Turkish Online Journal of Distance Education-TOJDE July 2003 ISSN 1302-6488 Volume:4 Number:3

Chemistry At A Distance: Instructional Strategies And The Internet Component Of The Courses- A Chronological Review of the Literature

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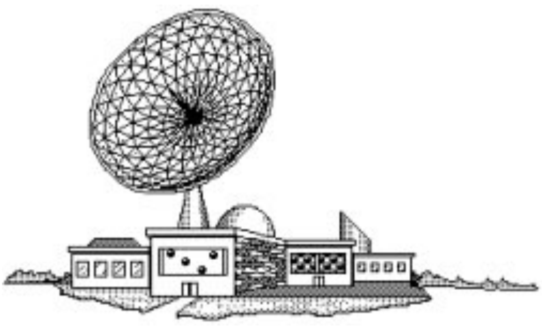
Introduction

Teaching chemistry at a distance has become one of the greatest concerns of educators aiming equity for all students, a goal in parallel with the basic tenets of distance education. Students in rural areas and many others lacking resources for learning chemistry are targeted in most projects of delivering chemistry courses out of site. Moreover, the reform movements especially in undergraduate chemistry education have been supported through the National Science Foundation (NSF) in the U.S. and administered by the Division of Undergraduate Education (DUE) to ensure the transformation and revitalization in college chemistry education (Nally, 1999).

Various instructional strategies are implemented in the courses in accordance with the characteristics of instructors, students, content, and delivery system. (Heiring & Smaldino, 1997, as cited in Simonson et al., 2003). To be effective, these strategies need to engage students as active participants, thus having an interactive nature (Simonson et al., 2003).

This article reviews the research on chemistry education at a distance, and aims to illuminate the instructional strategies employed. The focus is on the significance of these instructional strategies, how they are employed, and the Internet component of the courses.

Chemistry Course via Satellite Proposed for Rural Students (1988)



In 1988, a project of teaching chemistry to rural high school students via satellite was proposed. It was announced that a year later students in rural areas in the U.S. would be able to take an "advanced placement" chemistry course offered by Oklahoma State University (Worthy, 1988). Normally, advanced placement courses were offered to bright and hardworking high school students to earn college credits prior to their entry in college, but rural high school students were often excluded from that option. The project aimed to reduce the exclusion by utilizing the Arts and Sciences Teleconferencing Service (ASTS) of the Oklahoma State University. The proposed instructional medium was satellite television, and the instructional strategies included lecturing, discussion, and collaborative learning. The chemistry faculty members from Oklahoma State University were going to deliver the theoretical chemistry issues by satellite, and the students were going to be provided with an opportunity of two-way audio communication. Also, the instructors intended to have microcomputer links with the students to pool the data collected in the laboratory from chemistry experiments. Communication with the instructors was going to be made available through a toll-free telephone line or by electronic mail. Other course materials were proposed as being video demonstrations, graphics, and computer-generated animations. The laboratory component of the course was planned to be utilized on site, under the guidance of the chemistry teachers available

at the local high school.

Apparently, the Internet component of the course consisted of pooling student data in a bulletin board system, and the electronic mail. Additionally, an AP Chemistry by Satellite Lectureguide booklet was designed to assist students through their distance chemistry course. The booklet is available in electronic form and its World Wide Web address is http://intro.chem.okstate.edu/HTML/S1CHIX.HTM).

The Oklahoma State University's project, funded by the National Science Foundation (NSF), was a significant step toward the goals of the educational reform of undergraduate chemistry teaching and it provided numbers of rural high school students with equal opportunities as their urban friends. The proposed instructional strategies, discussion and collaborative learning, were promising in terms of fostering the active participation of the students in their learning, regardless of the disadvantaged conditions the rural students were in.

In spite of the promising nature of the project as laid above and its envisioned successful implementation at the time the proposal appeared, no documentation was found in the literature about the outcomes it might have revealed. It offers a number of ideas to educators willing to deliver chemistry courses from distance, such as integrating the two instructional media, television and the Internet, though.

