An Empirical Study Comparing the Learning Environments of Open and Closed Computer Laboratories

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ABSTRACT

In Computer Science and Information Systems courses, where the computer is an integral part of the course, there are two main ways in which the practical component of the course, the computer laboratory class, may be organized. They may be closed laboratories which are scheduled and staffed in the same way as other classes, or open laboratories where the students come and go as they please. In universities in the United States, the open laboratory is more common, whereas in Australia, it is the closed laboratory that provides the practical experience for students. This study investigates differences between students' perceptions of some aspects of the learning environment of open and closed computer laboratories, and also investigates differences in student outcomes from courses that adopt these two approaches to organizing computer laboratory classes. The use of closed laboratories requires more resources in terms of physical space and equipment and greater commitment on the part of the faculty. This study investigates whether the extra resources and commitment lead to an improvement in student outcomes. In the study, two previously developed instruments, the Computer Laboratory Environment Inventory (CLEI) and the Attitude towards Computing and Computing Courses Questionnaire (ACCC) were used. The CLEI has five scales for measuring students' perceptions of aspects of their laboratory environment. These are Student Cohesiveness, Open-Endedness, Integration, Technology Adequacy and Laboratory Availability. The ACCC has four scales, Anxiety, Enjoyment, Usefulness of Computers and Usefulness of the Course. Of the environment variables, significant differences in the means were found for Open-Endedness, Technology Adequacy and Laboratory Availability. There was also a difference for Anxiety. There was no significant difference in achievement by students on the courses.

Keywords: Computer Laboratories, Learning Environments.

1. INTRODUCTION

The first electronic computer was developed in the 1940s, and up to the mid-1950s, the use of computers was restricted to scientific and engineering applications. Commercial applications of computers started in a small way in the late 1950s and expanded rapidly over the following 20 years. However, up to 1980, computer usage was not very widespread. At that time, organizations used a central computer and had a specialist Data Processing or Information Systems Department. These departments were usually the only part of the organization with access to computers. This situation changed with the advent of the microcomputer in the 1980s, and later the local area network. Following their introduction, the use of computers spread to all levels of organizations and today it would be unusual to find a desk in any organization without a workstation on it.

This evolution in the use of computers is mirrored in the provision of computer education and training. Initially, computer manufacturers ran specialist intensive courses in programming and operating systems over three to five days; this practice continues and indeed has been extended to cover many aspects of the computing and communications industries. The first university computing courses started in the 1960s. They had titles such as Computer Science, Computer Studies or Electronic Data Processing and were intended for the computing specialist, who would start their careers as programmers or systems analysts. Computer Science has established itself firmly as a discipline in most universities. The other terms mentioned have, in general, been replaced by Information Systems, which has emerged as a discipline in its own right with its focus on the application of computers to business problems. All academic programs within these disciplines involve the study of programming as the means by which computer-based systems are developed.

The introduction of the microcomputer in the early 1980s led to the wider use of computers throughout post-secondary education in programs such as business, education and engineering. Here the computer is often used as a tool to assist in learning, as a means of delivering educational material and for on-line assessment. More recently, the availability of multimedia has extended the use of computers to graphic design and architecture, and the Internet has made the workstation an invaluable educational and research tool. This has led to the inclusion of some form of computer education in virtually every discipline at the university level.

2. COMPUTING LABORATORIES

The one aspect that most computing courses, both specialist and non-specialist, have in common is the use of computer laboratories. The use of a laboratory as part of a computing course began with the advent of interactive computing in the 1970s. It is understandable that laboratories play such a prominent role in such courses given that using a computer, particularly for programming, is perceived as a skill which cannot be learned by simply reading a book and needs practice in order for it to be acquired (Azemi, 1995). This skill must be mastered before any progress can be made, and laboratory classes provide an opportunity for students to gain proficiency. However, proficiency is not the only aim of a computer laboratory class. Other aims would include:

- familiarizing students with the computing environment;
- reinforcing material taught in the lecture;
- teaching students the principles of using computers;
- providing closer contact between staff and students;
- stimulating and maintaining interest in the subject;
- teaching theoretical material not included in lectures;
- fostering critical awareness e.g. avoiding systematic errors;
- developing skills in problem solving;
- simulating conditions in an information systems development environment;
- stimulating independent thinking;
- developing skills in communicating technical concepts and solutions;
- providing motivation to acquire specific knowledge;
- bridging the gap between theory and practice.

