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The Rationale and Efficacy of Problem-based Learning and Computer Assisted Learning in Pharmaceutical Education

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This paper explores two modes of teaching at schools of pharmacy and the benefits to be gained using such instructional methods: namely, problem-based learning (PBL) and computer assisted learning (CAL). Possible advantages of PBL over traditional approaches include its greater relevance to the practice of pharmacy, its ability to promote the retention and application of knowledge and its encouragement of self-directed life-long learning. Possible disadvantages include higher costs, both in resources and staff time. The current enthusiasm for PBL seems justified and its use is likely to increase further. CAL aims to bridge the gaps not fully covered by traditional and PBL methods. Using PBL and CAL as a supplementary resource for conventional teaching and learning is desirable for providing optimal opportunities to learn the processes needed to identify and treat drug related problems confronting today's practising pharmacist.

Keywords: Computer simulation; Pharmacy; Problem-based learning; Computer assisted learning

BACKGROUND TO CAL

Computers emerged in an educational capacity as early as the 1950s but did not extend into their present widespread use until after the invention of the microcomputer in the late 1970s (Thomas and Kobayash, 1987). In 1959 Donald Bitier began PLATO, the first large-scale project for the use of computers in education. The several thousand-terminal systems served undergraduate education as well as elementary school reading, a community college in Urbana, and several campuses in Chicago. The PLATO system is probably the best-known CAL project in the world and has been the object of considerable research. The system has been shown to be effective and cost efficient. Thus

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the era of computers in education is little more than 35 years old (Molnar and Andrew, 1990).

CAL is becoming increasingly prominent in education and, as a result, is changing the face of teaching and learning. While the driving force behind such innovation is multifaceted, the desire to increase teaching efficiency (Davies and Crowther, 1995) and quality (Coopers and Lybrand, 1996) have generally been regarded as the major contributing factors.

Burns (1985) wrote a comprehensive, interdisciplinary review in the research literature regarding the use of CAL as a supplement to traditional, teacher-directed instruction. He concluded, "Well-designed and implemented drill-and-practice or tutorial CAL, used as a supplement to traditional instruction, produces an educationally significant improvement in students' final examination achievement." However, research is inconclusive regarding the comparative effectiveness of conventional instruction alone versus CAL alone. Some authors found CAL superior, some have found conventional instruction superior, and still others have found no difference between them (Edwards *et al.*, 1975; Capper and Copple, 1985).

The use of computers to enhance clinical problem-solving in pharmacy has received little attention in the pharmacy education literature even though other health care disciplines have used computers for this purpose.

Studies examining the effectiveness of CAL in pharmacy education have suggested that it is comparable in effectiveness to other teaching methods (Kulik *et al.*, 1986). Clark (1988) found that when learning efficiency and student preferences are variables of interest, well-designed self-paced CAL programmes consistently outperform traditional methods of instruction. Clem *et al.* (1992) have also studied the impact of CAL on students' grades, and concluded that there was no significant difference in examination scores between students who used CAL programmes to learn material on a clinical psychopharmacy clerkship versus students who received traditional lectures. Kinkade *et al.* (1995) found that their computer simulation programme was as effective as their paper case presentation. They recommended that further research be done to investigate the utility of employing other instructional methods for teaching therapeutics.

WHAT DOES CAL PROVIDE THAT TRADITIONAL METHODS DO NOT?

Suppes (1966), author of the first adaptive CAL programme, predicted that developments in educational technology, and specifically in computer usage, would change the face of education in a very short space of time. This prophecy was based on his perception of the unique capabilities of the computer. He saw it as a tool that could be used interactively, presenting materials in novel ways not easily achievable through other media, and with the flexibility to adapt to different learning and teaching styles.

The seamless integration of any text, sound, still and animated images, and motion video under computer control is changing the look and feel of today's educational environment (Jacobs, 1992). These capabilities are gaining popularity because they are very effective in arresting the interest of their users and improving the retention of information by users; the educational capabilities of computers can also be very cost effective (Fletcher, 1990; Alexander, 1992).

There are many products on the market that provide limited benefits over more traditional methods of instructional learning. However, CAL has massive potential to be interactive and thus develop learning through both discovery and exploration (Jacobs, 1992). In CAL the student is constantly required to respond to questions or perform operations, without which the instruction will not proceed. This serves to focus attention on the instructional content.

Research has suggested that the length of time needed by students to learn new topics will differ widely even under ideal conditions. Aptitude for learning is the key factor in these differences. Students with higher aptitude for learning learn new topics within a shorter time than their peers with lower aptitude (Spencer, 1988). CAL is better adjusted to individual variations in students' learning skills than the typical lecture, textbook or TV lesson. Unlike these, CAL advances at the student's own learning pace allowing the learner to control an important part of the learning process. Students can make choices about the order of presentation, the amount of practice presented and the number of repetitions, making the learning process more self-directed.

