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Computers In Chemistry

Analysis of Student Use of a World Wide Web Site Created as a Supplement for General Chemistry Instruction

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In recent years, with the advent of the World Wide Web (WWW), tutorials and simulations in a hypermedia format have become widespread.

A World Wide Web (WWW) site was developed on the subject of acids and bases for use as a supplement to the General Chemistry course. The site was used in two consecutive years of the course. Its effectiveness was assessed with surveys and with comparisons of grades for users and nonusers. Results show that students in general do not use the site to target their self-reported problem areas; instead, they tend to progress through the site in a linear fashion. Those students who used the site to help them with their problem areas were able to achieve a modest grade improvement over their performance on other exams.

Introduction

Use of computers as supplements to chemistry instruction has become quite prevalent in the last 10 to 15 years in an effort to

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improve learning by students. Instruction aided by computers has been shown to enable students to learn material in less time than traditional methods [1], to increase achievement levels in certain subjects, [2, 3] and to uniquely demonstrate certain phenomena, such as rotations of three-dimensional objects [4, 5]. Studies on learning with intelligent technologies by Kozma [6] and Salomon, Perkins, and Globerson [7] conclude that a higher cognitive level of functioning can result from interactions with these technologies.

Perhaps the most pervasive type of computer-assisted instruction (CAI) is the tutorial, which teaches conceptual knowledge via drill practice, problem solving, or worked examples [8]. Interactive videodisc and CD-ROM versions of tutorials allow students to observe graphical displays of phenomena and to receive feedback on their answers or performance. In recent years, with the advent of the World Wide Web (WWW), tutorials and simulations in a hypermedia format have become widespread. This format allows for nonlinear exploration of a subject and inclusion of graphics, animations, video, and interactive materials. Because of the ease with which WWW documents can be created and accessed, there is an abundance of material available and still in development for use in the chemistry curriculum [eg., 9, 10].

Hypermedia has been repeatedly lauded for its characteristic of allowing users to make their own conceptual connections and of being more representative of human thought processes than other computer-based instructional tools [11, 12]. Studies of the effectiveness of WWW-based chemistry supplements, however, are relatively limited [10]. Two recent presentations at the 213th National Meeting of the American Chemical Society [13, 14] each reported on studies of student usage and found encouraging results indicating that students are likely to favor Web-based chemistry supplements. Neither of these studies, however, was able to examine the effect of these supplements on student performance in the class. In order to make the best use of the WWW as an instructional medium, it is important to assess its efficacy as a teaching tool and to become aware of its potential limitations and particular strengths. This work details the initial assessment results of a site on acids and bases that was developed for use in our General Chemistry course. The purpose of the study was to evaluate how students were making use of the site and whether their performance on exams was being affected. The results presented here are preliminary data based on a limited sampling of students and is intended to be continued in subsequent years with increasing numbers of students making use of the site. In their present form, these

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results will allow us to determine how best to develop other WWW resources for courses in our department, and how best to utilize the site discussed here.

Background: Design and Implementation of the Site

The Web site on acids and bases was designed to be a tutorial supplementing the classroom, laboratory, and textbook instruction in our General Chemistry course for science majors. The site can be found at http://kauai.cudenver.edu:3001/. The same topics that are discussed in class are covered on the site. Some additional topics are also included on the site, such as pages on the hydronium ion, the quadratic formula, and logarithm mathematics. A menu page is included at the beginning of the site; it is referred to as the *shortcuts* page. This page provides a linked list of all the pages on the site, allowing students to go directly to any page of their choice without having to work their way through all the topics. The list on the shortcuts page is written in the order in which the topics are covered in the lecture. The first page of the site (the home page) explains how to use the shortcuts page, and every page of the site provides a link back to the shortcuts page.

In addition to the home page and the shortcuts page, two other types of pages comprise the site. Content pages include textual descriptions of the concepts being discussed and examples of problems relating to those concepts. The examples show students how to solve problems and exercises related to the topic at hand, such as pH calculations, percent dissociation of an acid, buffer composition, and others. Practice problems are provided on pages that allow students to enter responses using the forms capability of HTML[1]. These responses are interpreted by CGI[2] scripts and an analysis is sent back to the student.

