Sarco*motion*: IMM Used Across the Learning Spectrum

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Abstract

Frustration at trying to lecture to a large first-year health science student audience about skeletal muscle led to the development of a computer animation of the microscopic process of muscle contraction. The animation was used as a moving overhead projection in a lecture setting, and was played from various points before being stepped through frame by frame to highlight the different parts of the process. The trial and evaluation of the use of this animation in Semester 1, 1995 was well-received by students and staff.

The second product of this work is an Interactive Multimedia (IMM) tutorial, called Sarco*motion*, which provides information and explanations of parts of the contraction process, plus background information relating to skeletal muscle contraction, calcium metabolism and energy turnover. The animation forms the user interface by which the students access the tutorial. Students explore the moving animation with the mouse to get basic descriptive information, and click to access more specific information on each individual topic. Navigation through the specific information is provided by a series of questions, based on actual experience of the range of questions typically asked of the lecturer by the students.

The tutorial is designed to allow for access to a range of resources outside the scope of the tutorial itself. This is achieved by a link from the tutorial to a World-Wide Web home page. This leads to the concept of finger food multimedia, where a platter of other resources on the Web are served as finger food, from which the student can choose to use as little or as much as they wish.

This paper describes the development approach and formative evaluation of the first prototypes of the Sarco*motion* program.

Keywords

interactivity, animation, muscle contraction, lectures, tutorials, web resources

1. Introduction

The logistical difficulties of teaching and learning in a large-intake unit where students have a large range of differing learning experiences and backgrounds has been addressed previously in relation to the development of IMM (Fyfe and Fyfe, 1992; Fyfe anf Fyfe, 1993).

The large-intake Human Biology unit at Curtin University covers the topic of skeletal muscle contraction in both a lecture and a tutorial session. A didactic approach is used to outline the main features and sequence of events, and the tutorial provides a basis for students to ask questions and spend the time they need to understand the concepts. The lecture format has to date been restricted to two-dimensional overhead transparencies due to the lack of other suitable material. The main difficulty experienced in understanding muscle contraction is that the process is dynamic; it involves a group of moving three-dimensional objects interacting over time. Teaching this process with two-dimensional static overhead transparencies was time-consuming, ineffective and frustrating for everyone involved.

The need for a working 3D model was realised by the lecturer (GMF) as she stood at the podium wiggling her fingers to mimic the myosin heads, in a desperate attempt to help students understand. Anecdotal evidence from tutors showed that students had problems with a number of key concepts important to the understanding of muscle contraction: the role of Ca^{2+} (Calcium) as a moderator of cross-bridge formation, the relationship of ATP (Adenosine Tri-phosphate) to the contraction process, and a sense of relative scale from the molecular- to the cellular- to the gross anatomical level.

Given that there was a recognised need for something that might overcome the restrictions of static two-dimensional overhead transparencies to aid student understanding, we looked at commercially available resources. We were aware of the “not invented here” syndrome, but after careful consideration of available audiovisual material decided that these resources did not satisfy our requirements. Much of the commercially available courseware was either too simplistic or contained detail irrelevant to our unit objectives. Some older video material was aimed at the correct level but did not provide the interactivity we needed. Our requirement was for an animation that could be manipulated by the lecturer in a lecture hall presentation, but which could also be used by the student through an interactive tutorial.

2. Pedagogical Issues

In developing IMM courseware we needed to consider the paradigm on which we would base our design. The earliest applications of computers in education, mainly in the corporate training sphere, were based on an *objectivist* or *behaviourist* learning theory. In this theory (Marra and Jonassen, 1993) knowledge is seen as existing independently of any human experience. Objectivists place a strong emphasis on defining learning objectives and assume that the learner is an empty vessel, to be filled by the instructor (Reeves, 1992).

