Asynchronous Learning Networks at Brown University:
Phase One Evaluation of the Chemistry 21 Project

Roger B. Blumberg
Institute for Elementary and Secondary Education
Brown University
Introduction

The Asynchronous Learning Networks (ALN) Project at Brown University uses a digital network in support of an established undergraduate curriculum, integrating networked communications and network-based course materials into a traditional course with the aim of improving both the efficiency of instruction and the quality of student learning experiences. Begun in the Fall of 1998 by Professor J. D. Doll, the Jesse H. and Louisa D. Sharpe Metcalf Professor of Chemistry at Brown University, and based on earlier work using the World Wide Web in support of undergraduate courses in chemistry, the first phase of the Project involved the implementation of an Asynchronous Learning Network (ALN), in the form of a World Wide Web site, in Brown’s largest introductory chemistry course (Chemistry 21). The goals of this phase of the Project were: to implement and integrate an ALN in Chemistry 21; to better understand the educational benefits and costs of using an ALN in undergraduate teaching at Brown; and to inform the second phase of the Project, in which certain course materials in Chemistry 21 will be available to students exclusively through the ALN. This report is an evaluation of the first phase of the Project, as well as a summary of our examination of how students made use of the materials at the site.

Background

The ALN Project builds on previous work by Professor Doll to develop ALNs for use in the teaching of undergraduate chemistry. Sponsored by the Alfred P. Sloan Foundation, Professor Doll initiated one of the first efforts to integrate Web-based materials into undergraduate chemistry in 1994, and in 1995-96 he and his colleagues created and used a prototype ALN in an “honors” course designed for undergraduates concentrating in chemistry.1 Having established the utility of ALNs in courses for students with relatively homogenous academic preparations, the current Project, sponsored by the Davis Educational Foundation, was designed to expand and generalize the ALN format for use with larger courses, in which academic homogeneity could not be assumed.

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1 For details of this earlier work, see J.D. Doll, “1997 Annual Report to the A.P. Sloan Foundation” (Brown University, 1997).
Why Chemistry 21?

Introductory Chemistry has long been one of the most challenging courses in the undergraduate curriculum, whether at Liberal Arts Colleges or Research Universities. The course is traditionally a prerequisite not only for students intending to major or concentrate in Chemistry, but for those majoring in any of the natural sciences, in certain fields of engineering, and for those pursuing a pre-medical education as well. Enrollments are traditionally large in introductory chemistry courses, the atmosphere is often competitive, and students’ intellectual interests and academic backgrounds are enormously heterogeneous even in light of the large enrollments. In the United States, high attrition rates are often characteristic of introductory chemistry courses, and there is predictably not only a substantial literature devoted to reforms in Introductory (or Freshman) Chemistry, but a comparatively long-standing interest in using the World Wide Web to support and improve elementary chemistry education.² Because of the possibilities ALNs and other computer technologies offer for more flexible, individualized models of instruction, Introductory Chemistry is clearly a course in which the use of ALNs and other technologies are thought to be capable of significant contributions.

At Brown University, introductory chemistry is offered in two different ways to undergraduates, who usually take the course in their first semester of study. Students with a strong interest in physical science and who come to Brown having taken two or more years of chemistry, calculus and physics in high school, and having scored exceptionally well on either the AP or Achievement Test in Chemistry, as well as on the mathematics portion of the SAT, take an accelerated introductory course, Chemistry 31. All other students who wish to take an introductory course enroll in Chemistry 21.³

According to Professor Doll, the greatest problem facing a faculty member charged with teaching Chemistry 21 is the great disparity in basic skills among the students who enroll, but an important additional problem is the significant portion of the curriculum that is viewed as “remedial” by many of the students as well as the faculty. Eliminating or even reducing the remedial portion of the course can leave academically under-prepared students feeling rushed or lost, while devoting class time to all the remedial material necessary for the most under-prepared students can leave many

