

Computer managed learning: Its use in formative as well as summative assessment.

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Abstract

The computer managed learning (CML) system in use at Curtin University of Technology, Perth, Australia is a mainframe-based computer testing system run through a central testing laboratory. Each year approximately 30,000 student tests are generated and marked by the system. Multiple choice questions are used almost exclusively although the system is capable of supporting a selection of question types. Most lecturers use the CML tests as one component of the unit assessment. Although the CML system is used mainly for summative assessment it has features that enable its use for formative assessment. One approach is to allow students to perform practice tests which do not contribute marks to their final assessment. Students can receive immediate feedback about their performance and so can test their knowledge about the topic and be shown where they need to improve. Of those lecturers who use the practice test facility, most allow a single practice test before the first assessed test. This paper summaries several studies demonstrating that those students who perform a practice test score higher marks on the subsequent assessed test. This effect is seen for students from a number of different subject disciplines. Further, the data do not suggest that this effect is due only to students becoming more familiar with the CML system, nor to the possibility that it is the more able students who choose a practice test. The findings seem to suggest that using the CML system as a formative assessment tool improves student performance on summative assessments.

How CML Works

Computer managed learning (CML) systems are software packages with several common functions, including generating tests from banks of questions, marking the tests generated, analyzing the results and keeping records of students' marks and progress. They have a template or a course-map where the parameters used to generate any test are stored. The tests generated using the CML system provide feedback relating both to student performance and the effectiveness of individual questions in the bank, hence the information can be used for either formative or summative purposes. Most systems are able to generate tests that use multiple-choice, true-false, short answer, matching, calculation and assignment questions. They usually have the ability to mark all except the assignment questions, although the short answer questions are often quite restrictive.

Use of CML at Curtin University of Technology

The computer managed learning system in use at Curtin University of Technology is a mainframe-based computer testing system run through a central testing laboratory. Each year approximately 30,000 student tests are generated and marked by the system. While the system is capable of supporting a variety of question types, multiple-choice questions are used almost exclusively. Questions are held in testbanks and students draw randomly generated tests according to parameters set by the lecturers but held within the CML system.

Lecturers use the CML system in a variety of ways. Some use it to encourage a self-directed learning approach by students while others prescribe mandatory time frames for each test. Most use the CML tests as one component of the total unit assessment with marks typically contributing about 20% towards the final unit mark. The number of assessed tests generated by the CML system for a particular unit varies between one and five. While some lecturers allow an optional practice test before the first assessed test, very few make this compulsory and most lecturers do not implement a practice test at all. Where the practice test facility is used it is only made available by lecturers before the first assessed test.

Features which make CML a formative assessment tool

Practice tests, which do not contribute marks to final assessment, are one use of the CML system as a formative tool. These practice tests can be generated using the same parameters and with questions drawn from the same test banks as those used for the summative assessment.

The CML system also has the option to give students immediate feedback about their performance, which is the basis of its use for formative assessment. When the practice test and feedback facilities of CML are used, students can test their knowledge about the topic and be shown where they need to improve.

Students receive feedback at the completion of CML tests. They are given the correct answer to any question they answered incorrectly and are encouraged by staff in the CML laboratory to rework their test paper with the correct answers available, before they leave the CML laboratory. Some lecturers make a textbook or notes available for student reference. All students are able to have their test paper sent to their lecturer if they wish to get a further explanation on any question.

Traditionally, the purpose of feedback has been to confirm or change a student's knowledge, however its value is now placed in the broader context of self-regulation (Butler & Winne, 1995). It is generally agreed that learners are more effective when they take note of externally provided feedback (Bangert-Drowns, Kulil, Kulik & Morgan, 1991, Kulhavy & Stock, 1989, Meyer, 1986) which is seen as a catalyst for all self regulated activities. Butler and Winne (1995) see feedback stimulating cognitive functioning which in turn generates internal feedback that can contribute to the learner's future cognitive engagement. So, the purpose behind advising students to go over their test paper with the answers is to encourage them to use the externally provided feedback to review and monitor their work.

As well as feedback to students the CML system provides feedback for the lecturer. Because students' answers to questions are retained by the CML system, a report of the distribution of question responses and students' marks can be generated. This feedback can be formative if used by the lecturers because it can alert them to problem areas in terms of question quality and also student performance.

Studies on the use of the practice test

A small proportion of lecturers allow students the option of a practice test preceding the first CML assessed test. Lecturers in most cases view the practice test as a way of students becoming familiar with the CML system. Several studies have shown (Sly, 1999a; Sly, 1999b; Sly & Rennie, 1999; Sly & Western, 1998) that those students who do the practice test tend to increase their performance on the subsequent unit assessment. There are a number of possible reasons for this and familiarity with the CML system is only one of these. We have conducted studies to investigate several factors concerning the practice test, including student choice to do an optional practice test, its influence on later performance and other factors such as student ability that may contribute to the effect that the practice test has on the following unit assessment. In the remainder of this paper we summarize some of these studies and discuss the results.