A strength of objectivism is its ability to address novice learning situations and therefore many lecture courses given are strongly based on objectivism. However, it is not a suitable approach to use for many aspects of university learning. Critics claim that there is little scope for dealing with individual learner differences (Marra and Jonassen, 1993). Marra and Jonassen (1993) also challenge the presumption that instruction can externally control what individuals learn. Laurillard (1993) identifies a further problem with the objectivist approach, in that ‘the analysis into components of the teaching-learning process is not followed by any synthesis’ (p. 74).

At university, students not only have to learn knowledge and skills, they also have to learn how to think and make judgments, and to prepare themselves for lifelong learning (Candy, Crebert and O’Leary, 1994). The constructivist approach attempts to resolve these issues.

The *constructivist* epistemology is referred to frequently in the current literature and claims that reality is more in the mind of the knower and the knower constructs or interprets a reality from his or her perceptions (Marra and Jonassen, 1993) . In this view, students construct their own knowledge from their environment . The job of the teacher is to provide material and facilitate, while letting the student synthesise his / her own knowledge.

The constructivist approach assumes that the learner can build his / her own knowledge, so the student is viewed as a researcher. A major goal of the constructivist approach is that the learning environment is as rich as possible, and interactive multimedia has clear possibilities for producing rich learning environments that students can explore at will to build their own knowledge. However, a drawback of the constructivist approach is that it assumes the student has research skills, which may not be the case. In addition, a rich source of stimulation may work well for some learners, but others may be distracted and need help to focus on main issues (Trollip and Alessi, 1991; Fyfe and Fyfe, 1993).

Reeves (1992) has pointed out that there is a continuum between objectivism and constructivism. Current thinking indicates that it is appropriate to bias interactive multimedia learning materials towards the constructivist end of the spectrum (Marra and Jonassen, 1993). Gillespie (1995) , in a recent discussion on the ITForum electronic discussion list, contended that a well-designed piece of courseware should incorporate the most appropriate aspects of each learning theory.

Laurillard (1993) approaches the issue from the viewpoint of student learning. She argues that there are four main aspects of the teaching-learning process:

i. Discussion between the teacher and learner at the level of descriptions.

ii. Interaction between the learner and some aspect of the world defined by the teacher.

iii. Adaptation of the world by the teacher and action by the learner.

iv. Reflection on the learner’s performance by both teacher and learner.

She has analysed different educational media in terms of these aspects. Laurillard argues that the only use of technology that can meet these aims is the “multimedia tutorial simulation”, which leads to guided discovery learning. It is based on a rich environment in which the student has control in discovering knowledge, but the discovery is supported and scaffolded by extra support and feedback. Our development of Sarco*motion* was influenced primarily by the constructivist approach with cognisance of the issues that Laurillard raises about supporting student learning.

3. Development

All members of the project team have been involved in Computer-based Learning developments since 1992 (Fyfe and Fyfe, 1992; Phillips, 1993) . This experience has led to the Computing Centre developing a Developer’s Guide as an attempt to impose some of the rigour of standard software development methodology onto the complexities of interactive multimedia development (Phillips, 1995). The Sarco*motion* project progressed under the influence of these guidelines.

This development process uses an incremental prototyping model, with a strong emphasis on the *paper* design of as much material as possible before any programming is done. The approach requires a high level of teamwork and focusses on effective communication between content and educational design experts, programmers and graphic designers.

The design cycle consists of *Design*, *Develop*, *Evaluate*. There are nominally three parts of the design cycle as shown in Figure 1.

3.1 Educational Design Cycle

The Educational Design cycle essentially determines the scope and purpose of the project. All aspects of the project need to be analysed and defined. For example: what are the topics? How does one move between topics? How will the user interface work?

The development commenced with a presentation of the lecture content, and proposed ideas for the animation by the lecturer to the rest of the team and other Computing Centre staff. A brainstorming session initially clarified some of the aspects of the project then a series of other meetings were held over several months to define progressively the structure and functionality of the project. The outcomes of these meetings were recorded in an evolving *requirements specification* document which helps all members of the project team to clarify their understanding of the project.