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³ Enrollment in Chemistry 31 is typically and significantly larger than enrollment in Chemistry 21. In the fall of 1998, 109 students enrolled in Chemistry 31, while 405 students enrolled in Chemistry 21. In both courses, most of the enrollees were first-year students.
students feeling bored and impatient with the course. Based on his earlier work with ALNs, Professor Doll believed that integrating ALNs in Chemistry 21 offered a method for substantially reducing the disparity in students’ backgrounds while allowing students with very different secondary school experiences to flourish in the course.4

The ALN Project 1998-2000

The purpose of the ALN Project at Brown is to use the World Wide Web as a medium for an expansive ALN that will reform the largest introductory chemistry course offered at the University, improving both the quality and efficiency of chemistry education for all students enrolled in the course. Specifically, the ALN Project aims to:

1. Reduce the time spent in Chemistry 21 on remedial content, while at the same time providing all students with the learning materials they need for success in the course.

2. Allow students in Chemistry 21 to acquire a knowledge of the subject that is both broader and deeper than in past years.

3. Use the resources of the Department and the University more effectively and efficiently in Chemistry 21.

4. Develop a model for course offerings at the University in which faculty need not choose between simplifying material in order to reach a large audience, and offering advanced materials for those prepared for such materials.

In the first phase of the Project, in the Fall of 1998, a content-rich ALN is integrated into the learning experience of all students in Chemistry 21, and attention is paid to which materials are of greatest use to these students. In the second phase of the Project, in the Fall of 1999, Chemistry 21 will be offered with some of the remedial content available exclusively through the ALN, and a comparison between students’ reception of the ALN, academic performance, as well as student and faculty satisfaction, will be made between the fall semesters of 1999 and 1998.5 In the third phrase of the Project, the Chemistry Department will experiment with offering an ALN-based option in Chemistry 21, offering those students who demonstrate mastery of the Chemistry 21 ALN-based curriculum the option of entering the second semester of the introductory course, Chemistry 22, directly.

The First Phase of the ALN Project

In the Fall of 1998, an ALN for Chemistry 21 in the form of a World Wide Web site was created and rigorously maintained throughout the semester. Although web sites for introductory chemistry courses are common today, the Chemistry 21 site was distinguished in several respects:

1. The Chemistry 21 site included an exceptionally complete set of course materials, including lecture notes, problem sets, practice exams, laboratory notes, study tips and course announcements.

2. The Chemistry 21 site was used exclusively for dissemination purposes, with two-way communication facilitated by electronic mail rather than Web-based technology.

3. The Chemistry 21 site relied almost exclusively on Adobe’s Portable Document Format (PDF) to present course materials. More than Hypertext Markup Language (HTML), PDF allows authors to control the presentation of documents, which is especially important when formulae and equations are routinely used in such documents.

The Chemistry 21 site was updated regularly and in a timely way, with new lecture notes, problem sets, lab notes, etc. appearing well in advance of their being covered in class. In addition to the Web-based course materials, students also used a required textbook, *Chemistry: Structure and Dynamics*. Although Professor Doll did not change the course’s coverage because of the existence of the ALN, he did lecture from the notes available at the web site (these notes being projected on a large screen as he spoke), and referred regularly to the materials available there. Similarly, in every class session it was clear that many students followed the lectures using lecture notes they had printed from the Chemistry 21 site.