(adapted from Boud, Dunn, & Hegarty-Hazel(1986))

The joint Association of Computing Machinery – Institute of Electrical and Electronic Engineers (ACM-IEEE) Curriculum Task Force recommended that introductory computer science courses should be supported by extensive laboratory work (Denning et al, 1989; ACM/IEEE-CS, 1991). The ACM SIGCSE (Special Interest Group on Computer Science Education) Working Group on Computing Laboratories published guidelines for the use of laboratories in computer science education (Knox et al, 1996). Their report was predicated on a number of assumptions, one of which was that laboratory experiences are relevant almost all computer science courses across all levels from literacy and language courses for non-specialists to graduate level theory courses. In a collaborative effort, the Association of Computing Machinery (ACM), the Association for Information Systems (AIS), the Association of Information Technology Professionals (AITP), and the International Conference on Information Systems (ICIS) developed guidelines for an undergraduate Information Systems Curriculum (Davis, Gorgone, Cougar, Feinstein, & Longenecker, 1997). In their report, they identified three types of laboratories, the structured laboratory, the open laboratory and the specialized laboratory. The structured laboratory is a closed or formal laboratory (Prey, 1996; Lin, Wu, & Chiou, 1996). It is scheduled in the same way as lectures and tutorials with specific exercises being set for students. Such laboratories are generally staffed by the instructor who is available to help guide the students. On the other hand, open or public laboratories are provided so that students may complete exercises and assignments outside scheduled laboratory classes. Students are allowed to come and go as they please with technical assistance, if any, being provided by laboratory assistants who are often senior students. For open laboratories an instructor assigns a problem and students work on it in their own time usually individually but sometimes in groups. Finally, there is the specialized laboratory, which is provided to support up-to-date programs with state of the art technology. Examples of specialized laboratories are systems development laboratories, providing access to CASE (Computer Assisted Software Engineering) tools, data communication laboratories with hands-on access to network management tools, and decision conferencing laboratories with access to group support systems software (Davis, et al., 1997).

There are a number of ways in which a computer laboratory may be staffed, and these can affect the way in which the instructor interacts with the students. For closed laboratories, it is usual for these to be staffed by the instructor themselves, with an alternative being a graduate teaching assistant. In either case, the instructor would be able to give a high level of interaction, answering questions on advanced concepts, as well as on technical details. One advantage of closed laboratories is that they tend to encourage both active learning (Huss, 1995; McConnell, 1996) and cooperative learning (Prey, 1996).

The level of assistance provided in open laboratories varies from none to the provision of technical help supplied by non-academic staff. Many universities use undergraduate student assistants in this role to help students with basic questions. Often, because of staffing problems, this is the only help that students get, particularly in open laboratories. This can lead to senior students passing on bad practice to their junior colleagues and generating a philosophy of ‘getting it to work at all costs’ (Newby, 1994). One reason for providing technical help in laboratories is the need for rapid feedback (Pitt, 1993). A student can spend hours looking at a program which will not compile and which produces an unhelpful error message, when all that is needed is for a semi-colon to be removed.

Institutional support is necessary for the success of computer laboratory classes. The provision of computer laboratory facilities does not just involve a room full of workstations. There must be an infrastructure of technical support for both hardware and software, together with a help desk available to both staff and students. A number of issues arise from using computer laboratories as an integral part of teaching and learning, and these include technology, both hardware and software, physical environment, organization, assignment difficulty, technical support, and staff training. Problems can arise when any of these aspects are not addressed (Pitt, 1993). The hardware must be capable to running the software satisfactorily and in the case of shared resources such as multi-user systems or networks, able to handle the required number of users. The software must be suitable for the curriculum, and enable some of the requirements of laboratory classes given above to be satisfied, as deemed necessary by the instructor. At the very least such classes should teach practical skills and reinforce the theoretical aspects covered in lectures and tutorials. Also, the fundamentals of such software must be able to be mastered in a relatively short period of time, for example, half a semester. It has been recognized that some software is extremely complex (Knox et al, 1996). This applies particularly to commercial software, and it often means that the learning curve for its use is too extensive for such software to be included in a single course (Granger & Little, 1996). This difficulty makes the provision of realistic laboratory assignments problematic. In some cases, this situation is exacerbated by an unrealistic use of software. For example, in a laboratory class where students access a multi-user system, there may be as many as 30 students performing similar tasks using the same software whereas in a practical (commercial) environment there would be only two or three at any one time. In the student environment, this may lead to poor performance with slow response time, giving the impression that the software is inadequate, an attitude that may remain with students after they graduate.