The requirements specification:

- defines the scope of the project and its navigational strategies;
- describes details of the user-interface;
- may contain some guidelines about the graphic design; and
- does not contain any content, other than the headings of the topics.

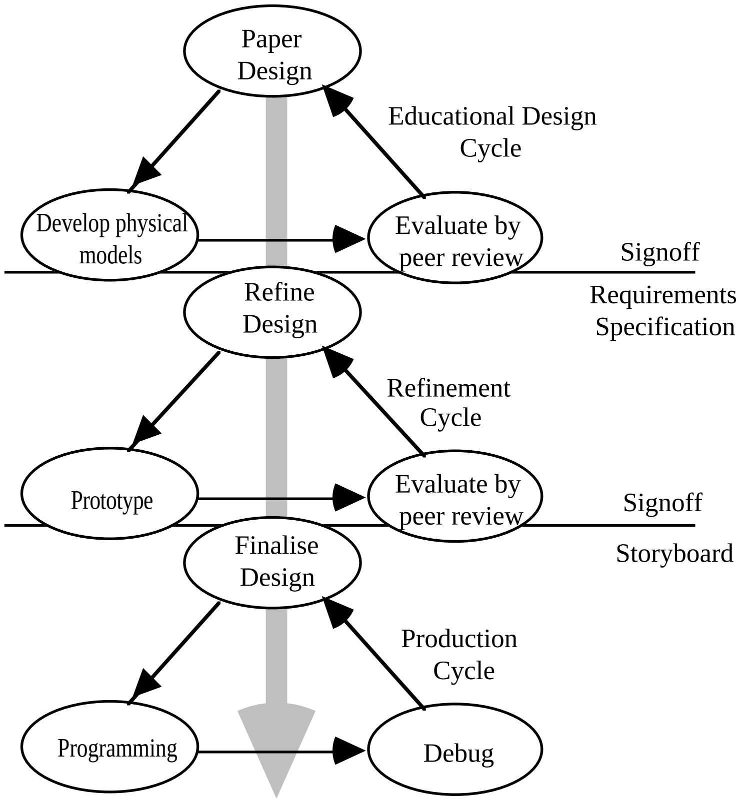

Figure 1. The Project Design Cycle.

3.2 Refinement Cycle

Once the requirements specification has been defined to the satisfaction of the team, work can begin on a prototype. Graphic design work can commence and working models of the user interface can be produced. At the same time, work can start on the curriculum content. The prototype, containing the structure of topics, but only enough content to give an indication of the overall structure, is formatively evaluated by peers and students. The results of the formative evaluation return development to the educational design cycle, and eventually the requirements specification will be finalised and signed off.

At this stage, development of a paper-based storyboard can continue, until all content is finalised. The storyboard describes exactly what will be on each screen, including all the resources, and how it links to other parts of the project. Production work should not start until the storyboard is checked thoroughly, finalised and signed off.

3.3 Production Cycle

Because so much effort has been spent in the design of the project, the actual production can be quite efficient. Any difficult design or programming issues should have been resolved in the prototype stage. Standard project management techniques and timelines can be used at this stage to ensure completion of the project.

This developmental model was followed during the Sarco*motion* project, with some exceptions. Because the interface, educational design and the content were very closely interwoven, it was not possible to use students to evaluate the overall structure until some of the content had been added. In addition, the spiral of development included some paring-down of content as we realised that alternative web technologies would allow the access of packages which would alleviate the need to reproduce some of the content in the tutorial. The exponential growth of this area since the beginning of the project changed the scope and logistics of the tutorial resources along the way.

4. Details of the Project

The Sarco*motion* project involves two components, each representing learning at either end of a spectrum. At one end, the animation is used as a moving overhead transparency to illustrate a didactic lecture presentation. At the other end of the spectrum, students explore the animation and associated topics in a relatively unstructured tutorial which operates on three levels.