Faculty Collaboration to Design Chemistry Courses at a Distance (1990s)

The project in Iowa targeted college chemistry faculty with a goal to enhance communication and interaction among the members and to exchange ideas about distance education and curriculum reform in Introductory Chemistry Courses. Funded by the U.S. Department of Education, the Iowa General Chemistry Network (IGCN) was created and university, private college, and community college chemistry faculty were involved. This project used the Iowa Communications Network (ICN), allowing "real time video communication, remote classroom teaching, statewide broadcasting of demonstrations and lectures, and simultaneous testing of new curricula and teaching methods in multiple locations" (Greenbowe & Burke, 1995). The project both involved the faculty themselves in the use of new technologies and encouraged them to develop various instructional strategies and resources for their students, collaboratively. Cooperative learning, discovery based laboratories, and conceptual problems were the instructional strategies proposed in the project during regularly held meetings. The utilization of the Internet in the courses was another issue that came up during the IGCN meetings. Although the Web site is no longer functioning fully, some of the materials developed for the IGCN project are still available at the following World Wide Web address: http://www.chem.kaist.ac.kr/SEE-KAIST_2001/FIPSE/homepage.html.

The chemistry faculty participating in the IGCN, agreed on the following instructional methods:

- **Agreements regarding the laboratory component of the course, which is usually the most difficult to utilize at a distance chemistry course:**
    - **The student would come to campus on a weekly basis to participate in laboratory experiences. The advantage of this approach seemed to be the availability of all chemicals and equipment, and a laboratory supervisor. The disadvantage was that the student might not be able to travel to campus each week.**
    - **The student would perform "do-at-home" laboratory exercises. The advantage**

of this approach was safety, readily available household products, etc. However, there were not general chemistry laboratory manuals for this purpose at that time.
  - Demonstrations of laboratory exercises would be performed over the ICN. These could be designed in a way that full student participation is ensured. Writing up a report would be one of the responsibilities of the student.
  - Students would be provided with computer simulations of the laboratory experiment and would send their reports via electronic mail to the instructor.
- Agreement on demonstrations:
  - All students at all sites would have the same demonstration kits and perform the same exercise with the instructor simultaneously.
  - If the previous option was not feasible, the instructor would travel to each site on a rotating basis and perform the demonstration.

Greenbowe and Burke (1995) reported the following: "Introductory college chemistry courses are being changed as a result of the collaborations between chemistry instructors, all made possible by the use of distance education technology". A significant point in this study is that the instructional strategies proposed by faculty were actually experienced by them at the time of development, which ensured quality implementation in their distance courses, later. This is documented by another article published by the same authors in 1999, also reviewed in a following section. In other words, both theory and practice had their place in the initial stages of the IGCN project.

A Chemistry Course over the Internet: The Issue of Planning (1994)

In 1994, a cross-listed course, "Chemistry 869/Curriculum and Instruction 869", was offered over the Internet at the University of Nebraska. The target audience was in-service high school chemistry teachers. "The course dealt with using small-scale chemistry in high school laboratory teaching" (Liu et al., 1998). A list server was created as a basis of communication between students and the instructor, and among the students themselves. CD-ROM materials were used to support instruction serving as textbooks and laboratory manuals. 23 modules were designed and the students had assignments related with each module. The students were expected to participate in the on-line discussions, as well. In some of the modules depending on the topic, they were expected to gather experimental data from their own classrooms, record them on spreadsheets, and bring them to the list server discussions. As Liu et al. (1998) report, due to technological limitations (technology being a novelty at that time) and schedule mismatches, the completion rate of the course was very low; about half of the students completed the course. However, authors made significant implications and projected onto possible future courses similar to "Chemistry 869/Curriculum and Instruction 869". The emphases were made on using CD-ROM as textbooks widely to minimize the challenges of connecting to the Internet, pretesting the students on their technology abilities, replacing the list server with another Web based discussion system, and establishing a scheduled real time videoconferencing system.

The instructional strategies used in the course were Internet-based discussion, self-directed learning, and project development, varying according to module content and requirements. These are instructional strategies that are likely to involve students as active participants; however, the study suggests that in order these strategies to function properly, a good planning and organization step is necessary before development and implementation.

More details of this study can be found in the doctoral dissertation by Liu (1996) entitled "Teaching Chemistry on the Internet" and available at the following World Wide Web address: http://www.cci.unl.edu/Diss/DLiu/liuDiss.html .

Analytical Chemistry in South Africa (1995)

Steyn et al. (1996), evaluated the effectiveness and feasibility of a courseware that was developed by the Chemistry Department and the Center of Software Engineering at the University of South Africa (UNISA), a distance teaching university. The courseware called CHEMISTRY: BASIC CONCEPTS was designed as a computer-aided learning (CAL) medium for the first year analytical chemistry students at UNISA. It focused on problem-solving strategies as well as on basic understandings of theory. A tutorial was given for each topic and after that students were expected to go through various problems and practice the acquired skills. The dominating instructional strategy was drill and practice. The students valued the highly individualized feedback, the opportunity for frequent repetition and reinforcement, and the easy navigation. Although students' attitudes toward the courseware were positive, there was no significant difference in terms of achievement between the control group and the experimental group, the latter exposed to the treatment. The constraints found during the evaluation of the courseware were, limited or no access to computers by all students, voluntary participation in the experiment, and relevantly, not having a representative sample. Steyn et al. (1996) concluded with implications for distance teaching in South Africa, mainly framed around need of higher number of computer facilities, improved computer literacy, policy and curriculum changes. Findings supported the claim that to be successful, students needed unlimited access to the courseware. This study suggests that to implement effective instructional strategies involving students as active learners the infrastructure needs to be improved first.