As many university computing courses are preparing students for a career in a commercial or public sector environment, both the hardware and software must have commercial credibility. Of course, this requirement sometimes conflicts with the need for the software to be easy to learn. Organizations would obviously prefer graduates who have been exposed to the systems that they use rather than having to go to the expense of training. However, this is a somewhat contentious point and many surveys indicate that employers are at least interested in general skills as in specific ones (Trauth, Farwell, & Lee, 1993; Richards & Pelley, 1994). As stated earlier, to develop practical computing skills, students will have to complete various computer-based tasks such as laboratory exercises or assignments. Such tasks must be within the average student’s capability. If they are too simple, they give the wrong impression regarding the subject. If they are too difficult or time consuming, this can lead to frustration and a negative attitude towards the course, the software or computing in general. In recent years, there have been changes in the style of development software from text-based systems to graphical user interfaces (GUI) and multimedia. Systems developed using GUIs are usually easier for the user, but the development tool itself is more complex and more difficult to learn (Mutchler & Laxer, 1996; Wolz, Weisgarber, Domen, & McAuliffe, 1996).

Clearly, open and closed laboratories provide different levels of support and different learning experiences. In Australian and British universities most computing classes provide formal scheduled laboratory classes, with different levels of prescription with respect to the work to be done. However, in the United States, it seems that the open laboratory is the norm (Prey, 1996).

One study showed that only about a third of the university courses surveyed used formal laboratory classes (Denk, Martin, & Sarangarm, 1994). One factor that undoubtedly affects the provision of closed laboratories in the USA is the way that workloads are measured. It is done on the basis of course credits and in most US universities, a laboratory class counts as only half a credit. In Australia and the UK, laboratory classes carry the same weight as lectures or tutorials.

3. STUDIES INVOLVING COMPUTER LABORATORY ENVIRONMENTS

There have been a number of studies of the learning environments of classroom involving either computer-based learning or computer laboratories, and these have shown that the introduction of computers into the classroom changes the learning environment (Maor & Fraser, 1993; Levine & Donitsa-Schmidt, 1995). It was found that using computers effectively creates a classroom that is more student-centered and cooperative. This is consistent with the observation made earlier that the use of closed laboratories in computing courses is seen as an opportunity to introduce cooperative learning strategies (Prey, 1996). Other studies have focused on the psychosocial environment in computer-assisted learning classrooms (Teh & Fraser, 1995), professional computer courses (Khoo & Fraser, 1997), university computer courses (Newby & Fisher, 1998) and secondary school computer classrooms (Zandvliet & Fraser, 1998). All of these showed that the environment variables were strongly related to student attitudes, satisfaction and achievement. Further statistical analysis also indicated that between 16% and 36% of the variance in attitude could be explained simply by the environment.

In a study to investigate the effect of scheduled laboratory classes on students' ability to complete assignment projects and tutorial exercises, Duplass (1995) compared two classes of the same course for one semester. The course was introductory and included use of an application package. Both classes had the same number of hours of instruction, but one of them had 25% of the time in a scheduled laboratory, where the instructor gave "over the shoulder" advice, whereas in the other class, this time was spent in demonstration of the process. Open laboratories were available to both groups of students. The study showed that those who had the benefit of the scheduled laboratory completed their projects in significantly less time (about 14%) than those who did not, but there was no significant difference in times taken to complete the tutorial exercises. This indicates that computer laboratory classes may have greater influence on students' ability to tackle larger problems.