Method

Four groups of first year undergraduate students participated in these studies. These students were able to sit a CML practice test prior to their CML assessed test. This practice test was optional in Economics, Accounting and the semester two Psychology 2 unit but compulsory in the semester one Psychology 1 unit. The content covered by the practice test ranged from 50%

to 100% of the content covered by the assessed test. Differences in scores between groups were tested for statistical significance using t tests. The magnitude of the difference was examined using effect sizes where the effect size is the difference between means divided by the pooled standard deviation (Hedges, 1981). Effect sizes for correlated comparisons are calculated following Dunlap, Cortina, Vaslow and Burke (1996).

Student ability, prior exposure to CML and subject discipline were investigated in order to determine possible reasons for students' choice to do the practice test. Three alternative performance measures were used to investigate student ability. Performance data were obtained via a survey administered through the CML Lab for the second semester Economics group while for both the Accounting group and the second semester Psychology 2 group relevant marks were obtained from lecturers. Prior exposure to CML was considered with the second semester Psychology 2 group because 85% of those students had used the CML system in their first semester Psychology 1 unit. Data concerning use of the practice test across different subject disciplines were obtained from the CML system.

Results

This section is divided into two parts. Part 1 gives CML test results by unit of study, and Part 2 reports results of investigations into possible factors affecting student choice to sit a practice test.

Part 1: CML test results by unit of study

Study 1: Results for a first semester Economics unit

A study was conducted with a population of 277 Economics students (Sly & Rennie, 1999) who were offered an optional practice test which covered the same content as the assessed test. The results are reported in Table 1. The percentage means show that those students who sat the optional practice test increased their mean mark from 56.65 to 71.78, which is a statistically significant difference (dependent $t=12.66$, $p<.001$) with a substantial effect size of 0.98. On the first assessed test, this group of students also performed better than those who had not sat the practice test. The difference was statistically significant (independent $t=4.38$, $p<.001$) with an effect size of 0.54.

Table 1: Mean Scores (%) on the CML Assessment Component for Economics Students

Test	Practice test group			Non practice test group			t
	N	Mean	SD	N	Mean	SD	
Practice (optional)	152	56.65	16.17				
Assessment 1	152	71.78	14.45	125	63.56	16.36	4.38*

* $p<.001$

Study 2: Results for an Accounting unit

Table 2 reports test results for 190 students of whom 78 (41%) chose to sit the optional practice test. The group mean mark for those students who sat the optional practice test increased from 65.64 to 72.88, which is a statistically significant difference (dependent $t=4.06$, $p<.001$) with an effect size of 0.41. This group of students performed better on the first assessed test than the group who had not sat the practice test. The difference was statistically significant (independent $t=3.03$, $p=.003$) with an effect size of 0.45.

Table 2: Mean Scores (%) on the CML Assessment Component for Accounting Students

Test	Practice test group			Non practice test group			t
	N	Mean	SD	N	Mean	SD	
Practice	78	65.64	19.20				
Assessed	78	72.88	15.76	112	65.58	16.76	3.03**
Part A	78	75.90	17.95	112	68.81	16.96	2.77**
Part B	78	63.59	20.32	112	55.90	25.06	2.33*

* $p<.05$, ** $p<.01$

In this study, the optional practice test covered three quarters of the content covered by the assessed test. The results from the assessment test can be divided into two parts and the mean scores on these parts compared. Part A covers topics examined by the practice test, and Part B covers topics not previously examined. Table 2 also reports the percentage mean scores for Parts A and B of the assessed test.

The 78 students who sat the practice test performed better on Part A (topics which were included in the practice test) than on Part B, which was new work. The effect size for the difference between the practice test and Part A is modest at 0.55, but between the practice test and Part B is small and negative, at -0.10. Only the difference between the practice test and part A is statistically significant ($t=5.55$, $p<.001$). The group who had done the practice test performed better on Parts A and B than the group who did not. However, it can be seen that those students who did not sit the practice test also performed better on Part A than on Part B (68.81 vs 55.90), suggesting that Part B was harder.

Study 3: Results for a first semester Psychology unit (Psychology 1)

Psychology 1 (Sly & Rennie, 1999), the prerequisite Psychology unit for Psychology 2 (Study 4), had a compulsory practice test. Although the test was compulsory, 53 of the 376 students failed to take it. As the practice test covered only half of the content of the assessed test, the results from the first assessed test were again divided into two parts. Part A covers topics examined by the practice test, and Part B covers topics not previously examined. Table 3 reports the percentage mean scores on the different tests for the 323 Psychology students who took the practice test and the small group of 53 who did not in a parallel analysis to Study 2. For the practice test group, the mean mark increased from 70.90 to 75.76 for the total assessed test, a statistically significant difference (dependent $t=5.343$, $p<.001$) with an

effect size of 0.33. Further, these students performed better on Part A (topics which were included in the practice test) than on Part B, which was new work. The effect size for the difference between the practice test and Part A is modest at 0.45 and between the practice test and Part B is small, at 0.20. Both differences are statistically significant ($t=7.116$, $p<.001$ and $t=2.979$, $p<.01$, respectively).

