Chapter 20. Action Research Evaluation of "Reflex Control of Blood Pressure"

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1. Introduction

This paper reports on two cycles of action inquiry research conducted on a CD-ROM tutorial, "Reflex control of Blood Pressure" during 2000. The evaluation was undertaken as part of a national ASCILITE / CUTSD project "Learning-Centred Evaluation of Computer- Facilitated Learning Projects in Higher Education".

2. History of the Project

The tutorial was developed in 1997, and extensive formative evaluation undertaken in 1998. Analysis of the data collected revealed several shortcomings in the program, which was rewritten as a result. This round of evaluation was presented at ASCILITE '99 (Weaver, 1999). The aims of the current round of evaluation are to determine the effectiveness of the recent modifications on student learning processes and student learning outcomes, and to determine whether this program is relevant to, and appropriate for, the different courses in which it has now been introduced.

In 1999, the Medical course at the University of Melbourne changed to a problem-based curriculum. The number of lectures and practical classes was drastically reduced, and replaced with a 'Problem of the Week', where students work in groups of 10-12 with a tutor for 4 hours each week. As a result of these course changes, the subject material of blood pressure control is now covered in 2nd year Medicine, so was not taught in 1999. The effects of the change of course structure on how students use the program is not known, leading to a key question: How do students use a tutorial designed for traditional curriculum in the newly re-designed problem based curriculum?

In addition to the medical course, this program is also used by 2nd year Science students, as one of a series of weekly scheduled CAL tutorials, and was used for the first time in 2000 by 2nd year BioMedical Science students as part of a series of prac classes and CAL tutorials. BioMedical Science is a new course at The University of Melbourne, and this was the first cohort of 2nd year students.

2.1 Stage of Evaluation

Using the learning-centred framework adapted from Alexander, Hedberg & Bain (Phillips, 2000), this project is currently in both the development and implementation phases. In particular, the current evaluation study aims to focus on not only the formative monitoring of both the learning environment (to determine whether this CAL is functional and enjoyable to use) and of the learning process (to determine whether this CAL is influencing the learning process as intended), but also to conduct summative evaluation of the learning process and of the learning outcome. Some questions on the educational relevance of the project have also been included in student surveys to begin evaluation on the summative evaluation of innovation appropriateness.

2.2 The Project Group

The project group consists of 5 members of staff of the Department of Physiology, and all took active roles in development of the tutorial and are listed as authors of the program. The members can be described as:

- educational programmer (primarily employed on development) & author
- academic in charge of this topic
- co-chief investigator of the development grant
- co-chief investigator & Assistant Dean
- another multimedia author / head tutor

Other members of staff were consulted as required.

3. Introduction to the Software

"Reflex Control of Blood Pressure" is a standalone CD-ROM tutorial, aimed to assist 1st-year Medical students understand the baroreceptor reflex, which maintains blood supply to the brain during changes in posture, blood volume etc. This reflex is one of the best and most simple examples of negative feedback, where an initial signal invokes responses to decrease the signal (eg. an initial drop in blood pressure triggers a set of responses that act to increase blood pressure, to return it to its set point).

Traditionally, the function of this reflex has been taught in lectures, using diagrams of a 'black box' to describe what was happening to nerve impulses in the brain. Not surprisingly, students memorised the diagram, but had little understanding of how negative feedback occurred. A common student misconception (reported by academics) was that negative feedback mechanisms would overcorrect blood pressure beyond the set point.

"Reflex Control of Blood Pressure" provides introductory information on the regions of the brain involved in this reflex pathway, definitions of feedback control, and an introduction to the symbols used to represent elements of a neural pathway. The major section of the program is a model-building exercise, where students manipulate nervous system components to construct their own reflex pathway, and then can test this by increasing the blood pressure. Feedback in the form of animations and text panels are provided for every combination of elements. Once the model is completed, the effects of postural changes can be investigated. A case study is included, and a paper-based Tasks sheet is supplied in the classroom (the questions from this Tasks sheet are also included in the program).