The association between learning environment and student outcomes is well established (Fraser, 1991), and the studies mentioned above support this association. The purpose of the current study is to compare the learning environments of open and closed laboratories to see if there are any differences between how students perceive the psycho-social environment of different types of computer laboratory classroom and whether these perceptions have any effect on students' attitudes or achievement.

4. METHODOLOGY

This study involved the use of two previously developed instruments, one called the *Computer Laboratory Environment Inventory* (CLEI) for measuring aspects of a computer laboratory environment and the other, the *Attitude to Computers and Computing Courses Questionnaire* (ACCC) used to measure students' attitudes (Newby & Fisher, 1997). The research focussed on whether there were differences in a student's perception of aspects of their computer laboratory environment or in their course outcomes if they received their computer laboratory experience via open or closed laboratories.

4.1 The Computer Laboratory Environment Inventory

The instrument for assessing aspects of a computer laboratory environment has five scales, Student Cohesiveness, Open-Endedness, Integration, Technology Adequacy, and Laboratory Availability. Each scale consists of seven items, with each item being measured on a Likert scale of 1 to 5 with some questions being reversed. Table 1 gives a description of each scale with a sample item.

The first three scales are based on similar scales of a well-validated instrument called the Science Laboratory Environment Inventory (Fraser, Giddings, & McRobbie, 1993), and the scales Technology Adequacy and Laboratory Availability were designed specifically for this instrument. The use of the first four scales is justified by the guidelines for the use of computer laboratories (Knox et al., 1996). In the report the authors discuss the relationship between the lecture and laboratory in terms of how the laboratory component is organized within the curriculum, the content level, the type of activity, the type of interaction, and the objectives of the laboratory.

The laboratory component may be independent of the lecture, a situation which is desirable in some literacy courses where students are required to gain knowledge about computers and also skills in using them. The lecture and laboratory may be connected across semesters, with the theory course first followed by the practical laboratory course, or both may be integrated so a course consists of both theory and practical components in the same semester. The scale Integration measures students' perceptions of this aspect of the laboratory experience.

Table 1
Description of CLEI scales

Scale	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are supportive of each other	I get on well with students in this laboratory class (+)
Open-endedness	Extent to which the laboratory activities encourage an open-ended, divergent approach to use of computers	There is opportunity for me to pursue my own computing interests in this laboratory class (+)
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes	The laboratory work is unrelated to the topics that I am studying in my lecture (-)
Technology Adequacy	Extent to which the hardware and software are adequate for the tasks required	The computers are suitable for running the software I am required to use (+)
Laboratory Availability	Extent to which the laboratory is available for use	I find that the laboratory is crowded when I am using the computer (-)

Items designated (+) are scored 1,2,3,4 and 5, respectively for responses Almost Never, Seldom, Sometimes, Often, Almost Always
Items designated (-) are scored 5,4,3,2 and 1, respectively for responses Almost Never, Seldom, Sometimes, Often, Almost Always

The content level of a laboratory may vary from purely mechanical knowledge of a computer system, such as which key to strike to perform a certain task, to developing a computer based solution to a problem. Laboratories may also be used for exploration and the illumination of difficult concepts. The activity type describes what the student is doing in the laboratory. This could be using a computer-based learning (CBL) system for a tutorial and/or on-line assessment, developing a software system from scratch, modifying existing software, analyzing data, exploring a system to find out how it works, or using the Internet as a research tool. Each activity type will have different laboratory needs. Open-Endedness will measure students' perceptions of these aspects.

The interaction type is indicative of how the class members work together: students could work on their own, or in groups, and in addition, the staff member may be involved with students either individually or in groups. Closed laboratories allow for greater interaction between staff and students and amongst the students themselves. Student Cohesiveness will measure this aspect.

The uses of technology in computer laboratory classes may be classified by the activities they support and the concepts they reinforce. They include learning to use the technology, using the technology as a tool, using the technology to develop new systems, and using technology to support group work. In each of these cases, different demands will be put on the laboratory class, and the hardware and software must be able to cope with those demands. The Technology Adequacy scale measures students' perceptions of how well the technology performs.

The scale Laboratory Availability recognizes that access to computers outside scheduled classes is needed for students to complete their work. Although most university students have access to computers off-campus, the required software may not be available and so they will have to use the university computers in the laboratory.

