ninth-grade science course for the 27 students (6 from the experimental group and 21 from the control group) in this study who took that course is shown in Table 1. The grade distribution for the six students (of the 27) who went on to take the summer preparatory course is also given in Table 1.

Based on these grades we ranked all 27 students, with the same average rank assigned to all students who received the same grade (23). For example, rather than randomly assigning the ranks of 1–7 to the 7 students who received an A, each was assigned a class rank of 4, the average of 1–7. Similarly the three students who received an A⁻ were each

Table 1. Distribution of Second-Semester, Ninth-Grade Science Course Marks

Letter Grade ^a	All Students ^b	Experimental Group ^c
A	7	2
A ⁻	3	0
B	4	2
B ⁻	5	1
C ⁺	4	0
C	4	1

^aNo grades below C were given; ^b*N* = 27; ^c*N* = 6

Table 2. Comparison of Average Class Rank for Experimental Group Students versus All Students

Students Categorized by Course	Average Rank, Experimental Group Students	Average Rank, All Students
Second-Semester Ninth-Grade Science Course	12.60	14.00 ^a
First-Semester High School Chemistry	7.13	15.50 ^b
Second-Semester High School Chemistry	12.50	15.50 ^a

^aDifference in rank is not statistically significant using Wilcoxon Rank Sum Test, $p < 0.05$; ^bDifference in rank is statistically significant using Wilcoxon Rank Sum Test, $p < 0.05$

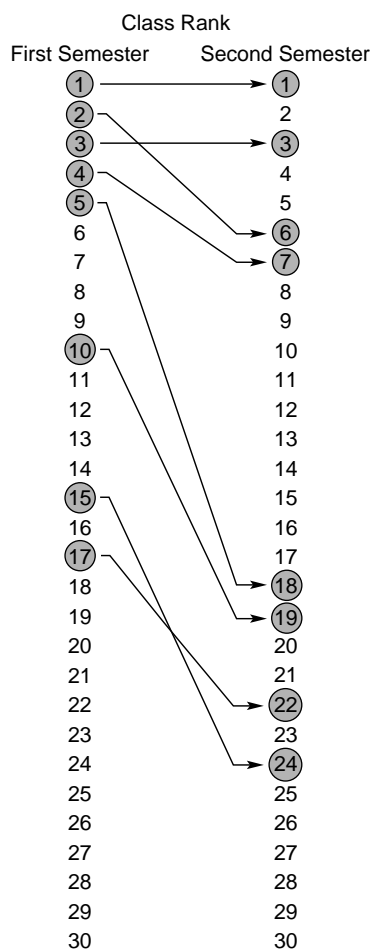


Figure 1. Average class ranks in first- and second-semester high school chemistry courses for students who took the summer preparatory course (experimental group students, $N = 8$), relative to all the students in the class. Arrows indicate the changes in ranking for each student between the first and second semesters of the chemistry course.

assigned a rank of 9, the average of 8 through 10, and so on. The average rank for the six students who went on to take the preparatory course was 12.6 compared to an average class rank of 14 for all 27 students. The difference was not statistically significant (Table 2). It is possible that we would have had a different result if we compared numerical grades rather than letter grades (e.g., if all the students who took the summer course happened to be at either the high end or the low end of their letter grade range), but only letter grades were available for us to use in conducting this test.

As seen in Table 2, for the first semester of chemistry the average class rank for the eight experimental group students who had taken the summer course was 7.13. The average class rank for the group who had not taken the summer course (control group) was 18.5. The eight students ranked significantly higher in the first semester than the students who had not taken the summer course, with $p < 0.05$. The top five students in the class had all taken the summer course, and all but one of the eight summer students ranked in the top half of the class (Figure 1).

For the second semester, two of the eight students who had taken the summer course maintained their class rank from the first semester, and six students dropped in class rank (Figure 1). The average class rank of the control group was 16.6, and the average class rank for the eight students who had taken the summer course was 12.5. Although this is better than the average class rank of 15.5, the difference was not statistically significant (Table 2).

Conclusions

The summer course clearly provided a benefit to the students in their first semester of high school chemistry. The results show that significantly higher rankings were achieved in the first semester of high school chemistry by students who took the summer course. While we had hypothesized that these students would perform better than the control group, the results were even more impressive than we had anticipated, as the top five students had all taken the summer course, and all but one of the summer school students finished in the top half of the class. This may be attributed to students' previous exposure to the material, better analytical and critical thinking skills, or increased self-confidence and motivation. However, we did observe a "fade-out effect" in the second semester of high school chemistry. Such an effect, in which an academic preparation program provides short-term gains yet less significant long term advantages for students, has been documented with regard to the Head Start Program (24, 25).

There are a number of factors that might account for the results of our study. One possibility is that the students who took the summer course gained confidence and thus had an advantage at the beginning until the other students caught up. In spite of our best effort to cover material that would be helpful throughout the school year, no course can cover all of high school chemistry in four weeks, two hours a day. There are certainly some second-semester topics that require knowledge of topics from the first semester. These topics might be less well-understood than first-semester topics at the end of the summer course. This, combined with the time

lapse between the summer class and the second semester, could be a contributing factor. The course content and type of pedagogy employed during the summer could also influence the results.

Recommendations for Future Research

It would be advantageous to repeat this study for a larger sample of students, over several years, so that the “fade-out effect” could be documented in more detail. In particular, a larger data set might reveal significant differences in second-semester student performance between the students who took the summer course and the control group (albeit a smaller difference than for the first semester of high school chemistry). One advantage of the small number of students in our study is that many control elements were included in the study, such as all students having the same teacher for their summer course and for their high school chemistry course, and 27 of the 30 students having the same teacher for their ninth grade course (and each of these three teachers was different). It would be difficult to maintain all of these control elements in a larger study.

This study raises the pedagogical question of how to best prepare students to succeed in high school chemistry. While students who took a summer course showed significant short-term benefits relative to students in the control group, these gains were not sustained over the course of the school year. The effect of different pedagogies on the short- and long-term efficacy of the summer program would be one important area to explore.

It would also be interesting to study the effect of providing students with continuous extra help throughout the school year instead of the intensive summer course. For example, the material in a 38-hour summer course could be spread out into one extra hour each week of the school year. With such a constant reinforcement of the material, the “fade-out effect” may be minimized or eliminated.

The results of our study have important implications for future research on approaches that will best prepare students for success in high school chemistry. They indicate that in order to carefully evaluate the effectiveness of programs, it is critical to monitor both short-term and long-term outcomes of student achievement.

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