4.1 Lecture Animation

The animation of muscle contraction was developed in Macromedia Director and saved as a QuickTime movie. It illustrates the intracellular parts of a skeletal muscle cell that are pertinent to the process of muscle contraction, including the component parts of thick and thin myofilaments (see Figure 2). It also shows calcium ions being released to flood the cell and attach to the troponin molecules of the thin myofilaments. This is turn causes a shift in the spatial arrangement of the tropomyosin molecules allowing the cross-bridges to form between the actin and the myosin molecules of the thin and thick myofilaments respectively. The animation shows the movement of the myosin heads and the subsequent shortening of the sarcomere, the contractile unit of skeletal muscle cells.

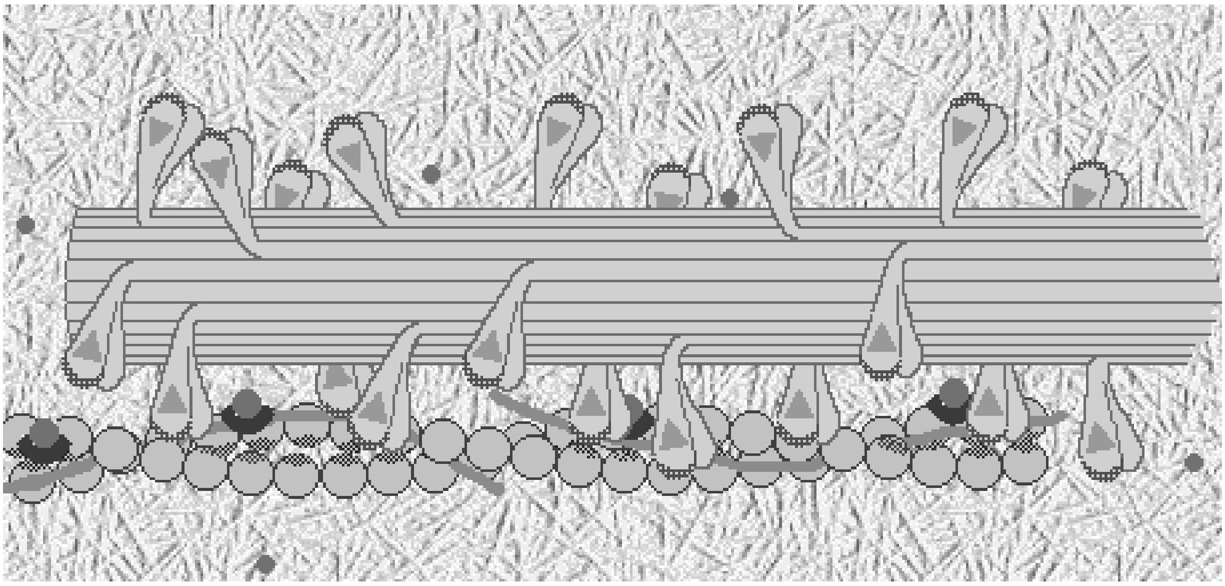

Figure 2. The animation of muscle contraction.

4.2 Self-paced Tutorial

The learning strategy adopted a combination of presentation and explanation of the animation in the lecture plus an opportunity for students to consolidate their understanding by using the self-paced tutorial in the computer laboratory.

We wanted the animation to form the interface for accessing the tutorial, so that the students would interact directly with the same metaphor they had viewed in the lecture, thus reinforcing their learning. Students who wish merely to take a few minutes to replay the same moving overhead they had seen in the lecture are accommodated, as are those who wish to explore in more depth. A further design goal of the project was to take the best advantage possible of available digital resources that may complement the animation material. The tutorial design must link easily to other existing IMM resources, and allow more resources to be added easily as they become available.

4.2.1 Observation

On the first level, the students simply observe and manipulate the animation, identifying the components and observing how they interact with each other. It is intended that this interaction will raise questions in the minds of the students, which they can answer at the second level.