The acid/base Web site was used in two consecutive years of the General Chemistry course during the spring semesters of 1996 and 1997. Students were informed about the site verbally by their instructors in class, by flyers passed out in class, and through the General Chemistry electronic listserver [15]. Furthermore, the site was mentioned during appropriate portions of the lecture when the instructors felt it would offer students some additional assistance. In this way, the site was constantly integrated into

[1]HTML is "**H**yper**T**ext **M**arkup **L**anguage," the programming language for the World Wide Web.
[2]CGI is "**C**ommon **G**ateway **I**nterface" and is a programming language which allows the server to manipulate data that is input through an HTML site.

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the course curriculum, but it was still left to the students to use it on their own. In both years, students were given a survey about the site and about the acids/bases topic after that section of the course was completed.

Certain differences existed between the sites in the two different years of use. During spring of 1996, students were given the option of either turning in the standard handwritten homework problems or of turning in a printout of their responses to the Web-site problems. This allowed them to use the Web-site practice problems as a substitute for handwritten homework. The site included six practice problems taken from the regular homework assignment but altered to allow for short answer input into the Web forms. In this year, the CGI scripts for the practice problems did not provide students with explanations of how to correctly do the problems. Instead, students received a listing of their own answers and a score, which served as the printout for them to turn in. The intention was to encourage students to look at the Web site by providing them some tangible benefit for doing so.

The site was changed before its incorporation into the curriculum for the spring of 1997 to reflect the results of surveys collected from students the previous year. The content pages for buffers and titration-type acid-base reactions (strong acid with weak base and weak acid with strong base) were expanded to include more details and examples. Additional examples were also included on other content pages. The number of interactive problems was increased, overall, from 6 the first year to 15 the second year. The CGI scripts for the problems were enhanced to give students not only a score and listing of their responses, but also a correct solution and explanation to the problems that they answered incorrectly. In addition, a script was added to automatically send all student responses to a file in the instructor’s directory allowing for an assessment of student use of the site. Most importantly, the site was no longer allowed as a substitute for homework, but simply encouraged repeatedly as a tutorial and supplement. This last change was made in an effort to reduce any kind of intimidation the students felt about using the site; survey comments showed that in the first year some students did not look at the site because they felt uncomfortable doing their homework that way. As a result, they lost any kind of tutorial or supplementary experience the site could have provided them.

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Results

Statistics on Student Use and Nonuse of the Site

Over the two years examined, an average of 36% of the students (78 out of 216) enrolled in the course used the site. The site was used by 50 students in the first year, and 28 in the second. In a majority of the class sections these two years, the rate of student use ranged from 33% to 50%. However, one section in 1997 had only a 13% use rate. This section was taught by a first-year, part-time instructor with very little computer background which may have had a significant impact on the results for that section. In 1997, the student survey asked students how many hours they had spent on the site. For that year, the average user spent a total of 2.8 (±2.1) hours on the site and another 4.7 hours on written homework over the three-week period in which the topic of acids and bases was covered.

Students who did not use the site were given a list of possible reasons why they did not use it and were asked to rate those from “a very important reason” to “not a reason.” Results are shown in Table 1. The reason most frequently rated as very important (60% of students) was a lack of access to the Web. At our institution (CU-Denver) all students are commuter students and a majority are “nontraditional” students, meaning they are employed and often homeowners, have family responsibilities to spouses or children, and have an average age of 27 [16]. Since most of them have full or part-time jobs in addition to school, it is common that they will not be on campus except during the hours of their classes and often only two or three days per week. The computer facilities which have simple access to the Web and are open 16 hours per day will often not be used by these students. Of the students who did use the site, 71% accessed it from campus. It is possible that for the nonusers, not having Web access at home simply made it too inconvenient to get onto the system. One student commented, “If I had access @ [sic] home, I definitely would have used it. It’s hard to find time in between classes to get to the computer labs.”

Of all the respondents, 47% expressed that not having time to get onto the Web was also a very important reason. This is likely due to the “nontraditional” lifestyles of many of the students at our institution. A student explained on the survey, “Did not use Web site because I have no time: work 40 hours a week, school 14 credit hours, find time for daughter, work on internship at hospital.”

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TABLE 1. Reasons for Not Using the Site By Decreasing Overall Importance (Increasing Average Score[a]).