3.1 Key Learning Objectives of the Tutorial:

The major aim of the CD-ROM is to understand how the central nervous system controls blood pressure with changes in posture or activity. Within this, the key learning objectives are to:

- Understand the concept of negative feedback (and the 2 different mechanisms to achieve this)
- Understand the concept of excitation and inhibition, to effect this feedback.
- Understand how blood pressure is controlled *reflexly* – the same simple system responds to either increased or decreased pressure and acts to return it to a set level.

4. Action Inquiry Evaluation of CFL

Action Research, or Action Inquiry, is defined as research, generally into social interaction, that has a major aim of producing a change in the environment or practise being researched, rather than producing written theories (Kember, 1993). It requires active participation by the researcher in the process.

Characteristically, Action Inquiry is conducted in a cyclical, or spiral, manner, and involves one or more series of cycles, which can be summarised by the following stages:

- plan experimental action & define key objectives
- take the necessary action
- evaluate results of action
- reflect on impact of action
- plan further cycles if necessary

5. Action Inquiry Cycles

Two cycles of evaluation were completed in 2000. In Semester 1, the CD-ROM was recommended to 2nd year Medical students as a key self-directed learning resource for their 'Problem-of-the-Week'. The expectation was that students would complete the CAL tutorial in the on-campus computer laboratories during that week. However, for the purposes of this study, a voluntary scheduled session was advertised during lectures and on student on-line noticeboards, with a lecturer present to entice attendance.

In addition, the CD-ROM was also scheduled for use by 2nd year Science and BioMedical Science students in Semester 2. Although both these courses are very different to the new PBL Medical course, evaluation with both groups of students have allowed us to test the impact of the modifications made since Semester 1.

170 2nd year Science students undertake weekly 2-hour scheduled CAL classes, with one tutor to about 30 students in each of 5

sessions. The course is of the traditional lecture / prac / tutorial structure, and we have been teaching this course for many years.

BioMedical Science is a new course which commenced in 1999, and this year saw the first crop of 80 2nd year students. The course is of the traditional format, with a weekly 2-hour timeslot of either CAL tutorial or laboratory prac class. Students within the BioMedical Science course are derived from amongst the highest-achieving secondary school students, and we anticipate these students will perform better when compared with students undertaking the more general Science course.

5.1 Key Evaluation Questions

Cycle One (identified from previous formative evaluation):

1. To investigate the effect of design changes made as a result of the previous round of formative evaluation.
- Has the simplification of the brain anatomy section resolved student frustration?
- Has the introduction of the practise screen and other introductory screens helped reduce the cognitive load experienced by students?
- Has the introduction of the Case Study helped reinforce the relevance of this material to the curriculum.

2. To compare the way the program was used by students studying the new PBL course, with our experience from the previous traditional course.
- Are there any noticeable differences in the way students now use this resource?

Cycle Two (identified from Cycle One evaluation)

1. Have the modifications implemented as a result of Cycle One evaluation been effective?
- Have the new names for the brain regions resolved the confusion about where the different efferent nervous systems arise?
- Does student use of the tutorial help explain the concepts of excitation / inhibition? Do students now read the hyperlinked definitions more? How do they use these?
- Do students now understand the different ways of achieving negative feedback?
- Did student use of the practise screen increase? If so, how did they use it?
- Did student use of this screen better prepare students for focussing on the content of the tutorial later?
- Does the new Summary screen help in highlighting the major learning issues of the tutorial?
- Do students notice the changes in rates of signalling in their circuit?
- Has student viewing of the case study increased? Does viewing of these screens help put the aims of the CD-ROM into context?

2. Does student use of the CD-ROM improve their understanding of the key learning objectives?

A summary of these evaluation cycles is included in Table 20.1.

6. Evaluation Methods Used

6.1 Written Questionnaire

All students (from all courses under investigation) were asked to complete an anonymous, written questionnaire at the end of their CAL session. A copy of this (without spaces for answers) is included in Appendix 20.1. Questions included number scales of student perceptions of understanding of the topic, both before and after the CAL, and specific questions on student use of particular areas of interest, as identified in previous evaluation cycles. The questionnaire also included many open-ended questions on areas of greatest difficulty, relevance to the course, and suggestions for improvement.