The results of three meta-analyses of research on CAL at the elementary, secondary and postsecondary levels in American schools found CAL superior to traditional instruction in its effect on learning rate. Several researchers have synthesised the results of a number of individual studies conducted at various levels to see if the results were consistent. This synthesis reveals that elementary level students who received CAL lessons as a supplement to instruction showed faster learning rates than those who received conventional instruction only (Kulik *et al.*, 1985). Research has shown that students using CAL learned the same amount of material in less time than traditionally instructed students and learned more material in the same time (Molnar and Andrew, 1990). The work of Capper and Copple (1985) led the researchers to the conclusion that CAL users sometimes learn as much as 40% faster than those receiving traditional, teacher-directed instruction. A comparative study of learning retention showed that student scores on delayed tests indicated that retention of content learned using CAL is superior to retention following traditional instruction alone (Kulik *et al.*, 1985). Students who learn on the computer remembered as much of the material as did students who received traditional instruction only. Similar results were revealed in studies of CAL with secondary or college and adult populations. However, the gains in achievement were less significant (Beau, 1986).

Some researchers have addressed the cost-effectiveness of CAL. Ragosta *et al.* (1982) concluded that equal lengths of time in CAL reinforcement and the more expensive one-to-one tutoring produced equal achievement. Hawley, Fletcher and Piele (1966) assessed cost differences between CAL and traditional instruction, and concluded that differences were insignificant. They suggested, "The microcomputer-assisted instruction was a cost-effective alternative choice".

When students practice skills on paper, they frequently do not know until much later whether or not they did their work correctly. If they complete work incorrectly, students may actually be memorising the wrong skills. The particular value of computers is their ability to provide immediate feedback, thus informing the student after each question whether they have answered appropriately, and providing further explanatory feedback that is relevant to the answer they have given. This kind of immediate individualised feedback is seldom available during other forms of instruction. This helps students in two ways: "debugging" and retention.

Another major advantage of CAL is that the computer can keep records of students' answers to questions, which can be analysed to provide the lecturer with rapid feedback about students' progress and understanding of topics, allowing appropriate and timely intervention (Heard *et al.*, 1997).

In traditional curricula, students are given a large number of facts but little instruction and limited opportunity for developing strategies for linking information. Research into the clinical reasoning process indicates that it is not the amount of knowledge that differentiates an expert from a novice, but the richness of the connections between that information (Elstein, 1995). The richness of the interconnections makes the information more readily accessible and more useable, which leads to recognition of situations in which it can be used. The educational challenge is therefore to support students in making effective connections between items of clinical information. CAL should be able to enhance this process by creating opportunities for students to practise and receive feedback on these skills.

A current issue facing lecturers in higher education is to learn and teach more in less time (Fox, 1998). There are two traditional demands on academic staff: time for research, and teaching and supervisory activities. It is important to acknowledge these pressures in order to avoid their negative effects on academic staff. The use of CAL as a supplementary resource for teaching and learning is crucial to reducing student contact time for academic staff and releasing more time for research.

CAL IN OTAGO SCHOOL OF PHARMACY

The traditional structures for academic pedagogy have been lectures, tutorials, practical classes, problem-solving exercises and assignments. The development of CAL for learning has generally been seen as an extra learning mechanism for students, either in the form of a self-paced tutorial done in the student's own time or as an aid to revision. Only limited examples exist where CAL has replaced part of the traditional approach to academic learning in higher education. Students are allowed to practice with real data in conditions that simulate reality. Computer simulations provide a safe way to "practise on patients" and avoid the dangerous mistakes students could make in reality.

The use of computers for teaching and learning in pharmacology, pharmacokinetics, dispensing, and pharmaceutical calculations is well described in the literature (Padernik and Walaszek, 1983; Hayton and Collins, 1991). However, studies describing the use of computers to enhance clinical decision-making among pharmacy students are limited (Kulik *et al.*, 1985; Clem *et al.*, 1992; Kinkade *et al.*, 1995). CAL aims to bridge the gaps not fully covered by traditional and PBL methods. Educational goals that could be gained by using CAL include:

1. to keep the education system at the forefront of technological development and students' skills up-to-date with those expected in the workforce;
2. to increase efficiency and productivity in teaching and learning;
3. to enable more self-directed learning, with students as active learners assisted by teachers;
4. to enhance critical thinking and problem-solving skills (PSS) skills in students;
5. to promote an appreciation for the scientific rational behind therapeutic decisions; and
6. to increase student enthusiasm for, and enjoyment of the study of pharmacotherapeutics.

BACKGROUND TO PBL

Traditionally, pharmacy education has consisted primarily of didactic, subject-oriented and knowledge-based teaching. While these are essential methods, they do not provide optimal opportunities to learn processes needed to identify and treat the drug-related problems confronting today's practising pharmacist (Strand *et al.*, 1987).