	Average	v. important	s. important	not important
couldn't get access	1.64	77 (59.6%)	21 (16.3%)	31 (24.0%)
didn't have time to use	1.73	60 (47.2%)	41 (32.3%)	26 (20.5%)
never used Web before	2.23	40 (31.0%)	19 (14.7%)	70 (54.3%)
don't know how to use the Web	2.24	36 (27.5%)	28 (21.4%)	67 (51.1%)
not comfortable using the Web	2.28	26 (20.5%)	40 (31.5%)	61 (48.0%)
didn't know about the site	2.71	14 (11.3%)	8 (6.5%)	102 (82.3%)
had technical difficulties	2.73	13 (10.6%)	7 (5.7%)	103 (83.7%)
had trouble using the Web	2.89	3 (2.5%)	7 (5.8%)	110 (91.7%)

[a]1 = "a very important reason", 2 = "a somewhat important reason", 3 = "not at all important"

There were a variety of reasons for not using the site rated by students as "very important" that had to do with technical and computer expertise. Approximately 30% of students said that having never used the Web before was a very important reason, 28% said that not knowing how to navigate on the Web was a very important reason, and about 20% said that not feeling comfortable with Web use was a very important reason. One student stated, "I'm not very comfortable working with computers; I'm much happier with one-on-one help." The numbers for our surveys may be higher than those that would be found at an institution with a more traditional student population because many of our students did not have the same access to computers in high school as students have available to them today. It would probably be helpful to some students, however, if a tutorial session on Web use and an orientation to the site were given to them in the computer room or with a projected computer screen before they were asked to use a Web site on their own for a class. One student suggested: "there should be an optional 1–2 hour explanatory session for those interested in using the tutorial but who lack the skills/know how or access to the Web."

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General Student Response to the Site

The 1996 and 1997 surveys gave students four statements about their perceived value of the site and asked students to rate them as "true," "somewhat true," or "false." During data analysis these were scored as 1 through 3, respectively. The comments were:

> It taught me concepts that I didn't see anywhere else.
> It clarified concepts that I was confused about.
> It made concepts from the book clearer.
> It made concepts from the lecture clearer.

The last three of these statements deal with the site providing clarification in general. These three statements received almost identical scores: their average was 1.7 (±0.7), which is between "true" and "somewhat true." The first statement essentially asks if the site was able to teach *new* concepts to the students. This statement was given an average rating of 2.2 (±0.7) which falls between "somewhat true" and "false." These results are not surprising because this particular Web site was created with the intention of being a fairly traditional course supplement. The Web medium was intended to allow ease and flexibility of use, but the content was not intended to instruct students independent of the classroom setting. General comments by students included:

> "It provides another reference means that is easily accessible at any time."
> "I enjoyed the Web site; hopefully there will be more on the next topics."
> "I learn well on the Web because I can review."

As a supplement to course work, the site appears to be at least partially successful according to students.

Both users and nonusers were asked if they would like to see more Web resources of any type available for the class. Overall, 63% responded that they would like to see more Web resources available. The types of resources students most often requested were additional practice problems, tutorials on other topics, and lab-related resources. A variety of comments were received from students stating that "anything and everything" or "material for all the topics covered" would be useful. Response patterns for this question for users versus nonusers of the site were very different, as shown in Table 2. Overall, nonusers tended to answer in the 50% to 57% range that they would like to see additional Web resources. Users, on the other hand, answered in the 70% to

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Table 2. Response to Whether Students Want Additional Web-based Resources To Be Available.

		1996	1997	Total
non-users:	no	26	24	50
	yes	26	32	58
	yes %	50%	57%	54%
users:	no	13	2	15
	yes	31	24	55
	yes %	70%	92%	79%

92% range in favor of additional Web resources. The marked difference shown in Table 2 between the two years is most likely caused by the change in the format of the Web assignment, because it was not a replacement for handwritten homework the second year, but just a supplement to the course. An examination of the data indicates that students may have felt intimidated by needing to use the Web for material that would count toward their course grade. By removing this option, students appeared more willing to look at the site for instructional purposes.

