Teaching Advanced Placement Descriptive Chemistry: Suggestions from a Testing Web Site

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Abstract: Since 1997, the World Wide Web (Web) has been used to enhance the performance of students on the Advanced Placement (AP) chemistry examination by providing a Web site dedicated to the descriptive portion of the exam. Previous studies have shown that not only do students and teachers use the site, but students learn from using the site and perceive it as effective for learning descriptive chemistry. Here we provide an analysis of use for a self-reported AP student population over the entire 1999-2000 academic term at the testing Web site. A subset of the AP student population who made extensive use of the testing components was identified. This paper includes both a general description of use and a comparison of two types of student users. The results from this study indicate that Advanced Placement chemistry teachers need to integrate descriptive chemistry across their curriculum and implement the use of repetitive testing such as that provided at the Web site. The authors advocate a mastery learning strategy to further improve student performance.

Introduction

For over forty years, The College Board has offered Advanced Placement (AP) Chemistry Examinations for high school students [1]. This service allows academically well-qualified high school students to remain in high school while still engaging in learning activities that are appropriately challenging and rigorous. In 1999, the College Board reported the grading of over 48,000 chemistry examinations [1].

The AP chemistry examination is broken down into five content areas: structure of matter, states of matter, reactions, descriptive chemistry, and laboratory. Anecdotal evidence suggests that the descriptive chemistry section of the AP chemistry examination is traditionally difficult for high school students. The College Board defines descriptive chemistry as follows [2].

> Knowledge of specific facts of chemistry essential for an understanding of principles and concepts. These descriptive facts, including the chemistry involved in environmental and societal issues, should come from the following areas:
>
> Chemical reactivity and products of chemical reactions
>
> Relationships in the periodic table: horizontal, vertical, and diagonal with examples from alkali metals, alkaline earth metals, halogens, and the first series of transition elements
>
> Introduction to organic chemistry: hydrocarbons and functional groups (structure, nomenclature, and chemical properties). Physical and chemical properties of simple organic compounds should also be included as exemplary material for the study of other areas such as bonding, equilibria involving weak acids, kinetics, colligative properties, and stoichiometric determinations of empirical and molecular formulas.

The examination's difficulty can be attributed to the nature of the material and the current structure of the AP curriculum. Descriptive chemistry is difficult to teach because it requires either a large amount of memorization or experience; it tends to be disjointed within the traditional curriculum.

Since 1997, the World Wide Web (Web) has been used to enhance the performance of students on the AP examination by providing a Web site dedicated to the descriptive portion of the examination [3]. This Web site provides repeatable testing with feedback in the form of quizzes produced and graded in less than one second [4]. The questions are stored in a database, and are served to the user in a format similar to that of the pencil and paper examination.

The current database contains hundreds of descriptive items, which represent those given on previous AP exams. Students are expected to write a net ionic chemical equation to represent a reaction statement (Figure 1). Students need not write balanced chemical equations, but just indicate formulas for the reacting and product species.

We have shown that teachers and students preparing for the Advanced Placement chemistry exam use this site [3]. In a follow-up study, we have further documented that students learn from using the site and perceive it as effective for learning descriptive chemistry [5]. However, two troubling findings have emerged from both studies. They include:

- The heaviest student use continues to be in the week and specifically the day before the examination.
- While student scores increase linearly with quiz number, students start out knowing little and the rate of learning is very shallow.

These findings suggest that, in addition to use of the Web site, further interventions are merited to maximize student performance.

The College Board directions [17].

> Write the formulas to show reactants and products for the chemical equation below. In all cases, a reaction occurs. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solution as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You need not balance the equations.
>
> dilute nitric acid is added to crystals of pure calcium oxide
>
> An acceptable response:
>
> $$H^+ + CaO \rightarrow Ca^{2+} + H_2O$$

Figure 1. An example descriptive chemistry question and accepted response similar to those used for the Advanced Placement chemistry examination.

Because users at our site represent the greater Web community, users are asked to categorize themselves on their initial login. These categories include different classes of student (high school chemistry student, AP high school chemistry student, college student), teachers (high school chemistry teacher-non AP, AP high school chemistry teacher, college chemistry teacher), and general users.