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5 Specifically, the in-class presentation of elementary stoichiometry and chemical equilibrium will be reduced from six weeks to one week, with the materials traditionally presented in class being available exclusively through the ALN.
6 The URL for the Chemistry 21 site is: http://casey.chem.brown.edu/.
7 See e.g. Chemistry 1403 at Columbia University (http://www.columbia.edu/itc/chemistry/chem-c1403/) and Chemistry 5.03 at the Massachusetts Institute of Technology (http://web.mit.edu/chemistry/www/5.03/). For a partial list of chemistry course web sites at colleges and universities in the U.S., see the WWW Virtual Library of Chemistry: http://www.chem.ucla.edu/VL/Academic.html#US.
8 Although we surveyed many web sites of introductory chemistry courses at both undergraduate colleges and research universities in the U.S., we did not find another example of such a complete set of course materials.
9 Although some web sites use Web-based bulletin boards and e-mail archives to facilitate two-way communication, we think the electronic “division of labor” in this Project, may account for some of the success of the ALN in Chemistry 21. That the use of the Web in this way does not discourage two-way communication is clear from the fact that Professor Doll reported receiving and responding to approximately 600 questions during the semester.
10 Because Brown University’s Computing and Information Services includes the Adobe Acrobat Reader in its standard Netscape (Web browse) package, students using computers on campus, whether in centralized clusters or in their dormitory rooms, could be expected to have easy access to PDF files as well as standard HTML files.
12 Chemistry 21 met, in the fall of 1998, in the Starr Auditorium in MacMillan Hall. The Auditorium is equipped
In October of 1998, approximately six weeks into the semester, a questionnaire was distributed to students in Chemistry 21 and collected by Professor Doll and his teaching staff at the end of one class session. The purpose of the questionnaire was to assess whether and how the students were making use of the ALN at Brown, as well as their academic experiences with the Web in high school (a copy of the questionnaire is included as Appendix A). Professor Doll and his staff reported that most if not all of those students in attendance on the date the questionnaire was distributed returned the questionnaire, and 223 questionnaires were collected and subsequently processed. A second set of questions concerning the ALN Project was included by Professor Doll as an additional page on the final exam for Chemistry 21 (a copy of these questions is included as Appendix B). Although students were given ten points for answering the questions as part of the exam, as an incentive for them to do so, the introduction to the questions made clear that they would receive these points no matter how they answered the questions. 370 exams were collected and the questions and answers from the final page were processed separately from the correcting of the exam.

Results of The Midterm Questionnaire

Asked about the frequency of their use of the Web in their studies at Brown, nearly half (47.1%) reported using it every day, while no one reported never using the Web. More than a quarter of those who responded (25.3%) said they used the Web about once each week and the same number (25.3%) said they used it several times each day. This is perhaps not surprising given that, on average, the students reported that half of their classes at Brown (50.3%) made use of web pages or web sites.

When asked about their use of the Web in secondary school, there was a much greater diversity of experience. Although few students reported never having heard of the Web in high school (1.7%), when asked about their use of the Web for academic purposes in high school nearly a quarter of the students (22.8%) said they had heard of the Web but never had reason to use it. Although most of the students said they had used the Web for academic purposes in high school at least once each month (69%), few said they used it daily (8.9%) and fewer said they used it several times each day.

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13 As requested by the author, Professor Doll kindly gave his students 10-15 minutes of class time to complete the questionnaire.
(3.1%). These responses, which seemed independent of the number of years of natural science courses the students had taken in high school, whether or not they had taken an Advanced Placement course in high school, and whether or not they identified themselves as being science concentrators or pre-medical students, might not be thought surprising given the comparatively poor access to the Web afforded students in high school. We think it important to note, however, that the great majority of students (88.3%) reported that they had no experience in high school with classes that made course materials available on the Web.

Given their minimal experience with the Web as an instructional resource in high school, it is significant that nearly all the students (99.1%) reported using the Chemistry 21 web site. Indeed more than half of the students who said they had used the site (59.8%) said they used the site a few times each week; many said they used the site every day (18.7%), and relatively few (2.3%) said they used the site only in preparation for exams. As the Chemistry 21 lectures were given only twice each week, the number of students who reported using the site each day is especially interesting, suggesting possibly interesting patterns of self-paced learning.

When asked to identify the materials at the Chemistry 21 site they found most useful, students expressed a variety of opinions. More than a quarter of the students identified the practice exams as especially useful, while more than half (51.5%) mentioned the problem sets. Most surprising perhaps was that the largest number, nearly three-quarters of the students (72.6%), identified the lecture notes as most useful. This is a significant result, since the inclusion of complete lecture notes is a feature almost unique to the Chemistry 21 ALN, and seems to indicate a genuine demand and use for such material as an aid for in-class study as well as self-paced study outside of the classroom.

