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Multimedia technology: A catalyst for change in chemical education

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Abstract

Multimedia chemistry lessons using video images stored on either videodiscs or CD-ROM allow students to safely investigate a wide variety of chemical systems. The technology also allows students to perform more experiments than possible in a laboratory setting alone and to interact with course content while conducting experiments. These capabilities challenge our beliefs about what kinds of activities are possible for introductory chemistry students.

INFORMATION TECHNOLOGY IS REDEFINING THE TEACHING OF CHEMISTRY

The need for a new teaching technique for chemistry

In an idealized model of chemistry instruction students learn through considerable hands-on experience with sophisticated techniques, exposure to a wide variety of chemical reactions, and close contact with a knowledgeable instructor. In today's chemistry classroom, direct experience with chemical reactions is often limited to materials that are inexpensive and judged safe for novices and to experiments that can be conducted within a short time period. In addition, large classes often limit direct contact with instructors.

Most chemistry instruction today takes place during lectures, while laboratory time is reserved primarily for illustration of concepts we assume students have already learned. A problem with the lecture mode of instruction is that, although it is a very efficient use of the instructor's time, it is not a very efficient way for students to learn. Some students are bored by the pace, while others have trouble keeping up with instructor. As a result, attentiveness drops. In a study conducted on a class of 20 adult students in a lecture course (ref. 1), observers noted that after 15 minutes the percent of students paying attention to the lecturer at any given time dropped to 60% and never rose above that again. In fact, the average attentiveness over the 90 minute class period was only 47%. However, attentiveness was increased by incorporating events that required student participation. For example, when keypads were used by students to answer frequent instructor questions, attentiveness rose to an average of 83%. Student retention of the material also improved when the keypads requiring student involvement were used.

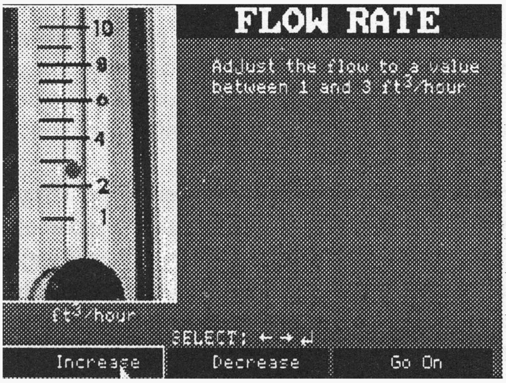
Further evidence for the importance of the active participation of students was found in a study of the use of a videotaped kinetics experiment in small classes (ref. 2). In this investigation sections of 24 or fewer students watched a videotaped kinetics experiment, took data from the screen, analyzed the data, and determined a rate law and mechanism with the continuous guidance of the instructor. Students who learned kinetics by this means achieved higher test scores than students who had learned kinetics by attending two lectures and performing a laboratory experiment. Students who attended lecture and laboratory did participate actively in the laboratory experiment; however, that performance was separated in time from the presentation of principles in the lecture and many students did not understand the connection. When the videotaped experiment was used in the classroom, principles could be taught during the same time period that measurements and analyses were made.

The laboratory experiences of students usually fall far short of our idealized model of laboratory instruction. A significant percent of the laboratory period is consumed by subsidiary activities such as writing, waiting in line, and reading the laboratory manual. In addition, the laboratory instructor has little time to devote to giving students direct instruction and feedback on their learning. For example, an instructor with 25 students performing a two hour experiment has at most 5 minutes of individual attention to offer each of them.

We need new teaching techniques that will allow students more control over the pacing of instruction, require them to participate more actively in the instruction, give them better feedback on their learning, and make more efficient use of their time.