Students were specifically asked if they would like to see more Web-based homework assignments. This question was worded differently in the 1996 and 1997 surveys, the former asking if students wanted “other homework assignments” on the Web and the latter simply asking if students wanted “homework assignments” on the Web. The difference in wording was needed due to the difference in implementation of the site in each of the years. Strictly speaking, the results to these questions cannot be directly compared; nonetheless, a qualitative comparison is revealing. In the first year, 73% of users and 48% of nonusers said they would like other Web-based homework assignments. These numbers are very similar to the response rates shown in Table 2 for students wanting other types of Web-based resources. By contrast, only 20% of users and 10% of nonusers in the second year responded that they would like to see any Web-based homework. This is dramatically different from the second-year responses shown in Table 2 for other types of Web resources. These data combined with those in Table 2 may show that having the experience of using the Web for a graded homework

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assignment seems to remove some of the apprehension about this method of doing classwork; however, it also appears to limit the overall appeal of the Web in students' eyes. One student summed it up as: "I cannot fit a computer into my backpack." Judging both from student comments and from these numerical results, students at our institution are not fully comfortable yet with computer-based homework assignments.

Students' Thoughts about the Acids/Bases Section of the Curriculum

In order to interpret the ways in which students utilized the site, we asked students in both years to give us their general views on how well they understood various portions of the acids and bases section of the course. Two types of data were collected on all of the surveys. In one, students were given a list of 15 different topics related to acids and bases and they were asked to rate each one from 1, "understood perfectly well," to 3, "did not understand." Students were also asked to write which portions of the acids and bases section they found the hardest and which they found the easiest. Students could provide as many answers as they chose to, and all answers from students were counted individually. The results from these two questions are compared in Table 3. The table lists the top least understood and most understood topics along with the mean scores they received (for items rated on a list) or the number of times that topic was listed (for free-response items). For the free-response items, the table also shows the percentage of the total number of responses that corresponded to the three most frequently mentioned hardest and easiest topics.

It is clear from the table that both methods of collecting the information produce the same list of easiest topics: the concept of conjugate pairs, simple pH calculations from OH^- or H_3O^+ concentrations, and the differences between the Arrhenius, Brønsted-Lowry, and Lewis definitions of acids and bases. These are all either memorization or simple algorithmic topics. On the free-response list for easiest topics there were 254 individual responses which broke down into 19 individual topics.

For the hardest or least understood concepts, the topic of buffers was included as one of the top three on both types of lists. It made up almost half of all the students' short-answer responses. The effect of salts on pH was also included in both questions, but to different degrees. The second most frequently mentioned short-answer response was the titration-type reactions between strong acids and weak bases and between weak acids and strong bases. Calculating final pH for these types of reactions requires students to have a very good understanding of chemical equilibria and is, therefore, a

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Table 3. Difficulty of Topics

	Rating Items on a List		Free Response Items[b]
	mean rating[a]	# answering "perfectly well" (%)	%of responses[c]
Three best-understood concepts:			
conjugate pairs	1.41	139 (64%)	15
pH calculations	1.49	129 (59%)	39
Acid-base definitions	1.55	116 (53%)	13
Four least understood concepts:			
effect of metal cations on pH	2.61	9 (4%)	0
effect of salts on pH	2.47	18 (8%)	6
buffers	2.25	39 (18%)	47
titration-type a-b reactions	2.19	35 (16%)	18

[a] "understood perfectly well"=1, "understood somewhat well"=2, "did not understand"=3.
[b] no difference in the response trends between users and non-users of the Web site.
[c] best-understood had 254 individual responses under 19 different topics, least understood had 207 individual responses under 20 different topics.

rather complex topic. The rating method included the effect of metal cations on pH as the least understood topic. However, because this topic did not appear on the homework or tests, it was not likely to appear in their short answer responses. For the hardest topics, there were 207 individual responses for 20 individual topics. These responses from students regarding their views of the difficulty of topics helped us to analyze their patterns of Web site use, as discussed in the next section.

Patterns of Student Use and Assessment of the Site as a Learning Tool

Initially, the student survey data was combined with student performance on exams and homework assignments to look for any change in performance that could be correlated to use of the Web site. The average student visited 13.3 (±6.5) pages on the site, and looked at an average of 5.6 (±4.3) practice-problem pages. It was found that exam scores did not change significantly for users versus nonusers in either year in which the site was used. This was determined by using the exam on acids and bases as

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the test variable and other exams as the control variables for each student; differences in students' normalized scores between these were examined, but none were found. Furthermore, no statistical correlations were found between improvement in test scores and number of hours spent on the site, number of pages examined by the student, number of Web site problems done by the student, or the fraction of pages that were problems rather than content pages, (only 1997 data is available for the last three of these four categories.) These correlations were done by simply compiling all the student data and examining the numbers as a group.