A Follow-up to the Iowa Project (1996)

The Iowa Chemistry Education Alliance (ICEA) was formed as a consortium of high school chemistry instructors and several members from the Departments of Chemistry and Curriculum and Instruction of Iowa State University (Burke & Greenbowe, 1999). The project consisted of two phases: Phase I and Phase II. In Phase I, four high school chemistry teachers collaborated with the faculty from the university and developed eight supplemental modular units for their students. These units were technology-based and had the potential to be incorporated in a distance-learning setting. The teachers' purpose was to help their students to build links between the chemistry topics and the real world by encouraging them to participate in certain learning activities in each module. The Iowa Communications Network (ICN) multimedia classrooms were designed in such a way that the students do not have any limitations while learning. Each classroom was equipped with "several television cameras and monitors, push-to-talk microphones, a computer, an overhead display device, a video cassette recorder, a laserdisc player, a telephone, and a FAX machine, with all devices connected to the state-wide fiber-optic network" (Burke & Greenbowe, 1999). In Phase II, the ICEA was expanded from four high school chemistry teachers to eight more across the state and the number of participating students became approximately 700, more than twice than the number of students participating in Phase II.

The instructional strategies implemented were lecturing, discussion, problem-solving, cooperative learning, and self-directed learning. Lecturing was used by the teachers and guest speakers through the ICN. Discussion was encouraged among students, both on site and the distant ones again through the ICN. Students formed groups and met over the video network, as well. Data and results were also shared via electronic mail. The teachers at different sites held discussions about certain experimental procedures and results. Students' use of the Internet for search purposes enhanced self-directed learning. Student groups at different sites discussed their experimental results. They were involved in problem-solving, too. For example, in one of the modules, the students were assigned to groups and given the task to analyze evidence found at a crime scene and determine the guilty.

In short, through the ICEA project, the students were actively involved in their learning

and their classrooms became more student-centered deviating from the traditional lecture-based teaching. They could relate the chemistry they were learning to the real world, and were exposed to variety of new technologies. Teachers learned a lot, too. They helped their students "to become more self-sufficient, mentoring them in their metacognitive evolution" (Burke & Greenbowe, 1999). The study is a representative example of balancing the technological infrastructure with the planning, development, and implementation elements of a chemistry course at a distance.

How to Develop an Internet-Based Chemistry Course (1998)

Mary Jane Patterson, a chemistry professor at Brazosport College in Texas discussed the issues related with an Internet-based chemistry course. She posed some important questions to ask prior to developing such a course. Dr. Patterson shared her own experiences in offering Introductory Chemistry online for six semesters (Patterson, 2000). A brief description of the course is available at the following World Wide Web address: http://www.brazosport.cc.tx.us/~chem/1405web/ .

Dr. Patterson used a multimedia presentation from Archipelago Productions that was a combination of a Web site and CD-ROMs. Each lesson began with a video clip of an overview. Following the overview were narrations, animations, step-by-step calculations, and video demonstrations representing the content. At the end, a summary was presented. The lesson then was supported by Web pages including real world examples of the chemistry just learned. At the end of the lesson, the students were expected to participate in electronic bulletin board discussions. Dr. Patterson also supported her students with specific Web sites that she developed on her own to meet the various needs. As the laboratory component of her course, she started utilizing a "take-home lab", the materials of which could be found in homes' kitchens, while previously she was requiring the students to attend on-site traditional laboratory sections.

Apparently, the dominating instructional strategies were lecture and discussion supported by multimedia including electronic bulletin boards. The Web sites developed by the instructor served as effective sources for help in homework assignments. Her use of the multimedia presentations as a basis for discussions instead of traditional textbook readings enhanced students' learning of chemistry. This approach had a significantly higher success rate for the class than the guided readings approach (Patterson, 2000).

Organic Chemistry Course for Rural Students (1999)

The purpose of Kurtz and Holden (2001)'s study was to compare the performance and attitudes of the students learning organic chemistry at a distance with those learning organic chemistry on site.

