Animated Biology:
Development of Computer Generated
Animations for Biological Teaching

Abstract:
Computers are becoming increasingly common as educational tools in Biology. One teaching method that has benefited greatly is the traditional classroom lecture. Seamless integration of digital video, sound, interactivity, and in particular, animations has revolutionized the once dreary lecture. Unfortunately, widespread use of animations has been hampered by their lack of commercial availability, difficulty in creating animations from scratch, and lack of awareness by faculty of modern animation tools and methods. The goal of the proposed project is to improve teaching in the Department of Biology by developing and incorporating animations into Biology courses and, more generally, increasing the level of awareness that Biology faculty have of animations and computer-assisted teaching, as well as of the resources available within the department, the Center for Multimedia, and the University.

Animations will be designed, created and incorporated into educational materials by the applicants and two undergraduate students during the Summer of 1999. The animations will be developed in the Department of Biology using predominantly two software animation tools: *Macromedia Flash* and *Autodesk 3D Studio Max*. The resulting animations will be incorporated into five Biology courses taught by the applicants in the 1999-2000 academic year and distributed to faculty both within and outside XYZ XYZ University over the World Wide Web. Furthermore, our efforts will be disseminated within the Biology Department by way of posters, presentations and informal conversation in order to raise the awareness of Biology faculty toward animations and more generally, the specific advantages of computer-assisted instruction.

Proposal

Background and Significance

Education is a conservative process. Traditional subjects such as history, calculus and biology are still largely taught in the same manner as 50 years ago because the educational methods are still effective. It is thus remarkable the extent to which computer and information technology have transformed education over the past 10 years. Computers are now being used by both students and faculty in all facets of the educational process. Biology teaching in particular has seen a tremendous growth in the use of computer technology. For example, computer simulations of biological processes are used to complement traditional "hands on" laboratory experiences; email, discussion groups and WWW delivery of materials promote improved faculty-student and student-student interaction; and CD ROM and WWW based tutorials are becoming effective supplements to traditional textbooks.

One teaching method that has benefited greatly from computer use is the traditional classroom lecture. Although lecturing has the disadvantage of often being passive and teacher-centered, it remains a common form of teaching. Fortunately, multimedia and interactive lecturing have transformed lecturing into a more active and engaging experience for both student and faculty. The seamless integration of digital video, sound, nonlinear navigation, and animation into computer-based presentations allows the teacher

to optimally match the educational media to the nature of the subject material and the needs of the students.

Computer animations are especially effective at improving lectures.[4,6] Animation are perfectly suited to elucidate complex and dynamic processes that underlie biological systems[8]. Furthermore, animations can better engage active cognitive participation from the student[10]. Students also perceive animations as being particularly effective teaching tools. In a study conducted by one of the applicants (CLC) at The University of XYZ, students identified animations as the single most educationally effective component of a highly multimedia-based lecture series[3]. Other studies have similarly demonstrated that animations improve student test scores[1,11,12], student attention[10], and perceptions of teaching.[3]

Although animations can be effective teaching tools in biology, especially in microbiology[9,13] and physiology[7], there are several obstacles to their use. First, unlike static images, there are few commercially or publicly available animations that can be incorporated into lectures[4]. Second, the creation of animations has traditionally been out of the reach of most faculty because of the difficulty of use, high cost, and limited availability of animation software[8,14]. Third, the limited use of animations has resulted in most faculty being unaware that modern animation tools can be simple and inexpensive[14].

In the Department of Biology, there is a strong commitment for educational innovation among the faculty, particularly in the use of computer technology. Yet, few of the 27 faculty have incorporated animations into their classroom teaching.

The goal of the proposed project is to improve teaching in the Department of Biology by developing and incorporating animations into Biology courses and, more generally, to increase the level of understanding and awareness that Biology faculty have of the development and use of animation in teaching. Because of the nature of biological material and the preexisting interest in innovative computer instruction on the part of the faculty, the Biology Department is perfectly matched to this project. Furthermore, by dissemination of results both within the XYZU community and nationally, we hope to instigate increased awareness and use of computer animations.

Specific Aims

1) *Design, Creation, Delivery and Dissemination of Animations* – During the summer of 1999, the applicants will design biological (physiological and microbiological) animations, which will be created in collaboration with two undergraduate students whose summer salaries are requested in this proposal. The resulting animations will then be incorporated into five courses taught by the applicants in the 1999-2000 academic year.