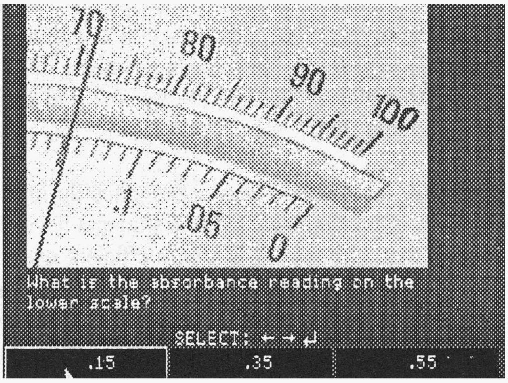
Multimedia technology as a solution

Advances in information technology have made it possible to place moving video images and sound under microcomputer control. This instructional technology is called interactive video or multimedia. Interactive video instructional programs can allow students to simulate the performance of experiments under different conditions and determine the effects by viewing realistic video images of the reactions. If appropriate video images can be made then reactions which are too hazardous, too expensive, too fast, or too slow to be used in normal laboratory periods can be studied with multimedia programs. Because the video images are recorded, applications in the real world outside the chemical laboratory can also be incorporated into interactive video lessons. For example, lessons written by the authors of this paper allow students to conduct investigations of air pollution in different settings without leaving the laboratory. Video of the collection of samples was recorded in three locations: commercial, urban residential, and rural environments. Students set up a gas collection apparatus by selecting choices such as flow rate and time of collection from the computer screen. They must then calibrate a spectrometer and analyze the sample for NO_2 in a multimedia simulation of the laboratory operations.



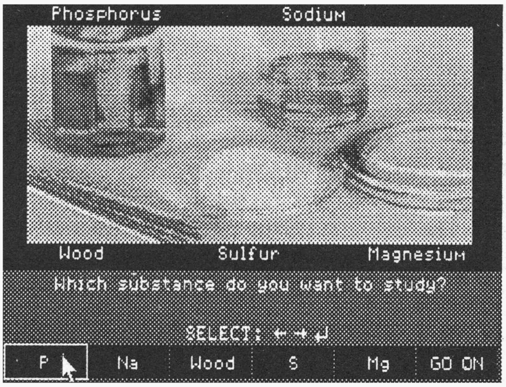
FLOW RATE

Adjust the flow to a value between 1 and 3 ft³/hour

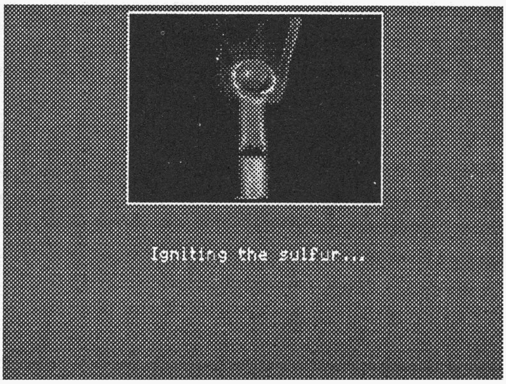


What is the absorbance reading on the lower scale?

Computer-aided multimedia programs represent a truly new teaching methodology for chemistry. Instructional designs may be used that monitor student progress, provide appropriate help and allow students considerable control over the pacing of the instruction. Such programs can expose students to many more chemical systems and have them make many more decisions about the way the experiments are done than is possible in a traditional teaching laboratory. An important feature of this technology is that it integrates all types of learning experiences, since principles can be presented and illustrated at the same time. In fact, students can discover the principles by conducting experiments. For example, instead of learning by rote that oxides of metals form basic solutions in water and oxides of nonmetals form acidic solutions in water, students can view the oxidation of their selections of metals and nonmetals, observe color changes of a universal acid-base indicator when the oxides are dissolved in water, and draw their own conclusions about the acidity of oxides from their data. Their conclusions are then checked against known evidence for verification.



Which substance do you want to study?



Igniting the sulfur...

THE EFFECT OF TECHNOLOGICAL DEVELOPMENTS ON COMPUTER-AIDED LEARNING

Developments in the hardware and software available to authors of instructional software can have a major impact on the type and extent of student learning.

