A Computer-Facilitated Collaborative Learning Environment for Tertiary Students

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Abstract

A student-centred collaborative learning environment (CLE) has been developed as a lecture replacement. A specific aim has been to enhance students' learning of concepts that are considered difficult using traditional methods. Central to the environment has been for students to learn in small groups with the computer being an interactive medium to guide, prompt and assist the group (and individual) learning. Their tasks within the CLE sessions are designed to encourage peer-learning and peer -teaching, with additional facilitation from a tutor and printed resources.

The majority of the program is structured around cost-efficient web-delivered tutorials incorporating re-useable interactive components. These are complemented with several stand-alone computer-based learning tutorials, some of which have been developed in-house for students to construct their own models of physiological mechanisms. The final learning strategy uses computer-facilitated semester-long investigative projects aimed to enhance the student's ability to organize physiological information, communicate their knowledge and start developing their critical reasoning skills.

The CLE appears to enhance student learning, at least as assessed by traditional examinations. Marked improvements in the examination performance were observed between students who were considered to effectively participate in the CLE sessions compared with those who did not. There was also a decreased failure rate for the poorer performing student group. The data does not allow us to relate this improvement to any

particular attribute of the CLE. Student surveys and tutor observations suggest that the evolved form of our CLE provide many attributes that encouraged student participation in effective learning.

Aims

Our principal objective was to develop and implement a new multimedia learning environment for second year Science Students in physiology that extended, enhanced and replaced some of their lecture experiences. This integrated and collaborative learning environment (CLE) was developed to broaden the range of learning formats and experiences, offering a variety of learning strategies and resources to develop and enhance students' independent learning skills.

Our concept of a collaborative learning environment (CLE) encompasses:

- the combination of a physical space that emphasises the strength of group interaction. We particularly wished to encourage student interactions in a learning environment to produce effective peer-learning and peer-teaching opportunities.
- the use of a tutor as a facilitator , to guide and assist (but not teach), and
- the virtual classroom of the Internet that provided linkages outside scheduled sessions and additional resources for developing personal learning skills.

An important component of the CLE was to bring different experiences to students learning. This diversity was essential to address the wide range of backgrounds of the students entering our courses, such as their achievement levels, approaches to learning and cultural backgrounds. Approaches included introducing scientific principles and methods for investigating physiology (eg simulated experiments), and using a diverse range of computer-aided interactive teaching formats. Importantly these approaches were not designed to stand alone, rather to integrate with other learning resources such as lectures and printed texts.

Finally, time was allocated for continuous self-evaluation and reflection. Course evaluation occurred twice in the year and included student surveys, interviews and detailed analysis of students' examination performance

Background:

There is broad recognition that traditional forms of university course delivery are inappropriate in preparing students for a dynamic workforce in a post-industrialist, knowledge society (Drucker 1995, Lohrey 1995). Where it has been successfully implemented, collaborative learning is recognised as a potent transition factor in supporting the development of higher order cognitive abilities (Johnson & Johnson 1992).

The global aim in our science teaching in physiology is to generate a curriculum specifically to develop in our graduates some understanding of the skills required of them as practising scientists. Emphasis is given to understanding the experimental, research, theoretical, communication and critical reasoning base of the discipline. Historically this has been separate from our approach to the teaching of medical students, with its emphasis on clinical relevance.

- In the 1980's initiatives were introduced with the aim of improving the overall performance of the poorest performing students. An example was the producing of revision questions and model answers after each lecture sequence. No improvement was seen in the poorest achieving student group.
- From 1993, the Department of Physiology has been broadening its teaching strategies for second year science students by supplementing its teaching by developing multimedia tutorials, supported by special purpose grants, such as CUTSD and special University of Melbourne grants. Initially the computers used were those obtained in1992 (when undergraduate physiology teaching laboratories were upgraded with 64 Mac IIci's and 64 MacLab recording systems). Today the Department supports a separate dedicated computer laboratory for the CLE approaches.
- In 1994, the Physiology Department increased lecture time for these students from 2 to 3 per week. The additional lecture was introduced to provide opportunities for lectures to explore issues with the class, without providing new topics, but again this extra teaching produced no discernible difference in students' performance.