2) *Promoting the Use of Animations within the Department of Biology* – The faculty of the department of biology will be involved and made aware of our project by 1) construction of a colorful, engaging poster placed adjacent to the departmental office, 2) a Fall departmental seminar describing our results, and 3) inclusion of sample animations onto the departmental WWW site. In addition, efforts will be made to informally involve other faculty and students at all stages of project development.

Courses

Together, the applicants will teach five courses containing 260 students next year. Dr. Cleland will teach *Vertebrate Physiology* twice (Bio 370; 48 students each) and Dr. Herrick will teach *Allied Health Microbiology* twice (Bio 280; 75 students) and

Microbial Ecology (Bio 453; 12 students) once. Animations will be used in all five courses.

Project Plan – Design, Creation and Delivery of Animation

The project consists of four components, described more fully below. Briefly, the components and timeline are:

- *Design* - during their teaching in the current academic year (1998-1999), the applicants will identify topics that are particularly suitable for animation and will design many of the animations.
- *Creation* - during the summer of 1999, the applicants and the two undergraduate students will refine the designs and create the animations using computer hardware and software available within the department.
- *Delivery and dissemination* - in the 1999-2000 academic year, the applicants will incorporate the animations into five courses. In parallel during the summer and Fall of 1999, animations will be made available to other faculty within the department or university, as well as outside the University through CERNAP (Computer-based Education Resources for Neuroscience and Physiology), a WWW teaching resource site developed by one of the applicants (CLC) and MICROEDU, a discussion list for instructors in Microbiology that is sponsored by the American Society for Microbiology.

DESIGN – Animations will be designed by Drs. Cleland and Herrick during the academic year 1998-1999 and continuing during the summer of 1999. The topics will depend on several factors: nature of the subject or process, amount of difficulty students have grasping the topic, and suitability to the capabilities of the animation tools. Many topics will meet some but not all of the criteria. For example, this semester one applicant (CLC) identified the fluid nature of cellular membranes as an ideal animation because of the nature of the process and the difficulty students had grasping it; however, none of the software tools could animate the process without an unacceptable time commitment. Similarly, many physiological processes are readily animated, but if students have no difficulty grasping the concept from words or static graphics, animation would be completely gratuitous. Thus, design must incorporate a thoughtful integration of educational needs and computer hardware/software capabilities.

In general, physiology and microbiology contain numerous topics that are particularly well-suited to animation[7,9,14] and that students have difficulty with. For example, muscle contraction arises from the mechanical interaction of several molecular components and bacteria propel themselves using different patterns of flagellar movement. In both instances, understanding does not come from memorizing the parts, but rather from learning the dynamic, physical interaction between components – processes often difficult to understand from static images but readily illustrated by animation. We anticipate creating 50-100 animations of varying complexity over the summer. Examples of some of the topics that have already been identified as appropriate for animation include:

- cross-bridge theory of muscle contraction
- inactivation of bacteria by circulating macrophages
- patterns of motility in bacteria and the gastrointestinal tract

- distinction between peristaltic and mixing contractions in the intestine
- lateral transfer of plasmids between bacteria
- exocytosis and endocytosis in cells
- relation between heart movements and graphs of heart function
- microbial chemotaxis (movement toward or away from specific molecules)
- enzyme binding and substrate cleavage
- replication of the bacterial chromosome

CREATION – Animations will be created using four Pentium II (333-400 MHz) class computers located in a room (Burruss 322) adjacent to the applicants' offices (Buruss.307 and 308). Both undergraduate students will have dedicated use of a computer. One computer is also equipped for video capture and scanning, and a digital camera is available. Creation will be the primary responsibility of the undergraduate students. Dr. Herrick will also be involved in creation to become more familiar with the software, allowing him to better match animation design to the capabilities of the software tools. Dr. Cleland will primarily advise and trouble-shoot the creation process.
Although several animation tools are currently available, two programs with which one applicant (CLC) has extensive experience will be used in this project: *Macromedia Flash* and *Autodesk 3DStudio Max*. Each program has unique advantages and capabilities. *Macromedia Flash* is a recently developed 2-dimensional animation tool that has two significant advantages over other available tools (e.g. *Macromedia Director, Autodesk Animator Pro/Studio*). First, *Flash* is vector rather than bitmap based; thus, drawings are much more easily modified and animations can be rendered (the process of creating a digital move, such as an AVI or Quick-time file) at different resolutions to meet improvements in computer hardware or changing educational needs. Second, *Flash* animations can be saved as a file of "instructions" (like VRML, which is the three dimensional parallel) rather than rendered as a digital movie (Quick-time or AVI file). The difference is that rendered digital movies are large whereas the "instruction files" are small. Consequently, *Flash* instruction files can be rapidly delivered over the WWW and rendered (converted to a series of bit maps, like an AVI or Quick-time file format) on the client's computer. Thus, "Client-side rendering" can be accomplished with a plug-in for Netscape or Internet Explorer. A further advantage of *Flash* is that it is a mature product that can be readily mastered by undergraduate students without extensive computer or graphics experience.