As the different materials available at the Chemistry 21 site vary in length and thus file size, students were asked which materials they routinely print out and which they regularly read on their computer screen. There seemed to be no consensus in the students’ responses to this question, with significant numbers of students reporting their preferences for printing and not printing most of the different materials. Still, more than half of the students (56.5%) said they printed the lecture notes --by far the largest files at the Chemistry 21 site -- rather than read them on the screen.14

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14 Several students who said they printed the lecture notes expressed concern that the large, non-adjustable font size in the PDF files were the caused of wasted paper, and this complemented a very small but striking group of students who said they never printed Chemistry 21 materials because this wasted paper. We mention this only because a number of Brown students seem to have strong environmental concerns, at least when it comes to printing from the computer, and we expect any effort to address or accommodate these concerns will be welcomed by such students.
Results of the Final Exam Questions

The questions that Professor Doll included on the Chemistry 21 final exam focused on how the students in the course characterized the contribution that the ALN made to their study of introductory chemistry.

Asked which of the course materials at the Chemistry 21 web site the students used regularly, only six students (1.6%) said they used none regularly. The largest number (93.2%) said they used the problem sets regularly, while more than three-quarters (85.6%) said they used the practice exams and nearly that many (82.4%) identified the lecture notes as material they regularly used. The Periodic Table (27%) and the Lab Notes (13.2%) were used less regularly, according to the students.15

Asked how the materials made available through the ALN contributed to their understanding of the subject matter in Chemistry 21, an overwhelming majority (82.4%) said that they thought they understood the subject better because of the availability of the on-line materials. Similarly, almost the same number of students (78.6%) said they thought their performance on exams and problem sets improved because of the availability of these materials. Yet, when asked to compare the materials made available through the ALN with those in the printed textbook, the greatest number (59.1%) responded that they thought they got something valuable from both the on-line materials and the textbook, but didn’t think a comparison of the two made much sense. Similarly, perhaps, a significant number of students (29.5%) said they found the textbook more useful than the on-line materials, while far fewer (8.4%) said they found the on-line materials more useful than the textbook.

Server statistics, generated from the log files of the Web server hosting the Chemistry 21 site, confirm the aggressive patterns of use reported in the questionnaires. In the 100 days of the fall 1998 semester, the site received approximately 150,000 “hits”, and while hits generally do not provide direct evidence of how well or to what effect a site is used, the efficient design of the Chemistry 21 site combined with the use of PDF files gives this statistic a more focused and impressive meaning than would be possible with other sites.16

15 These patterns are consistent with an analysis of selected log files generated by the Chemistry 21 web site server during the fall semester. While the log files are useful for confirming patterns of use, we could not have deduced such patterns from those files.

16 A “hit” is registered by the server’s log file each time either a page or an image used in that page is called, and thus a single page that uses many images may be counted multiple times in the log file each time the single page is requested. In contrast, the home page for the Chemistry 21 site uses no images, and as the documents to which it
While it is difficult to give a definitive interpretation to all of the results of the questionnaires, the students’ responses seem to strongly support several conclusions:

1. The first phase of the Project successfully integrated an ALN, in the form of a World Wide Web site, into the introductory chemistry course, Chemistry 21.

2. Students’ use of the ALN was sustained and extensive, and many students used the materials provided through the ALN aggressively and to good effect.\(^{17}\)

3. Generally speaking, the students in Chemistry 21 found the full variety of materials made available through the ALN useful and valuable to their study of introductory chemistry.

4. Students gave little or no indication that they viewed the on-line materials as a plausible substitute for anything else, whether it be the instructor, the classroom or even the printed textbook.

**Benefits and Costs of an ALN**

Before concluding our evaluation, we wish to raise several issues concerning how to assess the benefits and costs of implementing an ALN such as that successfully implemented by Professor Doll. As one of the explicit goals of the ALN Project is to use faculty as well as physical resources at the University more effectively, it is important to be clear about the notions of benefit and cost as they apply to uses of technology in education.