The growth of computing technology

Early computers available for instruction had monochrome screens and only text characters could be written to the screen, which made use of chemical notation difficult. Current inexpensive microcomputers allow for full color implementation of chemical formulas and realistic images of chemical systems and equipment. Motion video can also be displayed on the same screen as the computer graphics, allowing chemical reactions to be followed. Pointing devices such as mice and touch screens add the advantage that students can interact directly with images on the screen. As a result of these innovations, limitations on educational effectiveness are now largely due to the instructional design of programs, not the hardware capability. Although it is very easy to interact with a display by pointing and clicking, instructional designs need to go beyond simply selecting objects to ensure student learning.

Advances in video technology

When videotape was first introduced, although only black and white, its potential for education was viewed by many to be staggering. For the first time, the world could be brought to every student. The move to color television enhanced the perceived promise. However, although students learned well from videotapes, they often learned no better than they did with an instructor alone (ref. 3). Hand-held video control devices were introduced to allow students to respond to multiple choice questions and to choose options from the videotape. The videotape would then respond by rewinding or fast-forwarding to the chosen section. There were two major limitations of this system: the long time it takes to rewind a videotape and the fact that the only interaction with students was through the multiple-choice options. Laser videodisc technology provided a two-dimensional surface for the recorded video, which allowed rapid random access (less than two seconds) to every image. The computer control of motion video images became a reality.

Multimedia technologies

Several means of merging video images and motion sequences with instructional computer programs are now available. The technologies can be classified as those that use analog video, such as that stored on videodiscs and VCRs, or as those that use digital video, which can be stored in a computer or on high capacity storage devices such as CD-ROM.

Incorporating analog images into a computer program requires a videotape or videodisc player and interface hardware, such as an adapter card, to mix video images with computer graphics. One example of this technology is the IBM M-Motion adapter, which makes it possible to have traditional computer graphics and any size full motion video on a standard VGA computer screen at the same time.

If the analog motion video is digitized, it can be compressed and stored as a digital file. Decompression of the video images, mixing them with computer graphics, and displaying the moving pictures on the computer screen may be done with software alone or by the use of special hardware and software such as the Intel and IBM DVI technology. Because of the large amount of processing power provided, the use of special hardware allows for larger and higher resolution images than software decompression.

The instructional programs described here were originally designed to use videodiscs to store the motion video. A digital version has now been developed that uses IBM PhotoMotion software decompression technology with images stored on a CD-ROM. This technology was chosen because it does not require special hardware for playback. The figures in this paper were all taken from this digital version. In these programs we use 1/4 screen full motion images and up to full screen still images. The screen mode is MCGA, which has 320 x 200 pixels with 256 colors. The digital version offers the possibility of networking to reduce cost, but with current software decompression gives lower resolution images than the analog version.

USING MULTIMEDIA TECHNOLOGY TO TEACH CHEMISTRY

In order for instructional materials to have a significant impact on student learning, they must constitute a substantial fraction of the course, be well integrated into the curriculum, be required in the same way that home work and laboratory work are, and be effective, high quality instructional materials.

The University of Illinois at Urbana-Champaign has set up a learning center for chemistry (ref. 4). In addition to study areas, tutors, and other resources, 63 networked multimedia student stations are available 84 hours per week. Since 1986, approximately 2,000 introductory chemistry students per semester have used these stations to complete half of their laboratory requirement. Students in general chemistry courses for science and engineering curricula work wet laboratory experiments and multimedia lessons on alternating weeks. The number of multimedia lessons completed and scores on quizzes based on the lessons become part of the students' course grade.

The multimedia lessons used are part of the "Exploring Chemistry" series produced by the authors of this paper (ref. 5). These lessons are highly interactive and involve students in devising and testing hypotheses. They also incorporate training in the intellectual laboratory skills. For example, students learn the function of titrations and the operation of each piece of apparatus. They then conduct a simulated titration, using actual video footage of the process.