- In 1997, the Department decided to introduce fortnightly scheduled 3-hour sessions of computer assisted learning. Initially these CAL sessions were used to revise lecture material. Tutorials were based on HyperCard programs, produced in-house by one of the authors (Chemistry's 'Tutorial Tools' by Paul Fritze), and a variety of other standalone tutorials obtained nationally and internationally. However, although the in-house tutorials were well received, the standard of external tutorials was very mixed.

In 1998, we decided to produce a coherent set of in-house tutorials specifically designed for our students, supplemented by a select few of the best available standalone tutorials. Our highly interactive standalone tutorials were too costly and too time consuming for producing and delivering 24 weeks of material. The content was delivered more economically on an Intranet for a Web browser, using the templates and tools developed in association with Paul Fritze of the University's Multimedia Education Unit. The model for tutorials was that the students work on a problem in groups of three with the computer providing questions, feedback and hints as they proceeded with calculations and exploring issues. These 1.5 hr/week CAL sessions were not compulsory and were held in a Science Faculty Multimedia Computer Laboratory remote from the Department. There was no formal assessment of this component of the course. Attendance fell over each semester, largely because of the many technical problems experienced with the unsatisfactory maintenance of the software and hardware and the remoteness of the laboratory from the support systems within the Department. There was not significant change in student performance.

For the 1999 teaching year the Department of Physiology equipped a refurbished laboratory with 15 iMac computers and a G3 server. Additionally, we decided to introduce group learning of a topic covered in the curriculum, and to assess student participation. The duration of these computer assisted learning sessions was increased to 2 hours. This all helped to emphasise that the CLE as being important as lectures.

The Nature of the Collaborative Learning Environment in 1999

The CLE sessions can be regarded as a medium between students who actively construct meaning and skills, using resources of the environment that include discipline content, methods and experiences, such as laboratory work, demonstrations, real-life experience and particularly social interactions.

The Physical Work Space

Each collaborative learning environment (CLE) session accommodated 42 students normally working in groups of three on a computer assisted learning (CAL) package presented on an iMac computer. Groups of three were chosen as is said to be the optimum group size for interactive computer programs. A G3 Server used AppleShare 6.1 IP to network the 14 students' iMacs and the tutor's iMac. The tables and benches were arranged to encourage groups to talk and argue in a relatively noisy working environment. The tutor's approach further emphasised the friendly and relatively informal learning environment.

The CLE Sessions

Sessions were of 2 hours weekly. There were 12 sessions in each of Semester. This part of the course was assessed in 1999 and counted for 5% of the course marks (see Assessment). Most students enrolled for CLE. Attendance was maintained throughout semester in this new facility.

The Computer Assisted Learning (CAL) Component

The overall approach to our CAL development was to use a *constructivist* approach and addressed both the pedagogical and instructional design issues from the outset, such as using guidelines from the work of Reeves and Harmon (1994) that was designed for the evaluation of completed multimedia. We used a group development model with assistance from education experts, instructional designers as well as academics and multimedia authors who developed and delivered the material on the Web.

It was an iterative process, with formative assessment with students throughout the development process used to modify the tutorials in subsequent versions.

A true multi-media approach was adopted where students used a combination of paper based work textbook referencing and interactive computer delivered tasks, side by side. The idea was to develop activities that would allow students to build on their own knowledge within their own learning framework, with the computer available as a virtual tutor to help them check their answers, provide a level of tutorial feedback and to pose further questions to stimulate their interpretations. The problems were initially based on the areas of difficulties in physiology that tutors had previously identified.

Students were presented with problems to investigate that required them to examine experimental data, perform calculations, answer questions and keep written records of their work. A wide variety of tasks were presented on the Web, occupying about 1.5 hours of each CLE session.

Production of sufficient material for 24 weeks required an efficient production method that could be easily modified on reflection after evaluation. It also required a high degree of interactivity and variety of modes of operation to ensure student engagement and interest in the tasks.

These weekly problems were supplemented by a variety of highly interactive standalone tutorials that could occupy up to one hour of the CAL activities. These included two of our set of our highly interactive cell-model building multimedia tutorials (Weaver et al, 1996; Kemm et al, 1997; Weaver et al, 1999a & 1999b) as well as externally produced modules. Students were given the opportunity at the end of the session and during the last session of each semester to test their knowledge with a variety of multiple choice and open-ended questions.

