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Why use animations and simulations?

Brian Pankuch, Union County College, New Jersey
pankuch@eclipse.net

What can you do with new multimedia tools, such as Microsoft PowerPoint and Macromedia Director, that you aren't doing in your lectures already? What enhancements to learning can you make with these new presentation methods? Animations and simulations come to mind. Animations and simulations have the potential of being more efficient and effective ways of getting students to form useful mental models, by combining several topics in a unifying package.

Perhaps by combining topics together that are usually covered separately into an animation, time is spent more effectively on the combined topics. They are more intimately related to each other. Relationships are easier to see. It is generally recognized that the more senses that are engaged and the more interactive the learning, the better the material is understood and retained.

Viewing the animations linked to this page requires the latest versions of Netscape or Internet Explorer and the Shockwave plugin.

Why use animations?

Some years ago, when I first began to think about using computers with students (freshmen science and engineering majors), I decided it is an ineffective way of presenting my notes. Was there some way to use the power of the computer to increase learning and interest in chemistry for my students? My first foray was to write interactive programs to expedite the transfer of my problem solving ability to my students. The programs were and still are quite effective.

Similarly when presented with the wave of new multimedia and presentation software such as PowerPoint, I questioned how much long term enhancement of student learning would occur by just putting my notes into PowerPoint. After considerable searching [PDF] I'm unable to find any solid research that using PowerPoint to deliver old lecture notes is more effective. Most results are anecdotal and show positive outcomes, with students being enthusiastic about new methods of learning. It appears that most of this effect can be ascribed to using multimedia methods students are not familiar with (similar to the Hawthorne effect). So just putting my notes into a multimedia format would probably not have any long lasting effects. What could I do with this new media that I wasn't doing already, or what could I enhance with new methods of exposition? Animations and simulations came to mind. Animations and simulations have the potential of being more efficient and effective ways of getting students to form useful mental models. My work is not double blind research, just some more anecdotal results.

What to animate?

I'm fascinated by the continuing breakthroughs we have been making in understanding the macroscopic world around us, by better understanding the world of atoms and subatomic particles. Bonding is a very important chemical process which is very fast (Zeweil femtoseconds), and it is hard to visualize the many things happening at once. A good area for simulation!

Having built simulations into some of my computer programs I was very aware of the coding effort that goes into programming a simulation. I'd need a specialized program for developing animations if I were going to do much of it. A bit of research indicated that the program Macromedia Director was highly rated by most reviewers and was capable of producing the result I was envisioning. Additionally it can produce results that work on PCs or Macs, and can be played on the Internet. Using Aftershock and Shockwave from Macromedia you can store a good-sized animation in 200-300KB at an Internet site (as an animation project in Director it would be 800-900KB, or 10-11MB as a QuickTime movie). Designed with simple material at the beginning of the animation, and using streaming techniques a user can download enough of it to begin playing in about 10 seconds with a 28.8 k modem.

Director has a steep learning curve, meaning I found it time consuming to learn, and if I don't use it for awhile it takes time to get comfortable again. Director also has significant changes in the user interface from one version to another. Once you learn it you can do a lot, it is much easier than trying to code every line.

One of the first animations I made was a metal atom reacting with a nonmetal. I was trying to form a bridge between what was in the textbook, the usual Lewis dot structures and combine information about atomic size, transfer of electrons, and new ion size. As you can see this first attempt [Shockwave required], generated a second where the size of the atoms and ions were made more obvious. This then developed into a quantum electron cloud presentation (all three are shown in the same animation). Presently I've included some speculation [Shockwave required], as to how changes in atom and ion size can appear to have a bonding electron spending some time closer to the barium ion than the barium atom.

Using animations

Obtaining user reactions proved interesting. A number of students observed changes but were uncertain of exactly when a change was occurring and how to explain it. My solution at the moment is to emphasize transitions by having atoms change color and use a sound when electrons are lost or gained, and atoms becoming smaller or larger. Each change is accompanied by a myriad of sensory stimuli. Text, often in the form of questions, is animated to attract the users' eye toward an area. These questions serve for ongoing discussions.

The primary objective was to have an animation to use in lecture to build a more effective model. In lecture students asked me to run the animation more slowly, and to stop it while they ask about what was happening at a certain point. I also wanted to be able to interact with the animation more so I put in buttons to *stop* (to facilitate asking and answering questions), *back* (to cause the movie to back up 10 frames - instant replay), *faster* and *slower* (to adjust to the immediate circumstances of use). Director comes with a powerful scripting language Lingo, which I used to write scripts to control the behaviors you see. The current Lingo dictionary has almost 500 pages, so it is quite comprehensive. I've barely started to use this powerful language. The interactive buttons work on the Internet but not in QuickTime movies -QuickTime has its own set of controls such as resizing. Both Director and QuickTime are constantly adding to and improving their versatility.