The same basic questionnaire was used in both Action Inquiry cycles, with the only alterations being on relevance or appropriateness to the curriculum, allowing for differences in the two different types of courses being investigated. All student responses were transcribed, and collated into similar categories.

6.2 Observations

The author was present at every CAL session using the CD-ROM tutorial, and also encouraged tutors to pay attention to areas of particular interest. Observations were collated with results from the questionnaire analysis for each student cohort, and a report circulated to the project group, other interested academics and all tutors involved in the study. For each cycle of the evaluation, the observations

Table 20.1. Summary of Action Inquiry Cycles completed in 2000.

Action Cycle One	**Data Collection & Analysis**	**Key findings**
Major foci: 1. To investigate the effect of design changes made as a result of the previous round of formative evaluation. 2. To compare the way the program was used by students studying the new PBL course, with our experience from the previous traditional course.	1. Anonymous written questionnaire collected from students on completing program 2. Observations of student use of particular screens were noted 3. General observations of student progress through the program were compared with previous student difficulties. 4. Author attended tutor briefings before and after the relevant 'Problem-of-the-Week' to monitor how the program was presented to students and tutors, and to gain tutor feedback about student comments. 5. On-line student noticeboards were monitored for any feedback directly from students. All questionnaire responses were recorded and collated with observations, both by the author and tutors.	• Students enjoyed the model-building exercise, but most found it very challenging, and frustrating to get started • Students were confused about the terms used for naming regions of the brain • Students did not use the practise screen for its intended purpose • Students were confused about the concepts of excitation / inhibition • Students forgot the colour codes and graphical representation of the tools • Most students did not notice changes in rate of signalling • Students are confused what to do when finished building their model • The built-in case study was not viewed by students
Action Cycle Two	**Data Collection & Analysis**	**Key findings**
Major foci: 1. Have the modifications introduced as a result of the 1st cycle of evaluation been effective in resolving the problems identified? (see Table 20.2 for details of these modifications). 2. Does this program help with student learning of the key concepts?	1. Questionnaires and observations as described in 1-3 above, but focussing on the impact of change made since Cycle 1. 2. Students completed a short (3 MCQ) test prior to and after completing the CAL – (tests matched but anonymous) All questionnaire responses were recorded and collated. Pre- and Post-CAL tests were marked and statistically analysed. (Wilcoxon Matched-Pairs Ranks test).	• Students still found the model-building challenging, but achievable, and the level of frustration observed was much reduced. • Most areas of confusion identified in Semester 1 have been resolved by the modifications introduced. • Students are still experiencing difficulty with the concept of inhibition, (particularly the removal of inhibition) but the questions are now more advanced than previously • Student performance on the tests showed significant improvement on Questions 2 & 3, but Q1 appeared to be too easy! (most got it right before and after the CAL). (See Table 20.3 for test results)
Future Directions		
A further cycle in 2001 will evaluate the current version with Medical students in the PBL course. We will explore ways of improving student understanding of inhibition, and we may repeat the pre- and post-CAL tests with Medical students to gain more information about the student learning outcomes.		

focussed on the key evaluation questions for that cycle.

The author was introduced to students as the programmer of this CAL, but also has a strong background in Physiology, and was effectively acting as a senior tutor during all evaluation sessions.

6.3 Pre- and Post-CAL tests

A short test, of 3 multiple-choice questions, was given to students at the start and again at the end of the CAL session (Semester 2 cycle only). A copy is included in Appendix 20.2. Tests were anonymous but coded, to allow matching of pre- & post results. Tutors were instructed not to assist students with this test, but full answers were provided in the week following this CAL. Each question was designed to cover a particular learning objective, which had been previously identified as an area of difficulty. Question 1 was on the definition of inhibitory neurones, Question 2 was on ways of achieving negative feedback, and Question 3 was on regulation of blood pressure following haemorrhage.