Two rural community colleges were electronically connected to a regional university. Real-time interactive video was used for lectures. At the site the instructor was lecturing on-site students were presented, and so were at the two off sites. Two instructors taught in weekly turns during the semester, employing a strategy called "team teaching". The communication was made possible through "live video and audio feeds". The course was also supported by a Web component, used to upload the syllabi, homework assignments and their answers, and the quizzes. Electronic mail communication with the instructors was another available option for the students.

Although no significant difference was found between on-site and off-site students' exam scores at the end of the course, off-site students slightly outscored on-site students. The attitudes of the off-site students toward distance education were overall positive (Kurtz & Holden, 2001).

Having an Internet component, the organic chemistry course included lecture with real-

time discussion opportunity, and team-teaching as instructional strategies. The study is another example of at least providing rural students with opportunities otherwise they would never have had.

Computer Simulations to Supplement Chemistry Laboratory (2000)

In Canada's Open University, Athabasca University, "computer simulations employing digitized video images were incorporated into the laboratory component of an existing first-year university chemistry course" delivered at a distance (Kennepohl, 2001). The simulation package included quizzes for each topic, a feature of keeping track of students' performance, and access to the simulations. The in-laboratory time of the students using the simulation package was slightly reduced. The simulations were implemented as pre-laboratory exposures.

A control group with regular in-laboratory experiences was compared to the experimental group using the computer simulations. No significant difference was found between the two groups in terms of student performance in their chemistry course. However, the students using simulations completed their in-laboratory work in shorter time and demonstrated slightly higher knowledge level of the practical aspects of the laboratory work (Kennepohl, 2001).

The instructional strategy used was drill and practice. Easy navigation within the program was an important feature supporting this particular strategy.

Conclusions

Chemistry as a subject requires visual representations and active involvement of the students in teaching and learning not only in distance education mode but also in face-to-face courses. Strategies like drill and practice or lecturing are often insufficient for a deep, meaningful, robust, or intentional learning, in contrast with surface, rote, and inert learning (Chin & Brown, 2000; Dunlap & Grabinger, 1996; Edelson, 2001; Novak, 2002; Southerland & Sinatra, 2003). The former is in congruence with the recent science education reform attempts to enhance the quality of learning in schools, as proposed by the National Science Education Standards (NRC, 2000). Moreover, as Nally (1999) points, industry needs chemists with broad skills such as critical thinking and problem solving who are able to work in teams within a diverse workplace. All these point to the importance of effective utilization of instructional strategies fostering these skills in chemistry courses. Technology is an effective means to this end; even in face-to-face courses, the use of technological innovations is believed to enhance teaching and learning by giving opportunities for visual representations, hyperlinking, communication, and such. Research shows that technology and education integration enhances teaching and learning activities in a way that supports student-centered instruction (Alexander, 1999; Cajas, 2001; Cope & Ward, 2002; Edelson, 2001; Jonassen et al., 2000; Lancashire, 2000). However, technology needs to be utilized in courses and blended with appropriate instructional strategies along with a good planning stage.

Strategies like discussion, self-directed learning, problem-solving, collaborative learning, and case study are more likely to increase the interactions among the students, both on-site and off-site, the instructor, and the content. Others like drill and practice, and lecturing are essential as well, but mostly depending on the specific content; however relying only on strategies like these would limit the unfolding of higher level abilities of the students. Especially in teaching and learning chemistry at a distance, with recent innovations, technology utilization becomes more and more critical in terms of employing instructional strategies which foster these higher level abilities. Besides, thinking chemically, careful planning is the "activator" of the distance chemistry curriculum development "chain reactions".

It is apparent in most of the studies that distance chemistry learners are not disadvantaged compared with their on-site counterparts. If they were, there would have been significant differences in students' chemistry achievement favoring the on-site ones. Even the most difficult part, the laboratory component of the courses is being integrated more and more effectively via means of technological innovations. Arguments being made against distance education based on its lack of face-to-face component compared with traditional teaching and learning are getting weaker with such research findings. "Distance" can be well presented among instructors and students in traditional classrooms if student-centered instructional strategies are not employed and the instructor is the "sage on the stage". So, it is instructional strategies that matter; they need careful planning and implementation into chemistry courses at a distance, and are fed with technology. Thus, investments in infrastructure enhancing quality distance chemistry education are needed; first, to ensure equity among students, supporting those especially in the rural parts of the world, who are the actual "disadvantaged", and second, to establish learning communities worldwide.

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