Provided here is an analysis of use for a self-reported AP student population over the entire 1999–2000 academic term at the testing Web site. A subset of the AP student population is identified. This subset, labeled the *AP special group*, made extensive use of the testing and feedback features available at the site. This paper provides both a general description of use and a comparison of the general AP student sample and the AP special student sample. The results from this study suggest some instructional modifications for Advanced Placement chemistry teachers. In addition, we provide a suggestion for a mastery learning strategy to further improve student performance.

Methods

This study is grounded in literature concerning the use of the Web for teaching and learning [6–9], and the use of repetitive testing measures [10, 11]. Although use of the Web for teaching and learning is becoming very common, little is known about its effectiveness; however, much is known about the effectiveness of repetitive testing with feedback [12].

The design of the AP descriptive chemistry Web site emphasized tracking of an individual's use and surveying user perceptions. This design yielded information about the effectiveness of the site as a learning tool. The site's design was consistent with the suggestions and considerations of many experts in providing online instruction for high school science students [13–15]. In addition, this site was designed with the understanding that incentives positively affect student learning and performance [16].

Population and Sample

The research sample represents high school students interested in descriptive chemistry, especially as it applies to the AP chemistry examination. The sample was recruited by word of mouth, conference presentations, listserve postings (CHEM-ED-L, AP-CHEM), and newsgroup postings (misc.education.science, k12.education.science).

The final sample included 404 self-reported AP students, broken down into two groups; 349 students in the general AP student group and 55 students in the AP special group. The 55 users included in the AP special group took a minimum of seven unique quizzes. This subset of the AP student population represents a group of students that made extensive use of the site for taking quizzes. This subset was chosen to further elucidate and identify characteristics of a population intent on using the Web site as a means for achieving success on the AP chemistry examination.

When the AP special group is compared to the AP student population, the phrase *AP students* indicates all of the self-reported AP students *except* those members of the *AP special group*.

Database Structure

Study participants were identified by the email address they provided as a login. Creating an account and using our system required informed consent. Each time users logged in, all of their transactions were recorded together with the email login. The access time, access address (computer IP number), specific identity of the items sent, responses made, and tutoring requested were all recorded.

Once logged in, students requested a quiz. This quiz consisted of eight items whose content was similar to that used by The College Board. The probability of a duplicate quiz was extremely low.

The user had the option of having tutoring sent with the items. This tutoring was in the form of Web pages written for each category of items. Having tutoring with the items allowed the user to learn more about the item before submitting it for grading.

The user also had the option of choosing to have an entire quiz constructed from one of nine predefined item topic categories. Students could request *electrolysis* and then have their entire eight-item quiz chosen from the *electrolysis* topic area. If they chose *typical AP Quiz*, however, they received a randomized quiz similar to what they would receive at an AP examination. This feature allowed users to hone their skills on specifics with their choice of similar environment, or prepare for the randomness of the actual AP examination.

Results

Four hundred and four users logged into the descriptive chemistry Web site during the 1999–2000 academic term and self-reported as AP students. This group was subdivided by the researchers into two groups; 349 students in the general AP student group and 55 students in the AP special group.

Table 1. A Comparison of AP Student and AP Special Group Demographics

	AP Students	AP Special
Sample size	349	55
Male	50%	57%
Female	45%	41%
Not reported	5%	2%
Age less than 18 years	84%	86%

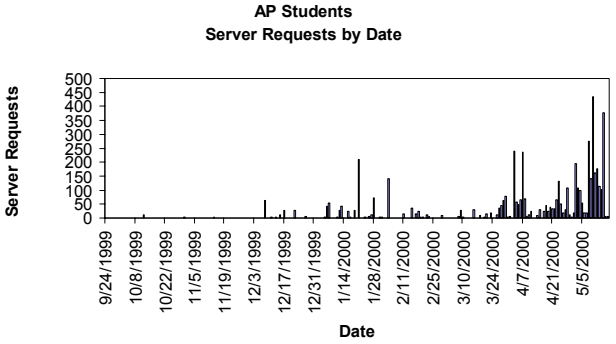

Figure 2. Server requests by date for self-reported AP students.