The Semester-long Tasks

In Semester One: Students formed extended groups (of six) to investigate one of four problems, such as the consequences of blood doping on physiological systems. This semester long project was introduced with the aim of students learning to be perceptive in their reading of short excerpts of scientific writing. They were required to determine the key phrases in the passage, their relative importance and then to write a concise clear report on their interpretation of that piece. This project was designed to assist students to develop generic skills in determining the level of knowledge required and writing abilities to communicate their knowledge more effectively.

Each group was given a weekly series of tasks, researching the material and progressively developing their interpretation. 30-minute periods at the end of each CLE session were designated for these assignments. Students submitted work on the various stages to their own private computer-based discussion forum. They were provided with weekly feedback on their progressive submissions as a computer checklist, and at the end of six weeks submitted their report to another group for peer review. The reviewing group was within the same class and had worked on the same question, therefore were "expert reviewers'.

We used the learning framework 'TopClass' to allow students to communicate within their group, and to keep track of their progressive work submissions on a semester long project. Science students study such a wide range of subjects that it is difficult for them to form cohesive groups to assist their learning (contrasted with professional courses eg. dentistry), so that electronic communication is encouraged to reinforce the exchanges that occur in the weekly CLE sessions.

The key learning issues were to work cohesively as a group and make consensus decisions about identifying and ranking the key concepts, being able to express themselves concisely, accurately and unambiguously and be able to read another text with some insight as to what is expected... In essence, we aimed to improve their collective skills in negotiation, communication, reading, and writing and reviewing their science.

In Semester 2: We chose to build on the collective skills of collation and consensus writing undertaken in Semester 1with a course aimed at providing students with some insight into critically reading their Physiology. We formally applied reasoning skills to a graded series of reading tasks using the interactive program 'Reason!'.

Although we have reported on this process applied to third year students (van Gelder et al, 1999), the introduction at this time was only done as a trial. Thus it is too early to report on any possible outcomes for equipping students for their third year studies.

Course Assessment

CLE Assessment: The CLE assessment (5% of total) was aimed at rewarding students who effectively participating in these sessions. The mark was based on attendance and tutors' records of student participation (by observation of a group's activities and their submissions, together with individual student's roles in discussion and record keeping). A student must have attended the majority of sessions and deemed to be participating (tutors observation and computer submissions) to have gained a score of greater than 3/5 (rated as good in Table 1).

Examinations: These are described in Section 5.1, which discusses attempts to relate the participation in CLE with examination performance

Evaluation Strategies

We have a number of evaluation strategies in place and collected data in 1998 and 1999, as part of our overall action research strategy.

We have found that students cooperate well with questionnaires and interviews if they are fully informed and can see that they are developmental and that timely feedback will assist their own learning. This is unlike their less enthusiastic response to repeated general University circulated questionnaires on teaching quality in each course. We obtained human ethics approval for these surveys and for us to log important student activities in the computer tutorials

The tutor-facilitators play a key role in the implementation of the program so their impressions of the course are most relevant to understanding student reactions. They made observations and kept records of students' work and participation in the CLE sessions.

We used a comprehensive set of methods to collate and assess information, in order to gain a broad understanding of student reactions and to obtain a more detailed examination of student learning processes and actions..

Student Questionnaires

Questionnaires specific to the CLE were used to survey students' attitudes to various aspects of the CAL tutorials and the CLE sessions, in consultation with our educational advisors.

In addition we investigated students' self-assessment of their approaches to learning. We used a modified study process questionnaire to extend the investigation of deep, achieving and surface learning approaches to learning (Biggs, 1987) so it included additional learner characteristics. This is discussed in application to one of standalone interactive tutorials (Kemm et al, 1997). Such additional information will be used to further analyse the results reported in this article at a later time

The student questionnaires were modified each semester from initially determining general reactions to the style and depth of coverage of the tutorials, to focus on particular issues that were relevant to the efficacy of the collaborative learning environment. The study process questionnaire was administered once each year. The last questionnaires had approximately 70 questions designed to reveal students attitudes and use of the CLE, covering aspects such their pattern of work with the CLE, development of independent learning skills, relevance to the CLE to their learning compared with lectures and their attitudes to group work. Additionally we had some specific questions about their use of the feedback screens in their learning and about the nature of some tutorials, as part of our interest in learning which tutorial styles worked best and for which students. Most questions required students to rank their responses on a 5-point scale, supplemented by several open-ended questions.