7. Results of Evaluation Cycles

7.1 First Cycle

Cycle One was conducted with 49 students (out of an enrolment of 180) attending a voluntary evaluation CAL session, in Semester 1, 2000. All students attending the session completed a written questionnaire at the end of the session, and observations of student use of particular screens was noted. Attention of this cycle focussed on modifications introduced as a result of a previous cycle (Weaver, 1999). In particular, previous evaluations had revealed students had experienced a great deal of frustration in getting started on the model-building exercise, and several causes for this had been identified, one of which was the large cognitive load associated with learning how to use the tools provided, identifying the graphical representation of components of the nervous system, and at the same time trying to build a difficult model. Several modifications have been made in an attempt to reduce this load, the key one being the introduction of a practise screen to encourage familiarity with the tools and animations etc involved. This cycle of evaluation concentrated on student use of these new features, and attempted to determine their effectiveness.

Analysis of the questionnaire, combined with observations and tutor feedback, revealed that students were still experiencing a great deal of difficulty and frustration with building their model, and amongst other findings, were not using the practise screen in the intended manner. The key findings are summarised in Table 20.2.

Students reported the best-understood parts of the program were in the roles of different efferent neurones, but the number of responses for each different answer to this question were low. Least-understood was the naming of regions of the brain, followed closely by problems understanding the concept of inhibition ("Do inhibitory interneurones increase or decrease signal, or have the same amount of signal but different neurotransmitter?"), both of which accorded well with our own observations. Most liked were the animations and visual representations, and the hands-on approach of constructing their own model, and least popular was the perceived lack of explanations – many students asked for more directive hints ("Just tell me what to do.") and more text they could copy into their workbooks.

26 out of 41 respondents thought the CAL was relevant to their Problem of the Week, and a further 5 students believed it was important material for their course, although not directly relevant to the Problem of the Week. Medical students rated their own understanding of this topic prior to the CAL as 2.8 (1=Understood topic not at all, 5= understood very well), and this improved to 3.8 after the class.

After analysis of the Semester 1 data, the project group met and decided on a range of modifications to the program. These responses are also summarised in Table 20.2.

Table 20.2. Summary of Action taken as a result of Cycle One evaluation.

Design issues (from Semester 1)	Modification introduced (for Semester 2)
Brain regions: Students experienced difficulty with the functional names given to regions of the brain– due to our use of terms which are also applied elsewhere.	• The brain regions were re-named, keeping functional terms, but avoiding terms which are also used to describe the end effects of this system.
Inhibition: Students were confused about the definition of excitatory vs inhibitory – what exactly makes a neurone inhibitory? We have not encountered this problem before, but this confusion is highlighted by the problem of naming of brain regions.	• Existing definitions of excitation and inhibition were clarified, and we attempted to increase the viewing of these definitions by making the hypertext definitions appear automatically at the end of a popular animation , as well as by the existing link.
Practise screen: This screen was introduced to reduce the large cognitive overload experienced by students starting on the model-building exercise. The current evaluation found that students were not using these practise features built into the CAL – mainly because it was not clear that they could do so.	• The title and instructions of the Practise screen were changed, to highlight that this is for practising using the tools.
Colour and graphical representation: Some students reported that while they were building their model, they forgot the colour coding / graphical representation used to depict different elements of the nervous system. (It was hoped that use of the practise screen would familiarise them with this, but these students may not have used this screen.)	• A box showing examples of the nervous system elements was included on the practise screen, and same box was also included on the main model-building screen, accessible by clicking on an 'information' button.
Rate of signalling: Most students did not notice the changes in rate / number of signals (action potentials) moving around their model, adding to the confusion about inhibition, since they did not notice when the signal increased or decreased. Also, they were unaware that they tested their circuit by increasing the original signal (increasing blood pressure at the receptor site) – the button they clicked to do this was named "Test Circuit", so gave no indication of what this test was.	• The first time the model is tested and an animation is run, a dialogue box appears to prompt students to consider the rate / magnitude of the signal moving around the circuit. • The "Test Circuit" was renamed "Raise BP", and clearer explanations provided about how the circuit is tested.
Finishing: Students are confused what to do next when they reach the end of the model-building exercise.	• A new screen ("Summary") was included, after the model-building exercise, to summarise the major points of the tutorial.
Case study: A case study (3 screens of a large cartoon image and small amount of text) had been included since the last version, and was intended to give some applied context to the main learning issue. The current evaluation revealed that very few students even saw this case study.	• The case study was moved to be the first item in the Contents menu, and screens were re-positioned, so that students who do not use the Contents menu to navigate (ie those who just click on the right arrow to proceed through the program linearly) will still view the case study.