Autodesk 3D Studio Max – is a sophisticated 3-dimensional animation tool. The current versions, however, offer a simple interface that, although more challenging than *Flash*, can still be effectively used by undergraduate students during the summer. Furthermore, the applicant has already purchased an extensive collection anatomical models ("clip art") that can be used for animation. Although most physiological and microbiological concepts are best explained using two-dimensional animation, some depend critically on three dimensional interactions, making three-dimensional animations necessary. Although *3D Studio Max* has the capability of exporting VRML animations (for client-side rendering), most modern computers are still insufficient to meet the performance needs of VRML. However, that is changing, and animations developed this summer can be exported in the future as VRML files to speed internet delivery

In addition, several supplementary programs are likely to be used. *Coreldraw* and *Photoshop* may be used to create vector and bitmapped media that would be imported into *Flash* or *3D Studio Max*. Animation may also be combined with digital video, using *Premier* to capture (Pinnacle/Miro DC30+ is available) and edit digital media and *After Effects* to compose the animation with the captured movie clip. File conversions will be accomplished using *Debabelizer Pro*. All of these software tools are available and the applicant (CLC) has experience with them.

DELIVERY AND DISSEMINATION - The final step is delivery. Drs. Herrick and Cleland will each be primarily responsible for integration of animations into their presentation tools and WWW course pages. Dr. Cleland will be responsible for distribution through CERNAP. Three software tools will be used to author presentations for classroom deliver and WWW distribution

Microsoft Powerpoint – will be used by Dr. Herrick to deliver microbiological animations. PowerPoint is the standard entry-level presentation tool and is well supported at XYZU. Although animation and multimedia integration and control in PowerPoint is limited, it will be adequate to deliver the created animations. Dr. Herrick is experienced with PowerPoint, and is already using it for class presentations.

Macromedia Authorware – will be used by Dr. Cleland to deliver physiological animations. Authorware is an extensive, interactive multimedia authoring environment that has the advantage that the animation controller can be better customized to the educational needs. Although more complex than PowerPoint, Dr. Cleland has 5 years of experience using Authorware to deliver presentations containing extensive multimedia and interactive content.

Microsoft Frontpage 98 and *Claris Homepage* – will be used to incorporate animations into course WWW pages and into CERNAP (http://www.physiology.uXYZ.edu/cleland/CERNAP.htm; soon to be moved to XYZU), where animations can be freely downloaded by faculty at other institutions.

Project Plan – Promoting the Use of Animations within the Department of Biology

Although the primary goal of this project is to improve teaching at XYZU by developing and delivering animations, a secondary aim is to entice other faculty to become more involved in the use of animations and computer technology in general. In the Biology Department, we are fortunate to have a faculty that is keenly interested in using innovative technology, but unfortunately, like all faculty, have more commitments than time. Thus, our first step is to motivate faculty to commit some their time to new computer approaches such as animation by showing how educationally effective animations can be; our second step is to demonstrate that with appropriate choice of tools, expert guidance within the department (the applicants) and outside (CMM), and the use of undergraduate students, that development of multimedia materials is realistic within their busy schedules. We will attempt to accomplish these goals by:

- Creating an eye-catching, constantly updated poster board (4'x3') that will be placed in a high traffic area adjacent to the Departmental office and mailroom. The poster will contain samples of our work, information on resources for developing animations, and student feedback.

- Presenting the results of our project at a departmental seminar in the Fall of 1999. Our seminars are well attended by students and faculty both within and outside the department, and will provide an opportunity to demonstrate both animations and how they can be incorporated into teaching.
- incorporating samples of animations into the Departmental WWW pages, thus serving to increase interest in our department from potential students and outside faculty as well as continually reminding our faculty of the educational possibilities.

Evaluation

Evaluation of the educational efficacy of innovative teaching techniques can be difficult[2,3,10]. Three possible approaches are outcome, student attitudes and perception, and tracking.

Outcome assessment (e.g., comparing test scores to different teaching methods) often requires large numbers of students, control groups that may be educationally disadvantaged by the study, and consideration and control of a large number of confounding variables. *Attitude studies* measure students' perceptions of educational efficacy, which only indirectly measure educational efficacy. *Tracking* measures how students use the educational material, again providing an indirect measurement of efficacy.