IMPACT OF MULTIMEDIA CHEMISTRY LESSONS ON STUDENTS, FACULTY, AND INSTITUTIONS

Impact on students

Several studies of the effect of these multimedia chemistry lessons on student achievement and attitude have been conducted. In one study, the impact of these lessons on student comprehension of the concepts of chemical equilibrium was compared to the gain in comprehension resulting from a laboratory experiment (ref. 6). 103 students were divided into three groups of similar ability. One group performed multimedia lessons in chemical equilibrium that challenged them to predict the consequences of disturbing an equilibrium system, then required them to find reagents that would perturb another equilibrium system in a desired direction. Tutorial guidance was available throughout. A second group performed the multimedia lessons as a preparation for a laboratory experiment on the same topic, with the same types of challenges. However, in the laboratory it was not possible to provide tutorial guidance, because of the great amount of instructor time required. The third group also performed the laboratory experiment, but they prepared by writing an essay on equilibrium. Later, a test on the concepts of equilibrium was administered to all three groups. Students in the group that performed multimedia lessons alone achieved an average score of 83% on the test, while students who performed the laboratory experiment alone achieved an average score of only 59%. Students who had performed the multimedia lessons as a preparation for the laboratory experiment achieved an average score of 80%, not significantly different from the score of those students who had performed the multimedia lessons alone. These data suggest that interactive multimedia lessons can be used to teach the concepts of chemistry at least as effectively as they can be taught in a laboratory experiment.

The lab reports written by both groups of students who had performed the laboratory experiment were graded and compared. Students who had prepared by completing multimedia lessons on equilibrium achieved higher scores on the report and were more likely to use chemical principles correctly when interpreting their observations than students who had prepared by writing an essay. Students who had prepared by writing were more likely to copy information from the laboratory manual rather than attempt to interpret the data themselves, even though in many cases the copied information gave an incorrect interpretation.

Questionnaires were used to determine student attitudes toward the multimedia lessons (ref. 7). 313 students in an engineering curriculum responded to the questionnaire. 74% of the students reported that they felt the multimedia lessons to be a more efficient learning mechanism than the laboratory experiments. 73% found the lessons to be helpful and at about the right level of difficulty. 68% of the students gave the multimedia lessons superior ratings as a learning device compared to 44% who gave the experiments themselves superior ratings.

Impact on faculty members

Because the multimedia lessons replace half of the laboratory experiments, laboratory instructors have more time to spend with individual students outside scheduled class time. They also have fewer lab reports to grade. This has resulted in an unanticipated benefit, since students can now be required to write longer, more comprehensive reports that are then read and graded by the instructors. Instructors report that their work is easier since the introduction of the multimedia lessons because students are better prepared for both lecture and laboratory.

Impact on the institution

Since multimedia lessons and laboratory experiments are scheduled on alternating weeks, the need for instructional laboratory space is cut in half. This releases space for laboratory improvements, such as new instrument rooms. The cost of the instructional laboratory program has at the same time been reduced, since fewer chemicals are required.

CONCLUSION

These multimedia chemistry lessons have now been used successfully for six years to teach chemical concepts and to provide laboratory instruction and training in intellectual laboratory skills. The technology allows students to explore a wide variety of chemical systems and procedures, more than would be possible in a laboratory alone. New kinds of experiments can be designed that challenge our beliefs about what is possible in a course in introductory chemistry. For example, with multimedia lessons students can perform a large number of trials in a short period of time, then draw conclusions from the data. They can learn concepts at the same time that they investigate systems illustrating those concepts. They can also study systems outside the laboratory, as well as systems too dangerous or unpredictable to study in the laboratory.

The introduction of multimedia technology forces chemistry instructors to question why most chemistry is taught by lecturing, a method that was developed before the invention of writing. Computers and instrumentation have radically transformed the way chemistry is done. Information technologies such as multimedia can have an equally powerful impact on the way chemistry is taught.

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