7.2 Second Cycle

Cycle Two was conducted in two stages – firstly with 80 2nd year BioMedical Science students in August, and then with 170 2nd year Science students in October. The same evaluation methods were used by both groups, and included a similar questionnaire as previously, observations and tutor feedback as well as pre- and post-CAL tests, in an attempt at summative evaluation. Again, observations focussed on the effects of modifications introduced since the previous cycle, and particularly on whether student use of introductory material and the practise screen was improving their ability to get started on the model-building exercise. All students were encouraged to complete the questionnaire, and no students refused to do this.

Results from the second cycle of evaluation were very encouraging. Nearly all students used the practise screen in its intended manner, and fully completed the mini- model-building exercise contained there. This appeared to have the desired effect of reducing the cognitive load previously found with the major task of the program, and was reflected in generally much more positive statements about the program from the students. Classroom discussion had moved from the technical difficulties of using the program or interpreting the feedback statements, to more physiological investigation of the reflex circuit, and tutors all reported that they were challenged more than they had ever been to resolve wider-ranging areas of discussion, as students attempted to integrate the topics covered in this CAL with knowledge from other sources. Other areas of difficulty previously identified (eg. confusion over naming of brain regions) were not reported and so are no longer apparent.

Students reported the best-understood areas of the program related to the overall physiological responses and control of blood pressure ("I now understand the effects of changes in blood pressure on sympathetic and parasympathetic activity"), which is very encouraging. Least understood was the role of the inhibitory interneurone, particularly the concept of decreased inhibition producing an increased response. The most popular aspect of the program was again the animated model-building exercise, and the high level of interactivity ("Building the circuit myself, rather than just reading and answering questions, required more thought and really improved my learning"). Responses to least popular were much less than previously seen, with the highest number of responses being "Nothing", followed by "Not enough explanation". Observations by both the author and tutors revealed that no students claimed negative feedback would overcorrect blood pressure beyond its set point, a common student misconception reported by academic staff teaching in previous years.

Overwhelmingly, both groups of students believed the CAL was relevant and appropriate for their course ("helped reinforce what was covered in lectures and extended some of the topics covered"; "I wouldn't have understood the lecture material without the tutorial"; "Pitched at a level that can be understood in 2nd year"). Most students also thought it helped to integrate material from different lectures or different subjects ("Autonomic nervous system and cardiovascular physiology were done separately in lectures so this was good to integrate them"; "Covers a number of topics in both our core subject and also aids in consolidation of material from Pharmacology").

BioMedical Science student rating of their own understanding of this topic increased from a pre-CAL rating of 2.2 (1=Understood topic not at all, 5= understood very well) to a post-CAL rating of 3.7. Science students' perception of their understanding increased from 2.4 (pre-CAL) to 3.5 (post-CAL).

7.3 Pre- and Post-CAL tests

Answers to the three multiple-choice questions were analysed in an attempt to determine whether the CAL session had achieved an improvement in student understanding of the key concepts. Results of this are shown in Table 20.3. It was recognised that any improvement in a test score may not arise purely from the CAL itself, but that the pre-CAL test may focus student attention on the particular areas, which would not happen if no test was conducted.

A difficulty in analysis arose because there were 2 correct answers to question 2. This was deliberate, as one of the key learning objectives of this program is to identify and understand the two different methods of

Table 20.3. Results of pre- and post-CAL tests.

BIOMEDICAL SCIENCE – AUGUST 2000	**PRE-CAL**	**POST-CAL**	**Significance**
Question 1	0.85 ± 0.36 (n=75)	0.89 ± 0.31 (75)	N.S. (p=.496, n=75)
Question 2	0.58 ± 0.26 (75)	0.77 ± 0.25 (74)	$p < 0.001$ (n=74)
Question 3	0.36 ± 0.48 (75)	0.49 ± 0.50 (74)	N.S. (p=.185, n=74)
Whole test	1.79 ± 0.66 (75)	2.13 ± 0.59 (75)	$p < 0.005$ (n=75)