In order to further clarify whether the site was of any use to students, an examination of hits to individual pages on the site and of which students were using them was carried out. This type of data is only available for the 1997 group of users. The histogram in Figure 1 shows the number of visits per page on the site. The horizontal axis represents the pages on the site in the order in which they appear on the shortcuts page of the site; this shortcuts page is organized in approximately the same order as the chronology of the topics covered in the classroom. The blue bars represent the content pages and the gray bars represent the practice-problem pages; practice problems comprise 52% of the pages on the site. Two things are evident from this figure. Students are visiting the pages on the site in mostly chronological order and may not have time to finish, resulting in the downward trend of the graph. Also, the most difficult topics (buffers and acid-base titration-type reactions), which are near the end of the site, received relatively few hits.

These results may suggest that students are not targeting the site to help them in the areas that they indicated caused them the most difficulty. Students are able to identify the areas that cause them trouble, but they are not able to use supplemental resources to help them in those areas. This may be exacerbated by the Internet-based format of this supplemental material. Students are clearly attempting to treat it like a textbook, where they begin at page one and try to read all the material and work all the problems in the site by a linear path. Students are not making the most use of the hypertext capabilities of the Web to navigate through the site to only those pages that they need to use. In essence, efficient use of the site is not seen in the analysis of these students' use patterns.

This premise is further supported by a comparison of individual students' answers to the questions in Table 3 and to their use of specific Web pages on the site. Figure 2

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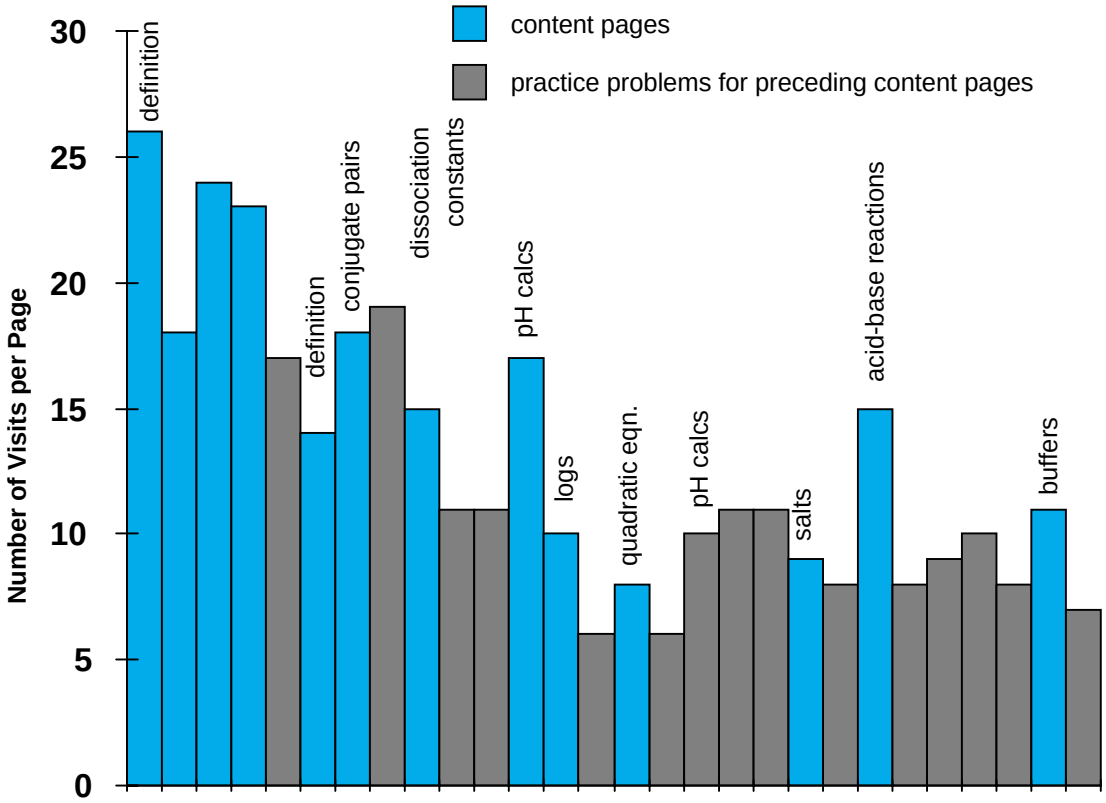