4.2 Attitude towards Computers and Computer Courses Questionnaire

The instrument for assessing students' attitudes towards computers and computer courses (ACCC) has been described in earlier studies (Newby & Fisher, 1997). For assessing attitude towards computers, the scales Anxiety, Enjoyment, and Perceived Usefulness of Computers were based upon an instrument devised by Loyd and Loyd (1985). A fourth scale was included to measure the student's perception of the usefulness of the course. As with the CLEI, all the scales have seven items and a description of the scales used in the instrument is given in Table 2 together with a sample item from each scale.

4.3 Samples

The instrument was administered to 104 students undertaking courses within the Business School of Curtin University of Technology in Western Australia, and to 109 students within the College of Business and Economics at California State University, Fullerton. All courses involved the use of a computer to solve problems. The Curtin courses provided the laboratory experience by means of formal closed laboratory classes. At Fullerton, laboratory classes were not scheduled and the laboratory experience was provided by open laboratories. In both surveys, the classes included those in which the development of software was the focus of study, such as Information Systems, and others in which the computer was used as a tool. The surveys were carried out in the last third of the semester in which the course was given so that students would have had a sufficient exposure to the laboratories. However it should be pointed out that the surveys were conducted at different times of the year.

The program at Curtin is accredited by the Australian Computer Society and follows their curriculum guidelines (Australian Computer Society, 2002). At Fullerton, the program is accredited by AACSB and the Information Systems courses are based on those in the IS '97 curriculum (Davis, et al., 1997). The Information Systems courses in both programs are similar as the Australian Computer Society core requirements draw heavily upon the IS '97 curriculum. The major difference in the programs is the length. As is the norm in Australia, the program at Curtin is 3 years, whereas the one at Fullerton is 4 years, but it should be noted that the Curtin program contains no General Education courses. The students at Curtin take their first computing course in Semester 1 and those surveyed were in their 4^{th} semester. At Fullerton, the students take their first computing course in Semester 3 and those surveyed were in their 6^{th} semester. This means that both sets of students were at the same stage of their program and were similar in both academic level and computer experience. The samples were also similar in terms of gender, age, and mode of study (part-time or full-time) as is indicated in Table 3 which gives the frequencies of these variables for both samples.

4.4 Achievement

Achievement was measured as the grade obtained in the course, as a mark out of 100. This grade was contributed to by three components, a final examination, assignments and laboratory exercises. Both the examination and the assignments tested knowledge and skills that should have been gained mainly in the laboratory classes, whose main purpose was to give practical experience of material covered in the lectures. Using means and standard deviations obtained for each course, each grade was converted into a z-score. Of the 104 students from Curtin, 77 provided their student number and of the 109 students from Fullerton, 74 did so. This allowed the grades of these students to be determined.

4.5 Research Questions

Closed computer laboratory classes require more resources and greater commitment than open laboratories and this provides the rationale for Research Question #1:

> Do students who receive their laboratory experience via open computer laboratories perceive their learning environment differently from those who receive their laboratory experience via closed computer laboratories?

Previous research shows an association between classroom environment and student outcomes (Fraser, 1991) and this formed the focus of Research Question #2:

> Are the course outcomes in terms of attitude and achievement different for students who receive their laboratory experience via open computer laboratories from those who receive it via closed computer laboratories?

5. RESULTS

Table 4 shows the alpha reliabilities and mean correlations with other scales for the scales of the CLEI for both samples. The reliabilities for the Australian sample vary from 0.56 to 0.89, and for the USA sample from 0.61 to 0.80. These are consistent with previous studies and indicate that the reliabilities of the scales are satisfactory.

The mean correlations with other scales vary from 0.08

to 0.23 for the Australian sample and 0.06 to 0.24 for the US sample. These demonstrate that there is little overlap in what the scales are measuring and the results are consistent with previous studies in which factor analysis was used to confirm that there are five distinct scales (Newby, 1998).

Table 5 shows the alpha reliabilities and mean correlations with other scales for the scales of the ACCC. The alpha reliabilities vary from 0.64 to 0.90 for the Australian sample and from 0.72 to 0.89, indicating that the scales have a satisfactory internal consistency for these samples. The mean correlations show that the scales measure distinct but overlapping aspects of students' attitudes towards computers and the course. Factor analysis has been used in a previous study to confirm a structure of four factors (Newby, 1998).