SCIENCE – OCTOBER 2000	**PRE-CAL**	**POST-CAL**	**Significance**
Question 1	0.84 ± 0.37 (n=124)	0.90 ± 0.31 (115)	N.S. (p=.18, n=115)
Question 2	0.48 ± 0.27 (123)	0.67 ± 0.34 (117)	$p < 0.001$ (116)
Question 3	0.24 ± 0.43 (123)	0.50 ± 0.50 (115)	$p < 0.001$ (114)
Whole test	1.56 ± 0.58 (124)	2.03 ± 0.59 (117)	$p < 0.001$ (117)

Statistics used: Wilcoxon Matched-Pairs Ranks Test

negative feedback, and we were interested to see whether students understood that there were 2 mechanisms involved. However, where students only selected one correct option, it is impossible to tell whether they believed there was only one mechanism, or whether they did not read the (bold) instruction at the top of the test that there may be more than one correct answer. The following results are based on students receiving 0.5 marks for one correct answer, and only receiving the full mark for both correct options.

Question 1 was not difficult to work out, or at least take an educated guess at, and this is reflected in the group results – a high number of students answered this correctly prior to the CAL, so it was difficult to see a significant improvement in performance. Performance on Question 2 improved similarly in both courses, with the BioMed science students generally performing better both prior to and after the CAL, but showing about the same level of improvement.

Performance on Question 3 was lower than expected, given that it is very similar to a question on the Tasks sheet which students had been working on. It was observed that a few groups of students did not know the definition of haemorrhage – some said it was a bruise, others used the word clot. The question on the Tasks sheet refers to blood loss, so the different term used may have led students to believe this was a completely different question. But since most students completed the test without discussion, as instructed, it is impossible to conclude where they had difficulty with this.

From observations only, we tend to believe that the CAL session itself was responsible for the improved performance on questions 2 & 3, since we did not observe students referring back to the questions during the class, or discussing these topics more than in similar sessions without tests, even though they had been informed they would be undertaking the same test at the end of the session. Even when specific reference was made in discussions with tutors to points which had been included as options on the multiple-choice questions, no students commented on this or seemed to recognise these from the test.

8. Conclusions

Both stages of Cycle Two of the evaluation study have revealed that student frustration with building the model has been reduced and the desired student learning outcomes appear to have been achieved. Students have generally enjoyed using the tutorial, and in a separate evaluation study taken over the whole Semester 2, have rated this CD-ROM the best of all the CAL sessions they have undertaken. The features most popular are the interactivity, or hands-on approach, and the animated responses to represent physiological mechanisms operating. Students report that concentrating on the concepts involved, rather than the quantitative detail, helps them achieve a deeper understanding ("Helped to visualise the concepts and apply them to problem-solving"), and improves their recall of the concepts later ("Easier to understand and remember concepts if you put them into practise"). Student discussion of these learning issues is greatly increased when group work is encouraged (eg. in smaller computer laboratories, where computers must be shared). One Medical student who first completed the CAL working alone, and then repeated the tutorial in a group setting, wrote that "Having demonstrators and other students to discuss the questions was great — I understood the model much better after discussing it than when I was alone".

The process of Action Inquiry has allowed us to evaluate different versions of the CD-ROM, not just for interface or useability issues, but on the whole learning experience it offers to students, and to systematically identify areas of concern, address these issues in an appropriate manner, and to focus further evaluation rounds on the impact of these changes.

9. Future Directions

Future cycles of evaluation will investigate the use of the current version of the tutorial by Medical students, who are scheduled to use the CD-ROM in Semester 1, 2001. This cycle will concentrate mostly on summative evaluation, but will still include open-ended questions to detect any unforeseen difficulties. Summative evaluation results will be compared with the results from the current study on student learning outcomes, to compare students from the different curricula under investigation.

Several Physiology Departments at external institutions, both national and international, have been trialing this CD-ROM with their students, and feedback has been positive. It is also being trialled with students from different disciplines (eg BioMedical Engineering). The CD-ROM in its current form is being released for commercial sale in December, 2000 (Weaver, 2000).

10. References

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11. Appendices

To conserve paper, the Appendices to this report are only available at

http://cleo.murdoch.edu.au/projects/cutsd99