Demographics

Both populations were equally split among male and female users with a large percentage reporting their age as less than 18 years (>80%). The students from both groups were located throughout the United States with the largest concentration in the northeastern U.S.

More than one-third of both groups reported using the descriptive chemistry Web site during chemistry class. Time analysis supports this claim with the largest student use for both groups during times and dates normally attributed to the school day. The AP special group reported a slightly higher percentage having taken the AP chemistry examination on May 16, 2000, however, than did the general AP student population. A comparison of group demographics is summarized in Table 1.

Use Patterns

While some members of both groups started using the descriptive Web site early in the 1999–2000 academic term, most delayed their use until March 2000 (Figure 2). A large comparable percentage of both groups' use of the Web site took place during the week prior to the May 16, 2000, AP chemistry examination, with a sizable quantity the day before the exam. The AP special students account for the January AP student use, however. Student use statistics are summarized in Table 2.

While the demographics of the two groups and their time and date of use are similar, the amount of use is very different. The AP special group averaged 62.5 logons to the Web site, more than four times that of the general AP student population. Twenty-five percent of the total 13,805 server requests are attributed to the AP special group.

Of the 13,805 logons, the AP special group averaged 20.1 tutoring requests, three and one-half times that of the remaining AP student population. Acid–base chemistry was the most requested tutoring component for both groups by a sizable margin. Tutoring requests for the AP special group are summarized in Figure 3.

The AP special group requested an average of 3.25 times more quizzes than the general AP student population. As with the AP student population, the quizzes requested were mostly of the *typical* category, indicating the quizzes were similar in item composition to an actual AP chemistry examination (Figure 4).

While both groups started out earning quiz scores indicative of similar knowledge levels, the AP special group increased their scores at a higher rate. With the established rates for both groups, the AP student population should have reached proficiency after 52 quizzes, while the AP special group should have achieved proficiency after only 35 quizzes.

Survey Response

A ten-item survey designed specifically for the AP students was sent on Tuesday, May 16, the day of the 2000 AP chemistry examination (see Supporting Material). The survey instrument was an email response survey composed primarily of Likert-scale responses. Two follow-up surveys were issued.

The overall survey response rates for the two populations were different, 23 % (82/349) for the general AP population and 33 % (18/55) for the AP special population.

Eighty percent of the general AP student group who replied to the survey responded that using the site improved their performance on the AP chemistry examination; 100% of AP special student respondents replied in the affirmative.

AP students who responded to the post AP examination survey generally felt that the site was helpful. AP students selected as the AP special group who responded to the post AP examination survey also felt that the site was helpful, but had much stronger feelings. AP special student comments are universally positive and affirm the design intentions of the site. The survey response for this question is summarized in Figure 5.

When asked the importance of the quiz score provided at the site, the general AP student group had different feelings than the AP special group (Figure 6). While some AP students felt the scores were important, the AP special group had much stronger feelings about the importance of the quiz scores provided at the site for their studying.

Discussion

Data from the AP descriptive Web site suggests that certain AP students used the quizzing and feedback components of the site to improve their performance and knowledge of descriptive chemistry.

Self–reported AP students used the AP descriptive Web site with the explicit purpose of improving either their performance on quizzes or their knowledge of the concepts needed to answer the descriptive questions on the AP chemistry examination. This is supported both by their use of the tutoring components and the quizzing and feedback components at the site. The AP students were not casual observers of the site; their use implies intent to learn descriptive chemistry.

