Evolution of a Student Model Building Program Designed to Assist Understanding of Biological Control Systems

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Abstract: Tertiary students in graduate and undergraduate medical and biomedical science courses have increasingly diverse backgrounds in prior academic achievements and culture. This presents problems for teachers assisting students to understand complex biological control systems. Our approach is to have students work in small groups to construct their own simple model of such a control system. This model then provides the basis for a structural framework for them to add further complexity without losing overall perspective, and allows exploration of deeper issues. Our interactive model-building program is suitable for many disciplines and student backgrounds, and provides a visual representation of a difficult concept, aiding in memory retention and providing a basis to ground further knowledge. Audit trail data have been analyzed to identify and resolve areas of student difficulty, and extensive surveys and observations on students’ use of the program over three years in several courses have been used to improve and test its effectiveness.

1. Introduction

This article reports on the development of a multimedia module (first described in Weaver et al, 1999) in which students are asked to construct and explore their own model of a complex biological control system and then use that model for further investigations. The long term continuous formative evaluation and adjustment has now led to the international distribution of this program on CD (Weaver et al, 2000).

Teaching Complex Control Processes in Biological and Medical Sciences

Our new approach is to introduce a qualitative conceptual framework for a model that is suitable for introducing complex control systems to students in biological and physical sciences, economics and engineering. In other words we facilitate the students' building of the 'big picture' of a complex system before going into the details. Such an approach has also been taken to bring teaching into alignment with practices in new curricula that increasingly rely on problem-based learning, problem-solving, student-centred learning, and self-paced learning. Biological science was previously regarded as a soft learning option, but the growth in biological knowledge has meant that concepts have become increasingly difficult to understand as systems are elaborated through research. It is always a challenge to teach difficult concepts in an engaging manner. This project is a direct response to student and staff difficulties with the teaching of biological feedback control. This approach might equally well apply to fiscal modelling in economics or to a complex engineering principle.

2. Program Design and Evaluation

Pedagogical Issues:
We use the computer program effectively as an expert system that assists students’ construction and testing of their model by providing construction tools, simple animations of their model operating, feedback screens indicating success or failure of their model and hints on possible changes they might make. Students may find deficiencies in their model, a need to adjust misconceptions, suggest modifications in the expert model for future implementations, or exhibit misunderstandings in common with other students. On completion of the model, students are given tasks with a strong element of reflection in their use of the tutorial as they try ‘What if?’ scenarios and elaborate on the knowledge into new areas.
Software Design Principles

The essential feature of the program is to present the information in a simple qualitative manner that could be used to give a global view of the control system. This conceptual framework can then be used by students to add specific details of the mechanisms or indeed to better understand a mathematical simulation of the system at a later time, such as would be appropriate for engineers. Teaching programs are always based on either explicit or implicit assumptions about learners and learning and the desired cognitive outcomes. Some issues we have tried to address are described in Weaver et al, 1999.

Model-Building as a Series of Cognitive Steps

Students are required to create and position components of an electrical (neural) circuit to create a control system that will allow a person to maintain the blood supply to the brain when they change posture. Students are then expected to select components consisting of receptors (signal detectors), input (afferent) neurones, processors (interneurones), and output (efferent) neurones.

Our educational approach is to provide feedback at every stage, and this is in the form of a simple animation of the system working (ie. electrical impulses moving around the connected components of the system), followed by textual feedback. The textual feedback is always in the format of a positive statement (what is correct so far), followed by a statement about what is not yet correct, and a hint about what to consider next.

Evaluation:

The first version of this computer aided learning (CAL) program was tested by electronic audit trails and questionnaires. An example of the information obtained was the requirement to separate the model building exercises from the use of tools and symbols, leading to the introduction of ‘practice’ screens.

The program was finally evaluated with three groups of 2nd Year students at the University of Melbourne: Medical Students in a curriculum with emphasis on Problem-Based Learning, 2nd Year students in a new Biomedical Science Degree and 2nd Year Science Physiology students. Approaches to evaluation included questionnaires, computer audit trails, pre- and post-CAL tests and analysis of exam results for misconceptions. The program has been distributed nationally and internationally to about 12 Universities who have trialled the program with their students and have provided useful feedback incorporated into the final program.

Overall, the students enjoyed the ‘hands-on’ nature of the model-building exercise immensely, and gave the program a very positive rating. They judged their own understanding as having increased from 2.23 (Biomedical Science) and 2.35 (Science) to 3.72 and 3.54 respectively, after using the program. Pre- and Post-CAL tests showed a similar significant improvement in understanding (Wilcoxon Matched-Pairs Ranks Test, p<0.005 for whole test score)

3. Discussion

Our approach to help students to learn about control systems by fostering the development of phenomenological understanding has been successful. It has overcome the difficulties our students had previously with a simulation or mathematically oriented approach that we deliberately avoided in our introductory program. The goal was to establish a level of qualitative fundamental understanding that can be overlaid later, where appropriate, with quantitative transfer functions when these are known. Thus our approach is usable in a wide variety of contexts, including those in which mathematical constructs are inaccessible.

This program is also more linear in model construction than others we have developed for modelling epithelial cells and it is difficult to provide specific feedback if students continue to place multiple elements all over the screen without much forethought, since the number of permutations and combinations becomes enormous. Once students start the construction appropriately, their construction problems are largely resolved.

The emphasis is to encourage student hypothesis formulation and visual testing as the continuity between control system input and output components is represented graphically. This approach lends itself to the description of control systems for which real components can be identified (ie receptors, neurones, blood vessels) rather than systems in which the components are conceptual. The use of task sheets as thought extension exercises provides the opportunity for students to both test and generalize their new-found understanding, and has proved useful in provoking discussion among groups of students. This opportunity was exercised in most classes and students liked to test their ideas extensively with the tutors.

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