Given the difficulty of outcome studies, we will use only the latter two approaches:

- Students will be given an attitude survey (similar to the one enclosed) toward the end of the course. The survey consists of Likert-style questions and comes in two versions, with each question written in a "positive" format on one and a "negative" format on the other to reduce question bias. The survey will be modified from the appended sample to include more questions on animations.
- The pattern of access of animation on the course and CERNAP web sites will be tracked using Marketwave Hit List Professional (version 4), which will be purchased by the College of Science and Mathematics and installed on the College server. Hit List Professional provides extensive information on usage which will allow us determine if and how student are using animations over the WWW, and if other faculty outside the University are showing interest.

Personnel

Corey Cleland, Ph.D. – new to XYZU this Fall, is a tenure-track Assistant Professor in the Department of Biology. Dr. Cleland has 6 years of experience at The University of XYZ developing multimedia, delivering interactive, multimedia intensive lectures using Authorware, developing laboratory classes in physiology based on computer simulations, and generally promoting the appropriate use of computer technology through workshops and presentations[2,3,4,5]. Most importantly, in the summer of 1997, Dr. Cleland directed a project similar to the proposed project, in which two medical students spent the summer designing and creating animations that the faculty used in teaching the subsequent year. The results of that project are many of the animations available at CERNAP.

XYZ Herrick, Ph.D. – is also a new (January 1998) tenure-track Assistant Professor in the Department of Biology. Dr. Herrick is an ideal member of this project because he is exemplary of the Biology faculty in that he has strong interest in incorporating computer

technology into his teaching but only relatively recent experience doing so. Dr. Herrick's commitment to educational innovation is evidenced by the efforts he is making to learn – he is currently enrolled in three of the CMM's workshops – Photoshop, HTML and Distance learning. Furthermore, on his own he has learned and used Powerpoint and has incorporated the few animations available over the WWW into his teaching.
Two undergraduate animators – Although we have not yet identified specific individuals, we do not expect any difficulty filling these positions given the exciting nature of the work. Based on experience in XYZ, it will not be critical to find computer-savvy students; since the software tools (*Flash* in particular) are straightforward to learn, background in biology and an interest in teaching are probably more important credentials than computer expertise.

Preliminary Results

As mentioned above, the applicants have experience in developing animations, using animations to teach, and supervising student animation projects. Since arriving, one of the applicants (CLC) has begun, time permitting, to develop animations for Vertebrate Physiology (Bio 370). A sample of three of these recently created animations is enclosed on the IBM/PC formatted disk (appendix C). These animation only required between 30 minutes and 2 hours each to create. Other examples of animations created by the applicant or students under his direction can be viewed at CERNAP (http://www.physiology.uXYZ.edu/cleland/CERNAP.htm).

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Budget

The only requested items are salary support for two undergraduate students, probably from XYZU, over 10-12 weeks during the summer (between approximately May 15 and August 15). Compensation for each student will be $3000 for the period. All other resources (software, hardware, supplies) are available (see below).
Amount requested: $6000

Resources and Endorsements

Resources for this project beyond support from the Center for Multimedia will arise from three different sources. Letters of endorsement are provided in appendix A.

- The College of Science Mathematics has committed $6000 in the academic year 1998-1999 to Dr. Cleland for hardware and software to support the development of multimedia. Those funds will significantly assist in providing the resources needed to conduct this project, but cannot fund undergraduate participation over the summer.
- The Department of Biology has agreed to $500 of matching funds if this proposal is funded, the money being used to upgrade software as needed. Furthermore, the Department will make available during the summer the four computers that will be used in this project.
- Dr. Cleland brought from the University of XYZ all of the software (including Flash, 3D Studio Max, Premier, After Effects, Coreldraw, Debabelizer, Authorware, PowerPoint, Streamline, 3D clip art) needed for this project.

Appendices

A. Letters of Endorsement from Dr. John Gilje, acting Dean, College of Science and Mathematics, and Dr. Doug Dennis, Acting Co-Director, Department of Biology.
B. Sample attitude survey questionnaire used previously at the University of XYZ.
C. Sample animations. The files are AVI format (IBM/PC) compressed using 8-bit RLE.

- Active transport.avi – depicts how substances enter and leave cells
- Filtration.avi – shows that membranes act as a sieve to molecules dissolved in blood
- Osmosis.avi – illustrates how water follows molecules that cross a membrane