My lectures are currently being given in renovated multimedia rooms. I use a 300 MHz Mac PowerBook and a 1200 lumen, ceiling mounted Sharp projector to project on a large screen. I have a remote and laser pointer so I can move freely around the room. Several methods have been tried usually starting with putting the animation up and letting it loop through several cycles. The animation is stopped at points where a lot is happening and we have a short discussion, sometimes with student study groups. Students are asked to take a few minutes and anonymously write out a description of the main points of the animation. I collect them and randomly read a few out loud and have the class critique them. The students are learning how to translate what they see into an accurate description of the bonding animation.

How effective is it?

To check how effective this was, for the next test I didn't tell the students specifically that the animations would be covered on the test. During the test I setup the animation and asked them, for extra credit, to write out a description of the main points of the animation. The results as you might expect were quite good. Errors were generally incompleteness, not mistakes in interpretation. The next semester a similar procedure was followed, except I didn't setup the animation during the test. Surprisingly the students did as well. Leaving out the step of discussing the student descriptions of the main points of the animation, resulted in somewhat less complete answers. The overall results were still quite good.

It is difficult to say if we're spending more time on the topics since I've combined a number of topics I usually do separately. It is probably some more time and definitely a more comprehensive way of presenting the material. It shouldn't be surprising that more effort (more time on task) results in more learning. Perhaps by combining topics that are usually covered separately together in an animation, results in more effective time spent on the combined topics. The topics are more intimately related with each other. Relationships are easier to see. Gaining and losing electrons, becomes more one process of transferring electrons. Also It is generally recognized that the more senses engaged and the more interactive the learning the more is understood and retained.

Evaluating the effectiveness of programs I previously wrote and used seemed easy to do since my purpose was to enable students to more effectively setup and solve problems involving math. Some of the questions I give on tests are the multiple choice type, but I require a complete setup and grade the problem 100% right or wrong. So when the students who used the programs did much better on this type of questions than students who did not use the programs, a positive correlation was likely, and I felt my time was well spent.

Before using the animations, answers to test questions on ionic bonding usually involved a discussion of the transfer of electrons and subsequent attraction by ions for each other. Now I expect this and information and additionally how and why electrons are gained or lost and the effect on atom and ion size. Student answers are now more complete and show better understanding. No one leaves the question blank, and they at least know what an ionic bond is. This is a rather subjective evaluation, much less quantitative than with my programs.

It looks as if increased learning is taking place. Whether this is due to increased efficiency of learning is somewhat in question. In other words increasing the amount of time spent on any topic will likely result in increased learning. Some of the increased learning is undoubtedly due to increased time spent on the combined material, but some is also likely due to the fact that the animations are new and interactive. I have no way of estimating how important each effect is. Is this an efficient way of teaching and learning? Students find the animations interesting and effective, but they take time and effort to make and time to use in lecture. In this bonding animation there is a lot of repetition each play shows the viewer the same ideas three slightly different ways, and I replay it for awhile.

Another animation [Shockwave required] involves changes in atomic and ionic size across a chemical period. This one is conceptually a bit more difficult. At this point I've shown students several times how to "read" an animation, so I've left out sound effects. I usually show it and discuss the questions raised in the animation. We don't write out what is happening on paper and discuss the papers. Students get the general trend, but frequently miss more of the details. To try a somewhat different technique to check student understanding, I'm going to put up multiple choice answers for the questions in the animation. The questions and the animation will be projected on the same screen. The students hold up cards with A, B, C, D to quickly show what their thoughts are on each question. The immediate feedback is helpful.

Technical details:

You can make an animation or film loop within another animation. Drawing seven different electron clouds for

atoms creates the quantum atoms, each has a different electron cloud distribution. These are then used to form a film loop that cycles through the seven frames causing the electron cloud to pulsate. The film loop can be treated like any other sprite (a sprite is an object that controls when, where, and how atoms appear in the movie). As you can see the electron cloud atoms can be stationary or moving. Quite complicated paths can be made, also speeds can vary and colors change.

Sounds can be created or imported, massaged, compressed. The sounds in the bonding animation were created in SoundEdit part of some Director packages. Even compressed they take up quite a bit of storage. I tend to make the animations and movies part of my PowerPoint lectures. Interestingly you can also import PowerPoint lectures into Director and use its power to enhance and make the PowerPoint lectures web ready with many transitions intact.

Additional observations:

I had two students repeat the course and they both seemed to retain much more of the information from the animations than in other areas. A hopeful sign.

The students are made aware of material at my Internet site, but at this time they are not required to use it so most don't.

I've had the delightful experience of using my animations in presentations to my colleagues and having engineers and scientists who are not chemists act as if a light has gone on, and now they see facts they know in new relationships they were not familiar with before.

We should be able to unify more separate facts into more complete pictures of what is happening. More interactivity between the animations and students, especially having everyone in the class respond to questions as the animation is paused, may increase learning. In lecture they provide me with immediate feedback as to how much is being understood. On the Internet embedded self-check multiple-choice questions could provide valuable feedback to a student. Perhaps seeing atoms as electron clouds instead of perfect solid, shadowed, spheres will make conceptualization more natural and accurate.

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