4.2.2 Interaction

On the second level, students can click to explore a particular part of the animation. This takes them to another layer that provides extra explanation, or guides them in their search for understanding. The detailed content is overlaid as a window on top of the animation, parts of which are still visible to maintain context. From here, highlighted words are linked either to a glossary or to other parts of the second-level information wheel. The way in which this part of the program functions has been the subject of substantial formative evaluation, both on paper and by the testing of prototypes.

In designing the Sarco*motion* tutorial, we realised that much of the Interactive Multimedia generally available answers questions by responding to the user with chunks of text. This is not how useful student-tutor interaction works. When a student comes to a lecturer with questions about a lecture topic, the lecturer or tutor first establishes what the student *does* understand, then uses that information to build up the explanation. Few lecturers would deal with poor understanding by bombarding the learner with reams of text, and yet many IMM tutorials are built on this pattern. Such courseware ignores the constructivist ideal of the teaching-learning interaction with which our team wished to underpin the design of Sarco*motion*.

With this in mind, we felt it was important to develop the tutorial material from the questions students typically asked, not from the questions we felt they should ask. It was also important not to place a value ranking on questions, so we as teachers do not impose our framework for learning about this complex topic on the user.

Therefore the structure of this second level of interaction is based upon the what / where / why questions that students ask. It also indicates to students that they may seek more information which is either at another depth or is lateral to the topic they are exploring.

The basic structure of the Sarco*motion* program consists of eight components of the process, interrogated by ten questions, as shown in Table 1.

	Components	
Thick Myofilaments	Myosin	Troponin
Thin Myofilaments	Actin	Ca^{2+}
	Tropomyosin	ATP / ADP
	Questions	
What is it made of?	Where does it come from?	How big is it?
What does it do?	Where is it made?	How does it work?
What does it interact with?	Where does it work?	Why do you need it?
What controls its activity?		

Table 1. Basic subject components of the Sarco*motion* program.

4.2.3 Other Resources

On the third level, users move away from interaction with the animation to view material available from other sources, such as the World-Wide Web (WWW), selected materials from a CD or video-disc, or other courseware. Indirect navigational clues tell the user that they have left one level and entered another by the overlay of windows. We considered it important that students should realise it was not essential to cover all the resources in the third level, but rather that these extra morsels provided back-up or alternative related information to help consolidate learning from the first and second levels of the tutorial.

We hope that Sarco*motion* will not only help students to understand the concepts of skeletal muscle contraction to meet specific objectives in the Human Biology unit taught at Curtin University, but also introduce them to the concept of the WWW as a resource. The use of a WWW homepage linked to other resources the students may choose to access through the tutorial may stimulate their interest to browse through other parts of the Web and return there at some later time. Previous evaluation has shown us that students are not as familiar with computer-based technologies as we often assume, and one unexpected spin-off from using the Osmosis Program was the increase in confidence of previously technophobic students whose computer skills were stunted through lack of confidence (Fyfe and Fyfe, 93). We aim to familiarise students with the WWW through practical application, and thus to increase their confidence to use it effectively as they would the university library. In this way we are providing a means for them to become active learners.

5. Evaluation

5.1 Lecture Animation

The moving overhead transparency was trialled in the lecture in Semester 1, 1995, and an evaluation of the lecture itself was undertaken. Using the Minute Paper evaluation technique (modified after Cross, 1993) students were asked to identify the best or most useful thing from the lecture. Of 300 students who completed the form, 64% stated that the computer animation was the highlight of the lecture, and other comments indicated that students had enjoyed the lecture and felt they had understood the process of muscle contraction. The lecturer noted that although she used the animation a number of times in the lecture, manipulating its speed and direction and talking about the significance of the various components represented, the process of explanation took only 20% of the time usually allocated to the explanation of this particular concept.