FIGURE 1. NUMBER OF VISITS TO EACH PAGE ON THE WEB SITE. BARS REPRESENT INDIVIDUAL PAGES ON THE SITE, AND THE VERTICAL AXIS REPRESENTS THE NUMBER OF VISITS TO THAT PAGE. THE PAGES ARE IN THE ORDER IN WHICH THEY APPEAR ON THE MENU OR SHORTCUTS PAGE. BLUE BARS ARE CONTENT PAGES AND GRAY BARS ARE PRACTICE PROBLEMS THAT CORRESPOND TO THE TOPIC OF THE PRECEDING, LABELED CONTENT PAGE (BLUE BAR). THE FIRST FOUR CONTENT PAGES (BLUE BARS) ALL DEAL WITH ACID/BASE DEFINITIONS.

shows the percentage of all the Web stops made by a student that are to pages with practice problems. This data is only available for 1997, and it represents the 27 out of 28 students who provided answers to the relevant sections of the survey. The vertical axis indicates the number of students at each percentage indicated on the horizontal axis. Overall, it would appear that students are making good use of the problems available on the site with practice problems making up 37% of the average student's Web stops. Figure 3a, on the other hand, shows the percentage of Web stops made by an individual student which are practice problems relevant to that student's stated most difficult topics. The trend is very different from that in Figure 2 and the mean is surprisingly low; only 8.2% of the Web stops are practice problems *relevant* to a

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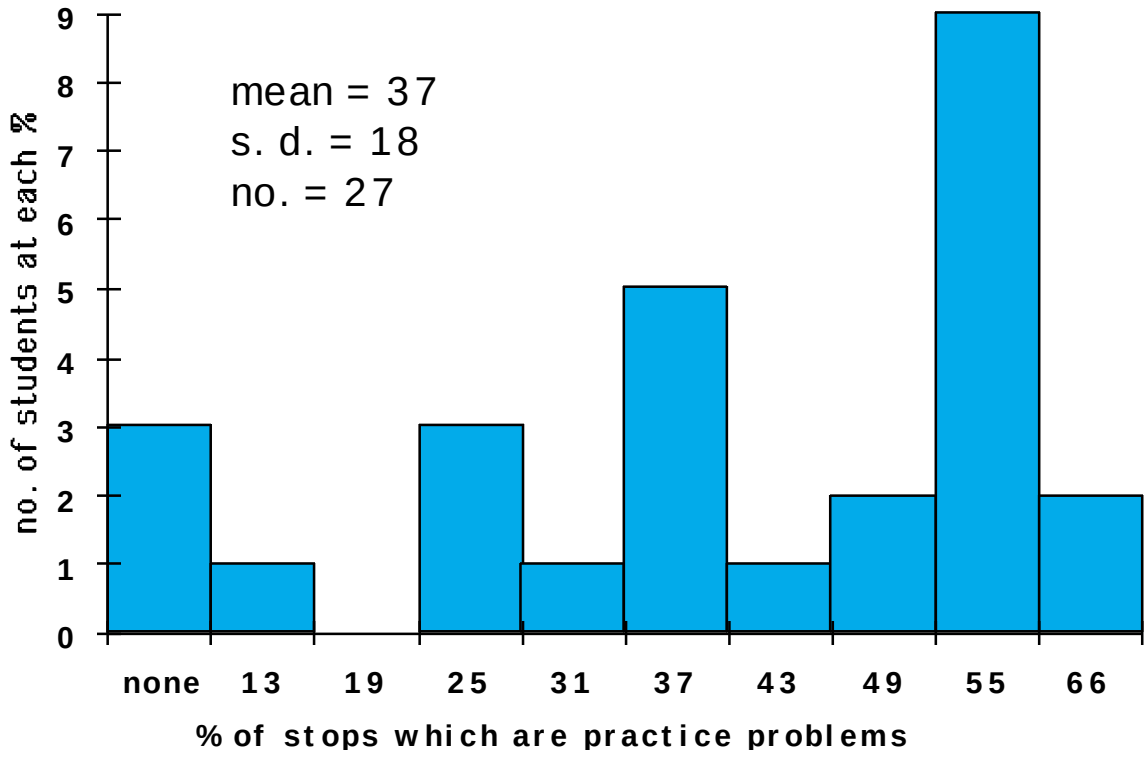