Table 2
Description of ACCC Scales

Scale	Description	Sample Item
Anxiety	Extent to which the student feels comfortable using a computer	Working with a computer makes me very nervous (+)
Enjoyment	Extent to which the student enjoys using a computer	I enjoy learning on a computer (+)
Usefulness of Computers	Extent to which the student believes computers are useful	My future career will require a knowledge of computers (+)
Usefulness of Course	Extent to which the student found the course useful	I do not think I will use what I learned in this class (-)

Items designated (+) are scored 1,2,3,4 and 5, respectively for responses Strongly Disagree, Disagree, Not Sure, Agree, Strongly Agree
Items designated (-) are scored 5,4,3,2 and 1, respectively for responses Strongly Disagree, Disagree, Not Sure, Agree, Strongly Agree

Table 3
Frequencies of Demographic Variables in Australian and US Samples

		Australian		United States	
Variable		Frequency	Percentage	Frequency	Percentage
Age	< 20	21	20.2	12	11.0
	20-25	54	51.9	63	57.8
	26-30	16	15.4	24	22.0
	30-35	3	2.9	7	6.4
	> 35	2	1.9	1	0.9

	Missing	8	7.7	2	1.8
Gender	Female	34	32.7	50	45.9
	Male	63	60.6	57	52.3
	Missing	7	6.7	2	1.8
Mode of Study	Full-time	89	85.6	97	89.0
	Part-time	9	8.7	10	9.2
	Missing	6	5.8	2	1.8
Sample Size		104		109	

Table 4
Internal Reliability and Mean Correlations for the Scales of the CLEI

	Australia		United States	
Scale	Alpha	Mean Correlation	Alpha	Mean Correlation
Student Cohesiveness	0.64	0.13	0.72	0.10
Open-Endedness	0.56	0.14	0.61	0.07
Integration	0.89	0.08	0.80	0.13
Technology Adequacy	0.84	0.23	0.78	0.24
Laboratory Availabilty	0.81	0.22	0.71	0.23
Sample Size	104		109	

Table 5
Internal Reliability and Mean Correlations for the Scales of the ACCC

	Australia		United States	
Scale	Alpha	Mean Correlation	Alpha	Mean Correlation
Anxiety	0.89	0.36	0.88	0.47
Enjoyment	0.90	0.41	0.89	0.47
Usefulness of Computers	0.82	0.36	0.81	0.49

Usefulness of Course	0.64	0.28	0.72	0.36
Sample Size		104		109

An independent samples t-test was carried out on the environment variables, the attitudinal variables and on achievement measured by the z-score, using country of study as the grouping variable. The results for the environment variables are given in Table 6, and for the attitudinal variables and achievement in Table 7.
Of the environment variables, the difference in the mean for Open-Endedness was significant ($p < 0.01$), with courses having closed laboratories being higher. Both Technology Adequacy ($p < .01$) and Laboratory Availability ($p < .001$) were significantly higher for courses which provided the laboratory experience via open laboratories.

Of the attitudinal variables, only Anxiety showed a significant difference ($p < .01$) in the means with courses using open laboratories being higher. There was no significant different between the means of achievement for the two groups.

6. DISCUSSION

The first research question that was posed for this study was:

> Do students who receive their laboratory experience via open computer laboratories perceive their learning environment differently from those who receive their laboratory experience via closed computer laboratories?