Expanding on Collis [1996], we can identify several general benefits of a Web-based ALN for both undergraduate students and their faculty.\(^{18}\) First, a Web-based ALN provides flexibility in both the ways that course materials can be presented and the ways they can be used. Therefore, students may benefit from an ALN not only because it allows them access to materials at their convenience, but because alternative modes of presentation (e.g. text, hypertext, audio, video) may engage and prove successful for students with different levels of expertise and/or with different learning styles. Similarly, faculty can continually update the material offered on the ALN and can make use of the ALN as an efficient, reliable way to communicate materials to students. Second,

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\(^{17}\) Although we will not present our analysis of the log files generated by the Chemistry 21 web site in any detail here (because they are not particularly relevant to the first phase of the ALN Project), the regular patterns of use observed in those files, especially in preparation for exams, clearly supports this second hypothesis.

creating or using an ALN-based course provides an opportunity for rethinking subject matter in ways that can prove beneficial to the intellectual growth and development of both students and faculty. Third, the use of an any computer-based ALN provides an opportunity to develop certain technology skills and to better learn to integrate technology into ones teaching or studying practice. One can see each of these benefits as accruing from the use of an ALN in Chemistry 21.

The costs of an ALN, however, are just as various as its benefits. In addition to basic hardware and software costs incurred in the installation and maintenance of a computer-based ALN, one needs to consider the support services required for students and faculty to effectively use the ALN as well as the faculty time required to compose for and publish to the ALN. There is an additional cost if students and faculty must keep up with changes in technology that affect their ability to make use of an ALN, and of course there is a cost associated with any time spent in class learning to use the ALN rather than learning the subject matter under study.19

Because of the extraordinary computing resources currently available to undergraduates at Brown, and therefore to students in Chemistry 21, and because of Professor Doll’s enthusiasm for and facility with the Web, many of the costs mentioned here are hidden in the ALN Project at Brown, while many of the benefits are already evident. As one of the goals of the ALN Project is to develop a general model for ALN-based course offerings in higher education, however, we think an accurate cost-benefit analysis of an ALN should take into account the value of both the physical and human resources that are largely taken for granted in the successful implementation of the ALN in Chemistry 21.20 As the ALN Project moves into its second and third phases, and ALN-based materials are used as alternatives to materials covered in the classroom, we will include an analysis of costs in our evaluations.


20 At Brown, such an analysis would involve discussions with Computing and Information Services (CIS) as well as Professor Doll and his teaching staff.
Conclusion

The first phase of the ALN Project must be considered a success. An ALN in the form of a World Wide Web site was successfully implemented and integrated into an introductory chemistry course, the largest chemistry course at Brown University, Chemistry 21. There was every indication during the fall of 1998 that students made good use of the materials available at the web site, and that those students felt they were able to study the course material with greater efficacy and flexibility as a result of the ALN. Furthermore, students demonstrated a willingness to use a range of ALN-based course materials in ways that will be required of at least some students in the second phase of the Project. Whether or how ALN-based materials, or an ALN itself, could serve as a substantive alternative to (and not just an important enhancement of) traditional undergraduate classroom courses, is the question that will motivate the evaluation of the Project’s second phase. Specifically, we are anxious to see how Professor Doll and his teaching staff will handle the dual objectives of using the ALN to present remedial content more effectively to students in Chemistry 21, while simultaneously serving the presumably more advanced students who wish to use the ALN to exercise an option to enroll in Chemistry 22 directly.

Finally, based on earlier ALN work, Professor Doll reported in 1998 that the number of students requiring tutorials in the basic use of electronic mail and the World Wide Web -- the fundamental components of the Chemistry ALNs -- declined enormously between 1994 and 1996, and that the need for such tutorials might be thought to have essentially disappeared.\footnote{See J.D. Doll, “Self-Paced ALN Environments for Introductory Chemistry: 1998 Annual Report to the A.P. Sloan Foundation.” (Brown University, 1998), p. 3.} While our study of the ALN Project in Chemistry 21 does not question this conclusion, it does show that even if most students arrive at Brown with basic facility in the use of e-mail and the Web, there is little evidence that these students have significant experience using these tools effectively for academic purposes, and no evidence that they have significant experience using Web-based course materials, or an ALN integrating e-mail and the Web, in their studies. As the success of ALNs in undergraduate chemistry, and higher education generally, depends as much on their intelligent use as on their expert implementation, we think this lack of experience is something to which the Project as well as the University might wish to give attention.