The AP special group is a subset of the AP student group who made extensive use of the quizzing and feedback components of the AP descriptive chemistry Web site. The AP

Table 2. A Comparison of AP Student and AP Special Group Use Patterns

	AP Students	AP Special
Average logons (logons/std.)	21.2	62.5
Average tutoring requests (requests/std.)	7.7	20.1
Average quizzes requested (requests/std.)	4.7	15.3
Quizzes needed for proficiency based upon rate of learning (quizzes)	52	35
Most requested tutoring category	Acid–Base	Acid–Base
Portion reported to have taken the AP chemistry exam	97%	100%
Portion of use the week prior to the AP chemistry exam	31.7%	34.1%
Proportion of use the day prior to the AP chemistry exam	10.2%	14.1%

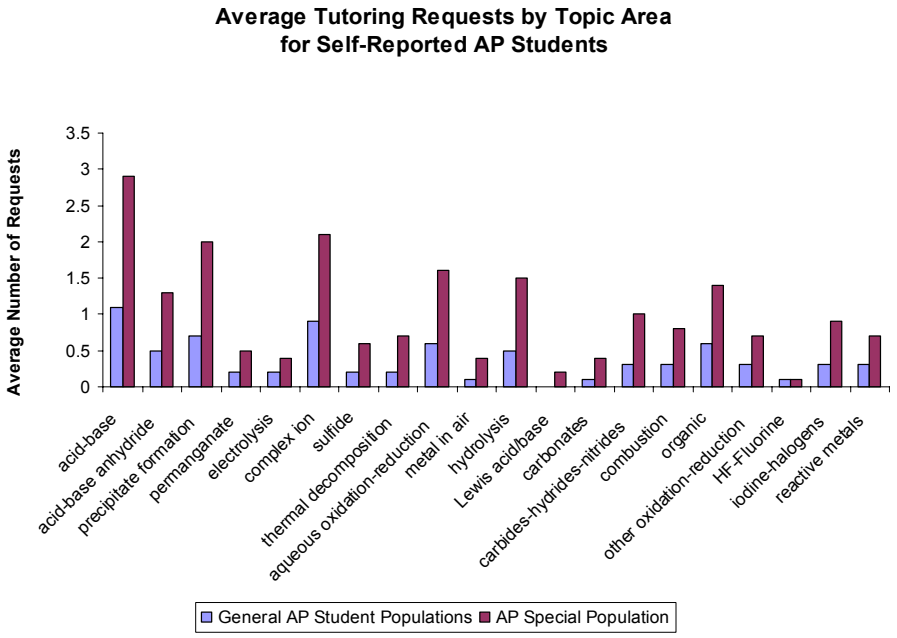

Figure 3. Server requests by quiz type for self-reported AP students.

special group had the highest use of both the tutoring components and the largest number of quizzes attempted. The AP special group was dedicated to using the AP descriptive Web site to learn descriptive chemistry and to improve their score on the AP chemistry examination.

The fact that both the general AP students and AP special groups used the site during the school day and reported use during chemistry class provides further evidence to support their learning intent. Yet, many students recorded their use in just a short time period before the AP chemistry examination was given. While the students have used the site at effective times in the day and under supportive circumstances, the fact that they access the site just before the AP chemistry examination limits their potential achievement.

While the AP students do show a linear improvement in quiz score with quiz number, they never acquire proficiency. The linear increase in the average raw quiz score with increasing quiz number suggests that the greater the number of quizzes attempted by students, the better the overall score. However, the students start out earning very low quiz scores, and few students achieve a perfect score.

These results suggest that AP students will benefit from taking as many quizzes as possible. The fact that the AP students in this study increase their scores at such a slow rate suggests that some other mitigating factor be required to enhance the effectiveness of the site. Early use of the site may influence both the maximum score earned and the rate of score improvement.

Results of the post-AP chemistry examination email survey support the effectiveness of the descriptive AP chemistry Web site as a tool to learn descriptive chemistry from the user's perspective. The degree of support for effectiveness of site is not uniform throughout the user classifications; however, consistent with the literature, the users who made extensive use of the testing and feedback components learned descriptive chemistry and generally felt the site was effective.