FIGURE 2. PERCENTAGE OF VISITS THAT ARE PRACTICE PROBLEMS. VERTICAL AXIS SHOWS NUMBER OF STUDENTS FOR EACH VALUE OF PERCENTAGE SHOWN ON THE HORIZONTAL AXIS.

student's trouble areas. Furthermore, Figure 3b shows the same type of data for overall Web stops (both practice problems and content pages). A similar trend is visible here as in Figure 3a with the average student visiting relevant pages only 13.9% of the time. Again, data in Figure 3 is only available for 1997 and represents the 26 out of 28 students who provided the needed information on the survey. For both Figures 3a and 3b, the majority of students for whom the data were examined visited *no relevant pages*. *Efficiency of use* could be defined as that use of the site most supplementing the areas that a student needs to work on. It appears that students were not able to target their use of the Web site to help them with their particular areas of difficulty, resulting in an overall low efficiency of use.

Correlations between the efficiency of use and student performance were examined. For students who had relevant-problem or relevant-page percentages greater than zero (Figure 3), the correlation was examined between this percentage and their test scores. Unfortunately, by selecting the sample with these criteria, the sample size becomes

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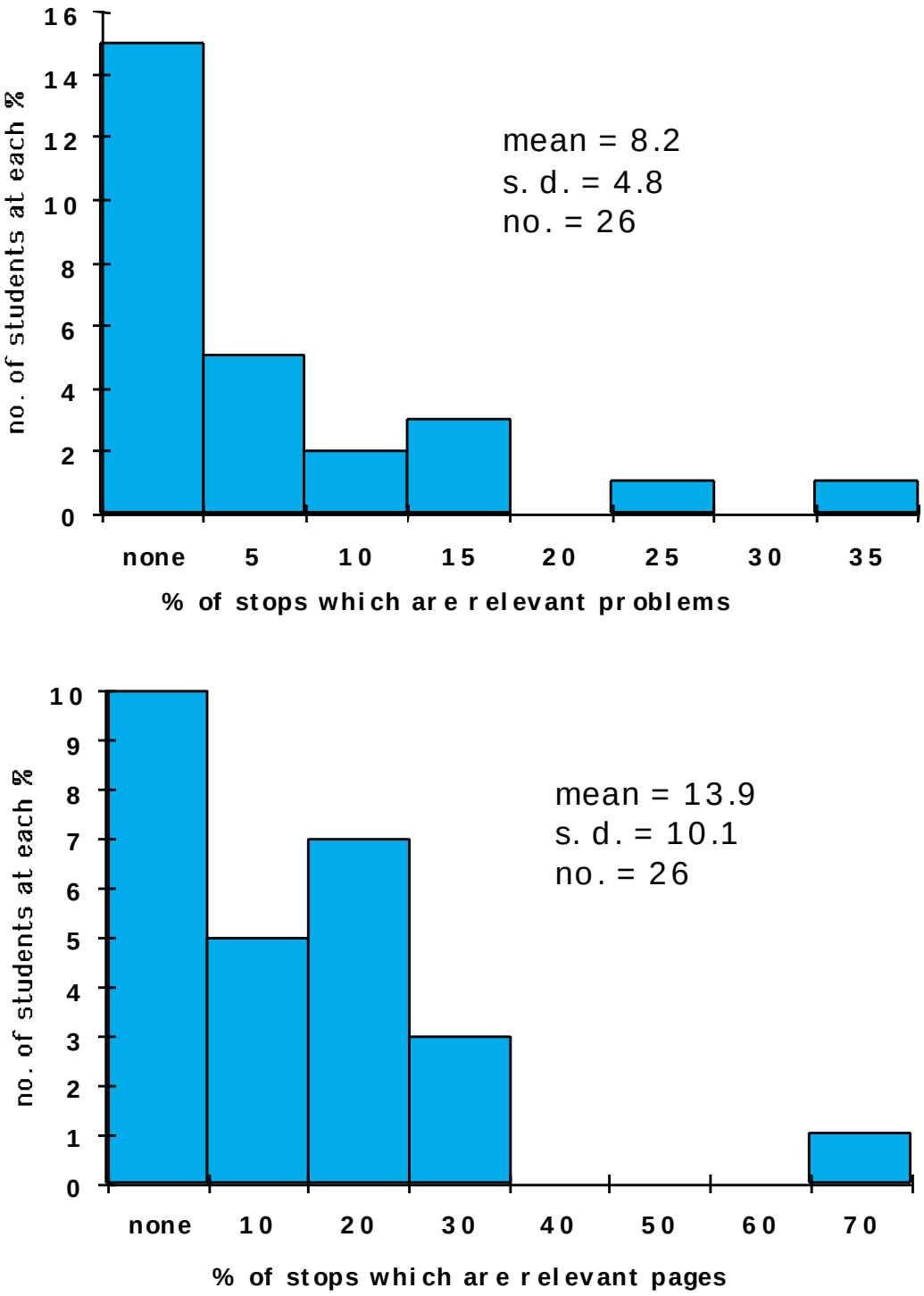