The results demonstrate that there are some important differences in students' perceptions of their computer laboratory environment depending whether they received their laboratory experience via closed laboratories or open laboratories. The only scale in which the mean was higher for courses employing closed laboratories was Open-Endedness. At first sight, this seems somewhat surprising as closed laboratories are designed to be much more structured than open laboratories. However, a possible explanation is that in a closed laboratory setting, students are more confident about experimenting with different ways of solving problems. In an open laboratory, students are more reliant upon laboratory assistants and each other and are likely to be satisfied when they get a solution that works. Of the remaining environment variables, both Technology Adequacy and Laboratory Availability have a significantly greater mean for courses using open laboratories. In many ways, the higher mean for Laboratory Availability is to be expected. With an open laboratory setting, the laboratories are available for use by students all day since there are no classes scheduled in them. The only competition comes from other students. Where closed laboratories are in use, much of the available time is taken by scheduled classes, and students are competing for the time that is unscheduled. The higher mean for Technology Adequacy for courses with open laboratories could have a number of explanations, most of which are not directly related to open and closed laboratories. One such explanation is that the technology at Fullerton is more suitable than that at Curtin for the courses being taught. Certainly, the fact that about half of the students in the Curtin sample used a centralized computer and the rest used a network of PCs, whereas all Fullerton students used a network of PCs could be a contributing factor. Another possibility is that the instructor using closed laboratories set exercises that would more consciously extend the student's knowledge of how to solve problems in such an environment. Being on hand to answer questions immediately as would be the case with closed laboratories makes this more feasible. With open laboratories, the instructor must be more aware that they are setting exercises where the students will, in general, be obtaining limited help. It is interesting to observe that although not significant ($p = 0.068$), the mean for Integration is higher for open laboratories than for closed ones. This could be also be explained by the awareness of the instructor of the limited assistance available to students, and so they make the laboratory work closed related to the material of the lecture.

The second research question was:

> Are the course outcomes in terms of attitude and achievement different for students who receive their laboratory experience via open computer laboratories from those who receive it via closed computer laboratories?

Of the student outcome variables, the only one that shows a significant difference in the means is Anxiety, where the mean is significantly greater ($p < .01$) for courses with open laboratories than for those with closed ones. This suggests that the presence of a faculty member when students are using unfamiliar software or hardware may reduce their anxiety about using computers. The lack of significant difference in the means for the other outcomes including achievement would indicate that there are factors other than laboratory environment that influence these outcomes.

7. CONCLUSIONS

This study compared the provision of computer laboratory experience by the use of closed laboratories and the use of open laboratories. It has demonstrated that there are some significant differences in both environment and attitudinal variables for the two groups of students. A previous study (Newby & Fisher, 2000) indicated that computer laboratory environment affects attitude which in turn affects achievement. An even earlier study (Marcoulides, 1988) demonstrated that there is a significant association between computer anxiety and achievement as measured by performance on computing assignments. Although the present study did not show a significant difference in the means for achievement, it did show a lower mean for anxiety those courses with closed computer laboratories. This would imply that the use of closed laboratories within courses could improve achievement by changing student attitudes towards computers. On the other hand, using closed laboratories would appear to reduce laboratory availability so students have less opportunity to work in a laboratory on campus outside formal classes. To some extent, encouraging students to purchase laptop computers, which some universities already do, could overcome this. However, software must be available to students at a reasonable cost. Overall, the results would also indicate that the students' perceptions of their laboratory environment by the adoption of a judicious mix of both open and closed laboratories so as to obtain the best of both worlds. Such a strategy would require more resources, particularly in the provision of closed computer laboratory classes, which requires a commitment on the part of faculty and college administrators, but this study indicates that such an investment would be worthwhile.

Table 6
Comparison of the Means for Environment Variables

	Australia		USA			
Scale	Mean	Std	Mean	Std	t	*p*
Student Cohesiveness	23.1	3.65	22.2	4.31	0.83	0.411
Open-Endedness	23.5	3.22	22.4	2.65	2.88	0.004
Integration	24.6	5.52	25.8	4.05	-1.83	0.068

Technology Adequacy	22.7	4.65	24.4	4.38	-2.74	0.007
Laboratory Availability	19.7	5.58	22.3	4.96	-3.57	0.000

Table 7
Comparison of the Means for Attitudinal Variables and Achievement

	Australia		USA			
Scale	Mean	Std	Mean	Std	t	*p*
Anxiety	13.7	4.61	15.4	5.39	-2.40	0.007
Enjoyment	29.0	4.96	28.3	4.83	0.97	0.334
Usefulness of Computers	30.8	4.11	30.2	4.14	1.07	0.286
Usefulness of Course	25.2	3.45	25.4	4.06	-0.39	0.695
Achievement	0.35	1.01	0.22	0.89	0.83	0.411

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