Recommendations

The results of this study indicate the potential for enhancing learning from instructional Web sites focused on teaching with repetitive testing and feedback. The results of studies related to

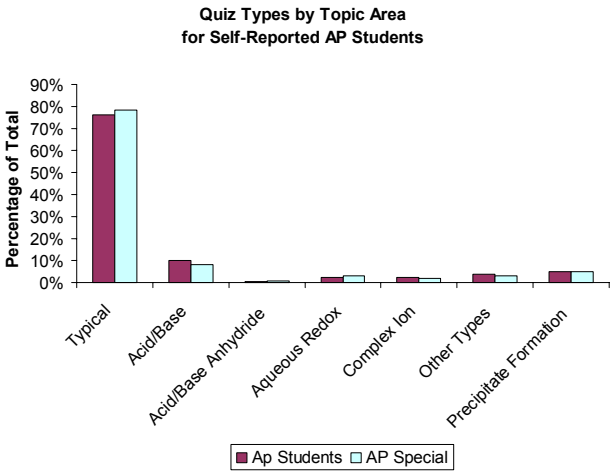

Figure 4. Quiz type requested for self-reported AP students compared to the AP special group.

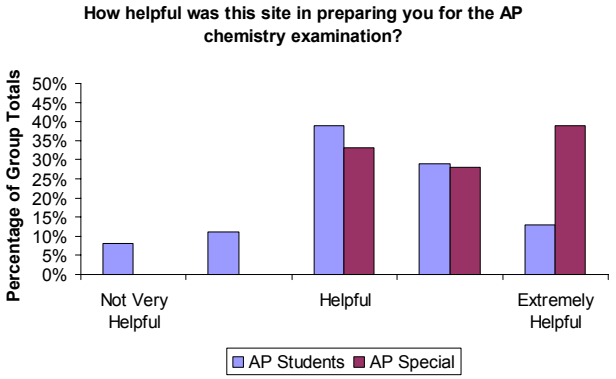

Figure 5. A comparison of survey responses from the AP student group compared to the AP special group when asked about the helpfulness of the site.

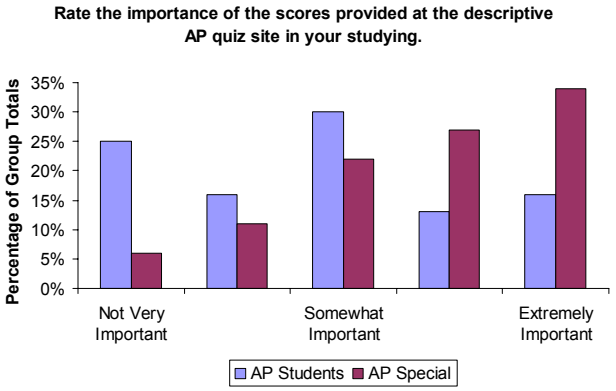

Figure 6. A comparison of survey responses from the AP student group compared to the AP special group when asked about the importance of quiz scores at the site.

this site give strong evidence for the potential of learning at testing sites. Successful teaching with repetitive testing, whether strictly via the Web or more traditional means, should emphasize random, repeatable tests with a large item database, and extensive feedback should be given with each item returned for grading. In this way, the Web teaching site focuses users on the content to be learned and supports user self-regulation.

In addition to the suggestions for designing Web teaching sites, this study merits several recommendations for AP chemistry teachers. Considering the distribution of tutoring requests, AP teachers need to better integrate the topic of descriptive chemistry into their teaching of acid–base and precipitate chemistry. The results from studies at our site strongly suggest that such sites should be integrated into school-based instruction. It should be noted that the site described here does not encourage student "surfing," but is focused on learning through quizzing with feedback.

Finally, users should be encouraged to practice with automated testing systems such as the Web site described here. This practice should occur long before the date of the examination and be sustained up to the examination date. While many would argue that repetitive testing is successful because students learn the test, research suggests that using such sites can promote the learning of content.

Recommendations from the results of this study have the potential to assist Web developers, teachers, and students. Web developers interested in teaching should provide repetitive testing components with feedback at their sites to maximize student learning. Chemistry teachers should scrutinize such sites and integrate them into their instruction where appropriate. Students should be encouraged to practice with testing systems focused on feedback to prepare for examinations such as the AP chemistry examination. Use of such sites should occur early and be sustained.

Supporting Material. A survey designed specifically for the AP students is available at http://dx.doi.org/10.1007/s00897000495b.

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