Results

Influences on Assessment

The aim was to determine whether any part of the CLE assisted students to have a better examination outcome.

In all courses, examinations consist of multiple choice questions (MCQ), short answers questions (about 10 min) and essays (about 30 minutes).

The written examination questions were set so that one question related to material only covered in lectures, one specifically designed around material obtained in CLE sessions and one question specifically aligned to the semester long CLE project (choice of the four projects undertaken). Multiple choice questions (MCQ) covered the whole syllabus were no different in their coverage from previous years.

Faculty Scores for students' 1st year performances (average of best 75% of subjects) were used to give an idea of the students' previous achievement levels.

Table 1 shows the influence of effective participation in the CLE sessions on the student performance. Student groups were divided into "levels of achievement" based on their previous 1st Year academic performance. Subgroups based on CLE participation ratings used scores of (3.5 and (3, a score that should distinguish combined attendance and participation from non-attendance or attendance alone (see course assessment). The data in table 1 shows a marked polarisation in the mean scores between these subgroups. Thus we are confident that the subgroups did reflect those students who got involved in the material and the learning process and those who did not. The data suggests that there is an improvement in exam outcome for all groups with good CLE participation, with a greater proportional change for the "lower achieving" students. The examination marks have the CLE component removed and are normalised, so a perfect score is 100%.

Table 1. Influence of collaborative group interactive CLE sessions on the results with each subgroup

Prior Faculty Score Grouping	CLE Participation Rating (Subgrouping)	Number in CLE	Mean Prior Faculty Score %	Total Exam Mark %	CLE Score (/5)
≥ 75	good	27	79 ± 0.5	71 ± 2	4.7 ± 0.1 *
	poor/none	11	78 ± 1.0	67 ± 3	1.9 ± 0.4 *
61-74	good	76	68 ± 0.3	63 ± 1 *	4.5 ± 0.1 *
	poor/none	39	67 ± 0.5	54 ± 2 *	1.3 ± 0.2 *
≤ 60	good	63	57 ± 0.5	51 ± 2 *	4.3 ± 0.1 *
	poor/none	39	56 ± 0.8	45 ± 2 *	1.4 ± 0.2 *
* probability < 0.05 for the good and poor/none pairing for each subgroup					

Table 2 shows the distribution of examination marks for science students dependent on their participation in the CLE sessions. The data shows a shift to higher grades for those students participating in CLE, again most significantly for the lower achieving students. Of interest is that 55% of the students in this group who attended and participated in CLE passed. By contrast only 35% passed of the group who chose not to participate/attend.

Table 2 Effects of CLE participation on the distribution of examination of results of science students taking second year Physiology

First Year Faculty Score Grouping	CLE Participation Subgrouping	Range of Physiology Examination Marks				
		>80	70-79	60-69	50-59	<50
≥ 75	good	**30**	**22**	**41**	7	0
	poor/none	18	**27**	**27**	18	9
61-74	good	7	**24**	**33**	**24**	11
	poor/none	0	6	**34**	**34**	**26**
≤ 60	good	0	7	**32**	**22**	**39**
	poor/none	0	0	12	**23**	**65**
Analyses are expressed as percentages of subgroups						

The final observation from the assessment was a marked reduction in the failure-rate to <15% compared with 25% over many previous years. It should be noted that we have not been able to reduce this failure rate in previous modifications of our teaching to assist the students most at risk. The students most at risk are as might be expected, those students with a poor first year performance.

What Worked and Why

As will be seen from the above data analysis, it was not possible to attribute changes in learning outcomes to any particular aspect of our CLE. We know from previous experience that there are many factors that can be detrimental, such as the students not realising that the concepts and material covered in the CLE are as important as lectures, and that students are intolerant of poor quality material or unreliable equipment or software.

We believe that the successful learning outcomes are due to a combination of successful attributes of the CLE, identified by the student surveys and observations, and these are presented in the following sections.