FIGURE 3. PERCENTAGE OF VISITS THAT ARE RELEVANT PRACTICE PROBLEMS (A, TOP) AND RELEVANT CONTENT PAGES (B, BOTTOM). RELEVANCE IS DETERMINED BY COMPARISON TO STUDENTS' SELF-STATED TROUBLE AREAS.

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very small (11 and 16 respectively). Students' scores on the exams were normalized to the class mean for each exam and these normalized scores were used in the correlations. The correlation between exam scores and the number of relevant Web stops of any type is 0.40 on the acid-base exam and 0.35 on the control exams. Even though these correlations are each statistically significant ($p < 0.05$), their difference is small and may not indicate that improvements are a result of Web-site use. However, the correlation between exam scores and the number of relevant Web-based problems is 0.45 for the acid-base exam and 0.32 for the control exams, again both statistically significant ($p < 0.05$). Here the difference is definite.

The indication, even with such a small sample size, is that efficient use of the Web, especially in the area of practice problems, may contribute to higher exam scores. In other words, students who are able to target the use of the Web site such that it supplements their knowledge in their trouble areas are able to improve their performance slightly over their normal (control) performance. Larger sample sizes from the continuation of this study will allow us to examine these critical correlations with a higher degree of reliability. Even these preliminary results, however, suggest that improved learning depends on efficient, directed use of a Web supplement rather than nondirected exploration.

Conclusions

Many instructors have begun to use material on the World Wide Web to either supplement their lecture material or to serve as a primary source of information. It is important to know if and how students are benefiting from such materials. The analysis of our Web site suggests that students may not know how to efficiently use a supplemental Web site to target their trouble areas. Although students can identify their trouble areas when asked and although they are able to access any page of the Web site in random order, they still feel compelled to try to start at the beginning and work their way linearly through until the end. Students, then, treat the Web site much like a textbook rather than taking advantage of its nonlinear, hypermedia structure. Furthermore, our data suggest that many students who try to work their way through the whole site linearly do not finish, and thus may never see the pages that target their trouble areas. Student inability to use a site correctly has been noticed by other researchers as well; Hunter et al. [17] point out that even on a site with the purpose of providing students with course materials, students often missed materials due to poor

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use strategies for the medium. Hunter concluded that students need to be oriented to Web sites and materials used as supplements to course instruction.

A closer inspection of our data, which examined individual students' usage patterns, shows that efficient use of the site may have a positive effect on their performance on exams related to the material. With this in mind, it seems that use of a Web site as part of the classroom curriculum should be guided to some degree rather than left completely up to the students. Providing increased direction to students to allow them to determine which pages they need to use, and doing so earlier during the course, may allow them to make more efficient use of their time and of the material on the site. Stull [18] pointed out that the rare student can learn on his or her own; but, it is what the teacher does in the classroom as a *guide* that allows students to make the most of the Internet as a supplement. The most appropriate methods to provide this direction to students would depend on the type of Web site being used by a particular instructor and in what capacity it is being used. In our case, an in-class demonstration to introduce students to the site as well as an assessment quiz to help them identify their trouble-areas earlier may suffice.

Students' individual responses to questions implied that they are not comfortable having required materials on the Web. This is more true for those students who did not have homework on the Web as an option than for those who did. It is likely, then, that this reservation is a result of inexperience with the World-Wide-Web medium and that more exposure would alleviate this issue. Students from schools with a more traditional student population may not experience this problem because their students are likely to have both more computer experience and access than the adult commuter students who form the majority of the population at this institution.

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