Research conducted by Chickering and Gamson (1987) suggests that students must participate beyond just listening. In addition to listening, the student must read, write, and participate in classroom discussion sessions. To improve PSS and link basic sciences to clinical practice, medical educators have turned to problem-based learning (PBL) as a partial replacement for traditional didactic approaches to teach basic and clinical sciences.

The terms PSS and PBL are often used interchangeably. Some authors also assume that PBL is a means to the end of acquiring PSS. The two terms, however, are not synonymous. PSS and making clinical decisions are critical skills involving thinking processes directed towards enabling the clinician to take the best-judged action in a specific context (Cervero, 1988; Harris, 1993). One of the controversies that exist in relation to the field of problem-solving is whether such skills can or should be taught, or whether they need to emerge in the process of developing clinical experience (Harris, 1993).

There is continuing confusion about the exact definition of PBL and whether it can effectively replace the conventional curriculum. Different authors describe widely disparate curricula addressing divergent objectives and using varied methods under the name of PBL. The taxonomy of PBL types developed by Barrows (1986) described PBL as an instructional method characterised by the use of patient problems as a context for students to learn PSS and to acquire knowledge about the basic and clinical sciences. "The basic outline of the PBL process is: encountering the problem first, problem-solving with clinical reasoning skills and identifying learning needs in an interactive process, self-study, applying newly gained knowledge to the problem, and summarising what has been learned" (Barrows and Tamblyn, 1980).

Barrows and Pickell (1991) propose that PSS and medical knowledge can be acquired separately. However, recent research in the health sciences has demonstrated that PSS are not separate skills that can be developed independently of relevant professional knowledge and other clinical skills (Schmidt *et al.*, 1990). Similar findings have occurred in other fields (Larkin *et al.*, 1980; Chi *et al.*, 1981). It has been difficult to demonstrate any change in measures of the PSS from the first year of medical school to clinical practice (Neufeld *et al.*, 1981). Similar comments apply to inquiry skills (Norman *et al.*, 1990), which also show little evidence of generalisability or improvement with education. Contrary to the view of Barrows, there appears to be no evidence indicating that one curriculum or another is able to enhance PSS independently of their acquisition of knowledge. Vernon and Blake (1993) define PBL as a "method of learning (or teaching) that emphasises (a) the study of a clinical case either real or hypothetical, (b) small group discussions, (c) collaborative independent study, and (d) hypothetical educative reasoning." Schmidt (1993) proposes a more comprehensive definition of PBL. He suggests that PBL be based on cognitive psychology principles such as "prior knowledge activation and elaboration through small group problem analysis; the construction of problem-oriented semantic networks, including contextual cues derived from professionally relevant problems and the fostering of epistemic curiosity."

It is clear that the debate on PBL is obscured by different views on the question of what is and what is not PBL. The addition of yet another definition of PBL will not solve the problem. We would prefer to return back to the basic elements of PBL and to be aware of the background of the development of this method. PBL in medical education was introduced first at McMaster University in 1969 (Campbell, 1970). Although there are various interpretations of PBL, the McMaster model—where the learning environment consists of small group, self-directed, self-assessed PBL—could be considered the original. The key elements of a PBL curriculum include the following (Pringle, 1998):

1. cases are assigned to students at the beginning of the course;
2. students are active participants in learning, not passive recipients of information;
3. the learning process is lead by students, with faculty as facilitators;

4. students are organised into small groups, with five to six persons in each group;
5. problems (or "cases") are the focus and motivation for learning;
6. problem-solving skills are promoted;
7. new information is acquired through self-directed learning;
8. students develop and enhance their interpersonal skills; and
9. students are encouraged to become life-long, independent learners.

WHAT DOES PBL PROVIDE THAT TRADITIONAL METHODS DO NOT?

Mayer and Greeno (1972) show that different instructional methods produce different learning outcomes. The way in which a topic is taught determines what students can do with the information acquired. Conventional instructional procedures do not always enable students to make appropriate use of what they have learned. Some students know information but cannot apply it in an appropriate or useful manner.

The essential factor in the acquisition of knowledge is that content must be linked to what was previously known. Schmidt (1993) suggests that the extent of prior knowledge in relation to a subject is one of the major determinants of the "nature and amount of new information that can be processed." An exchange of ideas between the participants in the PBL session assists in activating the prior knowledge of the students. This exchange needs to occur before students investigate further resources. The discussion has the effect of preparing the students mentally for subsequent stages of learning by asking them to generate hypotheses.