5.2 Self-paced Tutorial

An essential part of the development process has been the formative evaluation of the user interface. Much of this took place within the development team as part of the comprehensive paper design. The use of the requirements specification enabled us to walk through the details of the user interface. For example, we decided to use hot spots on the animation to access other screens of information. The team then needed to explore the ways by which users would return to the animation. Possibilities were identified and the side effects of these potential solutions were analysed to identify the most natural functionality consistent with the rest of the interface.

As discussed in section 4.2.2, a questioning strategy, based on questions typically asked by students, was chosen as a means of accessing content in the tutorial. However, our design team were extremely conscious of the fact that a list of questions on the screen would look like the main menu of typical objectivist IMM programs. A list of questions would imply a ranking or logical order, inviting students to start at the top and work through one by one. This would seriously weaken the effectiveness of the questioning strategy as a means for students to construct their own knowledge.

The approach we chose initially was to make the ‘what, where, how, why’ questions into the four sides of a spinning top. When this screen was entered, the top would spin a random number of times to leave a different question above. In Figure 3, ‘What’ is shown, with its sub-questions. Each sub-question could be clicked on to take the user to a single screen containing an answer to the question. Clicking on ‘Where’, ‘How’ or ‘Why’ rotates these questions to the top.

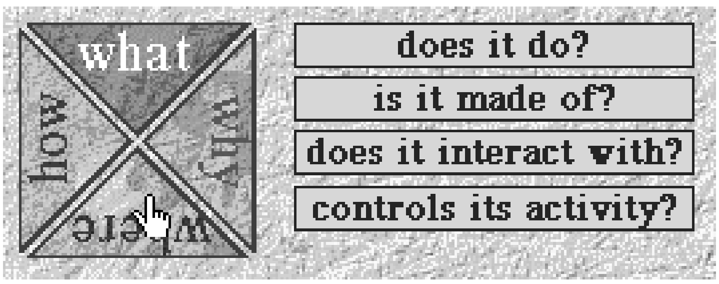

Figure 3. Questioning via the *spinning top.*

Most of our team really liked the spinning top idea. It was a quirky way of presenting a series of questions without a list, it was fun to spin, and the design looked great. It was displayed at a residential IMM workshop held at Muresk in June 95, with the aim of gaining some peer review.

Two serious problems arose with this aspect of the user interface when a prototype program was constructed. Formative evaluation with novice users of the program revealed that the spinning top metaphor was not successful. Users didn't make the visual connection between 'What' and 'does it do?'. A revised strategy uses a rotating wheel with questions in full on the outside rim. The second problem became evident when some content was produced to put in the prototype. The idea of having a single discrete screen for the answer of each question was not effective because of the varying amount of material for each answer. Some questions could be answered by a few words and a picture; others needed much more detail. Still others were more appropriately dealt with by linking the user to another part of the resource smorgasbord.

Based on these observations, the second prototype contains only one screen per topic, with the answers to all questions contained in a scrollable window, like a World-wide Web page. The size problems are alleviated, and the student has more context about the relationships of various aspects of the content.

At the time of writing, the animation has been incorporated into the lecture series for two first-semester Human Biology units at Curtin University, and has been used at Curtin as a working example of the use of computer technology to help make lectures work better. The tutorial prototype will replace the 50 minute tutor-led tutorial in semester two this year, providing opportunity for more rigorous evaluation with students.

6. Summary

The Sarco*motion* project explored ways of incorporating constructivist principles of teaching and learning into the design process of IMM courseware. It also provided an opportunity to symbiotically document and use a formalised process to monitor the development phase of the project. Formative evaluation of the user interface led to modifications of the mechanics of the screen interactivity. Parallel advances in Web technology allowed us to pare down the project to make best use of other people's resources and to introduce students to Web concepts through a three-tiered interactive tutorial. The result of Sarco*motion* is a richer experience in a formalised lecture setting, and a way for students to interact with the animation in a way that allows them to construct their own pathways to understanding.

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