The Physical Work Space for the CLE

The ease of installation and reliability of the iMac computers and the G3 Server has been crucial to the success of the project. They required minimal maintenance since at the beginning of 1999. Also, attention to software protection and automatic overnight reinstatement of any student modifications of the desktop eliminated significant problems that we had in teaching in an open access laboratory in previous years.

Our surveys showed that students preferred to work in groups of 2-3, although a proportion of students still liked to work alone. At the beginning of the Semester, more high achieving students preferred to work alone but most changed their minds, having experienced the benefits of group work. There may also be cultural differences in these preferences. Focus group interviews confirmed these results and the major advantage seen from group work were the interactions and discussions, which were confirmed by the noise levels in the classes.

The scheduling of sessions for group-work was crucial for collaboration, since our experience of other courses with open access computer laboratory sessions shows that most students tend to work alone, a few in pairs and rarely any more per computer. We believe this is a critical issue to encourage collaborative learning, especially in Science where the diversity of courses that students undertake make it difficult for them to find collaborators with similar timetables.

The CLE sessions induced a 'sense of belonging' to a community within a course where the students come from quite disparate backgrounds, generating more of the interactions that exist in our more selective professional courses.

There was identification within each session of 40, rather than just being an anonymous student amongst the class of 350. The open discussions and studying together also reinforced a common approach to scientific investigation and enhanced their appreciation of the philosophical approaches to learning.

The modern, pleasant and comfortable surroundings were found to encourage lively interaction, the main features being the open layout, lighting, carpets and comfortable seating. Furthermore, its location within the Department and easy access to support staff and academics next door showed the commitment of the Department to assisting the students. This sense of personalised support was reinforced by having a tutor look after each class and by providing easy email access by students to staff specialists. Lastly reference should be given to hugely successful paisley 60s style couch in the adjoining corridor, where many successful physiology and non-physiology related communication skills were reinforced.

The Web Delivered CAL Component:

It is not possible to relate the learning outcomes to any specific CAL components. There is insufficient space to describe all the characteristics of the computer-assisted web components that worked well with our students in the CLE sessions, but the highlights are as follows:

- Weekly tasks not only had a Web-delivered component, but also were accompanied by a paper task sheet indicating the scope of the task for the session. This gave the students some take-away material that could be used in later study/reflection. In addition students were required to keep a record book and make notes, do calculations as they progressed, so further reinforcing their learning and providing their own records.
- The developed Web-authoring tools were essential for producing the core of the material for the 24-weeks of CLE sessions in a cost-effective manner. A single important feature over stand-alone programs is that both material and tasks could be updated relatively easily to incorporate new knowledge, or change emphasis in tasks with changes in the staff presenting lectures. The collaboration between the Multimedia Education Unit and the Physiology Department was essential to both bodies, providing Physiology with a suite of Web based tools while allowing the authors the feedback to develop and test them using pedagogical requirements firmly grounded in the context of the real course.
- Students indicated that the diversity of tasks and web-presentations were stimulating and very helpful for their learning. These included calculations with relevant human data, interactive graphing of relationships, open-ended answers to questions, sorting sequences of processes, building models of cellular functions.
- A most popular format was the sorting of sequences of events in a physiological process, which they found challenging and rewarding and generated much discussion as they explored many of the possible solutions. As developers, we did not predict this preference. This emphasised that continuous evaluation of what is working is essential, since academics often misjudge what student will find useful and challenging.
- Students used the textual feedback on what was appropriate or inappropriate about their responses and found this to be very helpful in their learning. The feedback was designed to progressively reinforce students' development of an appropriate framework for their solutions to problems - such as their own summaries with the key features of negative feedback control by hormones.
- While the Students found the content challenging, the computer-aided tutorials gave them a better idea than lectures of the level of understanding required to understand physiological mechanisms.
- Students developed appropriate learning strategies: such as exploring mechanisms using interactive programs, reinforcing lecture material by more study, and by reflection of the material and by redoing components of the CAL.
- They found the interactive model-building standalone tutorials to be challenging and very helpful for understanding some difficult concepts. However, their approaches to using these tutorials is being researched separately (Kemm et al, 1997) and it too extensive to report here.

The Semester-long Tasks

Students undertook the semester long task with enthusiasm, although they were quite frustrated by some features of the TopClass Framework which meant it was less than optimal for our purposes. There was considerable variation in the standards of both the final submissions and the quality of peer reviews, but students generally produced good work.