The cognitive networks, which are restructured during learning, are referred to as schemata. Gagne (1986) defines schemata as "a set of interconnected propositions centring around a general concept, and linked peripherally with other concepts." Depending upon the existing knowledge of the student, a process of accretion, tuning or restructuring occurs to actively change existing schemata. This concept of restructuring may have important implications for pharmacy students who are frequently unable to apply their basic scientific knowledge to clinical situations. It has been suggested that the knowledge of these students has not yet been organised to a point where it can be utilised for this function. Barrows (1985) has proposed learning basic and clinical sciences in a problem-based format in order to structure the knowledge in such a way that students will better remember it and will be able to retrieve it when they need it in clinical practice.

PBL attempts to address the relevance of content within the specific pharmaceutical context. The PBL session assists in tuning students' knowledge (Schmidt, 1993). Discussion involves the learners more actively in medical problems and the challenge of developing solutions provides strong intrinsic motivation for learning (Barrows, 1986).

The closer the resemblance between the situation in which something is learned and the situation in which it will be applied, the more likely it is that transfer of learning will occur. PBL problems frequently use real-life situations. Well-written problems are those that present situations most commonly seen in practice (Albanese and Mitchell, 1993).

PBL enables students to develop the skills necessary for self-directed learning (Young, 1998). The emphasis on self-directed learning will encourage students to reflect upon and control their own learning activities and develop self-regulatory skills conducive to lifelong learning (Barrows, 1980).

PBL encourages student leadership and participation. Students studying in a PBL environment were found to have more interactions with faculty and performed as well or better than lecture-based learners (LBL) on broad examinations (Pringle, 1998).

Medical students receiving instruction under PBL curricula have been shown to perform better in the retention of knowledge, general PSS, ability to integrate basic science concepts into clinical problems, self-directed learning skills, and intrinsic interest in subject manner (Dolmans and Schmidt, 1996).

Compared to lecture and discussion, PBL is an instructional method that permits a high degree of inquiry, learner control, and active participation. In conclusion, according to Barrows (1986), PBL fosters activation of prior learning, high motivation to learn and the development of self-directed learning skills. In the health sciences, moreover, PBL promotes the structuring of new, accessible knowledge in clinical contexts and the development of effective clinical reasoning skills.

PBL IN OTAGO SCHOOL OF PHARMACY

Development of teaching methods to enhance critical thinking skills is a well-recognised objective for improving pharmaceutical education (Barrows, 1988). Consistent with this goal, Otago school of pharmacy implemented PBL in the undergraduate programme. The major objectives were to create an active learning environment for all students and to provide an appropriate context for students to begin to develop the skills needed to actively evaluate patient data, identify drug therapy problems, and apply a consistent strategy for clinical problem-solving and care planning. PBL is conducted in small groups of 4–5 learners who are presented with structured, multi-staged, professional situations and with problems to solve. These situations are designed to address carefully selected learning outcomes in order to guide students through their development programme. The group meets formally to address the case using a problem-solving structure, and the learners determine the schedule for working on the problem. As the discussion develops, learning issues and diagnostic hypotheses are generated and listed. This step in PBL is to examine the learner's existing or prior knowledge. After this initial case information has been exhausted, the issues and hypothesis are prioritised, clustered and assigned. Thus, each student has a number of tasks to complete and issues to explore. The students then enter information gathering mode as research is conducted. They are encouraged to utilise a variety of information sources during this process such as texts, journals, etc. The use of additional learning resources will further develop student learning. The presentation of problems is progressive disclosure, which allows students to learn the facts of a case gradually, just as they would by actually collecting information from a patient and accumulating data over a period of time. Researching information is an important component of the process, and enough time is allowed for students to research and assimilate information. Students work together to identify facts and information gaps, propose hypotheses or explanations of facts, and identify areas for further learning. The instructor or "facilitator" in PBL listens actively, and encourages critical thinking, keeping discussion on track, challenging students' reasoning processes, providing feedback and guiding the learning process rather than imparting information. At the end of the entire case, students engage in self, peer and case assessment. Thus, information is shared and discussed. During this discussion the viability of existing diagnostic and therapeutic hypotheses are assessed and a second round of learning issues is established. This sequence of events continues, with the introduction of supplementary case information by the tutor at strategic points during the process, until the case has been solved or its usefulness expended.

WHAT DOES CAL PROVIDE THAT PBL METHODS DO NOT?

The design of PBL includes dependence of students on the group for the unfolding of the problem and generation of solutions, where problems are solved by dividing the work (i.e. learning issues) and reporting information back to the group. Individual members may learn only one aspect of the case in depth. This design complicates the ability of PBL to foster mastery of important information. CAL tends to leave the student to reason independently and to contend with his or her learning as an individual effort. One can argue that this does not build the skills it takes for the students to operate as a part of a team. A counter argument is that the skills learned in PBL teams are not the same as those required for developing effective and independent pharmaceutical reasoning skills needed for the graduate to face the real work of a pharmacist.

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