Not many were able to identify all of the requirements, such as: the key issues in their problem, their relative importance, and then produce concise and unambiguous writing about the problem.

We will be interested to investigate further how these skills are transferred to either their general writing skills under examination conditions or to specific content questions.

Discussion and Conclusions

Learning Outcomes

It is extraordinarily difficult to use traditional quantitative methods to show differences in learning outcomes attributable to a particular curriculum intervention by using traditional statistical methods (Reeves, 1993).

Even if there are reasonable control groups, large numbers are often necessary to overcome the many confounding factors influencing the students in studying in a course, although there have been occasional successes such as (Reeves et al, 1997).

In this study, we were fortunate to have a self-selected control group who did not wish to participate effectively in the CLE. Although less than ideal, we are not permitted to design an experiment in which some students are not offered this learning opportunity. Nevertheless, they did represent a broad coverage of student achievement and there was no difference in the sub-groupings based on their prior achievements (first year Faculty Score).

The significant results show that effective CLE participation was associated with an improvement in learning outcomes of some groups of students when compared with their performance in another subject in the same year,

These improvements were observed in students across the achievement scale with students always doing better if they attended and took CLE. A significant outcome was a marked reduction in the failure-rate to <15% compared with an average of 25% over many previous years. It is of consequence that while CLE enhanced the outcome of the Physiology students most likely to fail (45% ± 2 to 52% ± 2) the same improvement was not evident in their Biochemistry mark, a closely related subject (51% ± 2 and 51% ± 2). This preliminary information gives further support to the notion that the CLE has enhanced learning in Physiology in this low achieving group. It is of note that we have not been able to reduce this failure rate in previous modifications of our teaching to assist the students most at risk. It is possible that the more diverse learning strategies provide these students with new and additional ways to understand and communicate their physiology.

It was not possible to identify the improved learning with any particular aspect of the CLE.
We believe that it is the combination of computer and human facilitated learning environment within which students work together and discuss the subject on a regular basis that has contributed to a general improvement in learning skills and attitudes

Successful attributes of the CLE

The main reasons for our successful delivery a computer based collaborative learning environment were:

- The choice of an appropriate and flexible set of delivery tools that allow development of an appropriate pedagogy for students to learn effectively from the tasks they are given. It is important not to allow one's development to be held up by awaiting the 'latest' version of any delivery tool, but to work our way around it to ensure that one can deliver an appropriate task on time, even if resorting to a greater dependence on written tasks. (We found our productivity far exceeded any previous multimedia development that we had attempted).
- Using the computer's interactivity to focus on concepts not easily covered in lectures, with the CAL not designed to replace all lectures or students' use of textbooks and other resources.
- A generation of a pleasant and friendly learning space is crucial to encouraging students to openly discuss issues and to discover the power of peer-learning and peer-teaching, with supportive staff.

- Choice of reliable software and hardware implementation (e.g. Our experience with iMacs, compared with previous years, meant that staff could concentration on learning issues and not solving technical problems).
- The students need to recognise that learning in the CLE sessions is as important as attending and learning from lectures. Assessment is an important signal that encourages students to attend, but one must be careful not to make it so competitive that students no longer wish to collaborate. We found that allocating 5% for participation in CLE sessions did encourage the CAL to be taken more seriously than previous years, but increasing this will bring on more issues of equity and accuracy of assessment methods.

Further Directions

We will continue to reflect on the student evaluation of the CLE sessions and design of our tutorials will allow us to make adjustments to the Web tasks to make them more effective

In particular we have a specific grant to modify the tutorials for delivery with a new set of tools that are more flexible and adaptable to provide tasks with a greater range of difficulty. (These tools are described elsewhere in these proceedings in an article by Fritze). Our questionnaires and our learning outcomes suggest that the CLE is providing more assistance to the lower achieving students and we would like to present greater challenges and opportunities for the higher achievers.

By identifying the key features that influenced improved performance, a transferable framework could be developed for establishing a successful collaborative learning environment. More specifically, it would help to create the more educative links between instruction, learning and assessment essential for the development of 'deeper' and more durable learning abilities (Boud 1994, Loacker, Cromwell. & O'Brien 1986).

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