Although the results need to be treated cautiously because of the small group, those students who did not sit the practice test scored lower than those who did. Although this group also scored less well on Part B than Part A, the difference was not statistically significant (71.76 vs 68.00, $t=1.35$, $p=.18$). It is possible that Part A and Part B were of similar difficulty.

Table 3: Mean Scores (%) on the CML Assessment Component for Psychology 1 Students

Test	Practice test group			Non practice test group		
	N	Mean	SD	N	Mean	SD
Practice (compulsory)	323	70.90	16.44			
Assessed	323	75.76	12.18	53	69.58	14.51
Part A	323	77.51	12.95	53	71.76	15.55
Part B	323	73.98	15.97	53	68.00	19.68

Study 4: Results for a second semester Psychology 2 unit

Table 4 reports test results for a second semester population of 360 Psychology 2 students. Of these students 85% had completed Psychology 1, which was the basis of Study 3. The optional practice test covered the same content as the assessed test.

The percentage means show that those students who sat the practice test increased their mean mark from 56.78 to 68.30, which is a statistically significant increase (dependent $t=8.39$, $p<.001$) with a substantial effect size of 0.78. On the first assessed test, this group of students also performed better than those who had not sat the practice test. Although the difference was not great, it was statistically significant (independent $t=2.24$, $p=.026$) with a small effect size of 0.24.

Table 4: Mean Scores (%) on the CML Assessment Component for Psychology 2 Students

Test	Practice test group			Non practice test group			t
	N	Mean	SD	N	Mean	SD	
Practice	148	56.78	15.78				
Assessment	147	68.30	13.38	213	64.99	13.98	2.24*

* $p=.026$

Part 2: Results of studies of possible factors affecting student choice to sit a practice test.

Subject discipline, student ability and prior exposure to CML were considered as possible factors affecting students' choice to do the practice test and their performance on it.

1. Choice to do the practice test according to subject discipline.

The following table shows data, taken directly from the CML system, reflecting student choice to do an optional practice test. When given the choice to take an optional practice test, an average of 55% of students choose to do so, however this ranges between 40% and 69%. It should be noted that the Psychology 2 group of Study 4 had the lowest percentage of students choosing the practice test, and 85% of them had done the Psychology 1 unit in first semester thus gaining experience using CML.

Table 5: Selection of Optional Practice Test by Subject Discipline.

Subject	Semester	Practice Test	
		Yes	No
Economics (Study 1)	1	152(55%)	125(45%)
Economics Instrumentation (medical science)	1	417 (69%) 29 (69%)	190 (31%) 13 (31%)
Accounting (Study 2)	2	78 (41%)	112 (59%)
Psychology 2 (Study 4)*	2	147 (40%)	216 (60%)

- 85% of this group had prior CML exposure.

2. Student ability

Three performance measures which reflected student ability were investigated. They were university entrance score, final exam mark for the unit and final exam mark for the prerequisite unit. Each measure was investigated for its effect on students' choice to do a practice test in a different subject discipline.

Student ability as measured by university entrance exam (TEE) score.

A student survey was handed to students enrolled in a second semester first year Economics unit when they took a CML test in the CML laboratory. The purpose of the survey was to obtain demographic information in order to link this to student choice to do the practice test. Questions included requests for students' mode of study (part time/full time), their sex and university entrance score. Students were required to identify themselves, by student identification number, as the information was to be linked with CML achievement. Three hundred and eighty three (40.3%) out of the 568 students who handed in the questionnaire answered the question related to their university entrance

score. They were not required to give an exact score but to select which of three bands contained their score. It is likely that not all of the students in this group gained admittance to the university on the basis of an entrance score because there was a proportion of overseas students in the group. Based on analysis of this sample of 383 students, no association was found between university entrance score and students' choice to do the optional practice test. (chi-square 2.80, $p=.246$).

Student ability as measured by final exam mark in unit

The final examination for the semester was the performance measure used as an indicator of student ability in Study 2 with first year Accounting students. This examination was worth 50% of the total unit mark, covered the entire course and was not run on the CML system. Based on this performance measure, there was no difference in the mean mark on the final examination between those students who elected to sit the practice test and those who did not (63.9% vs 60.0%, $t=1.49$, $p=0.14$).

Student ability as measured by final exam mark in a prerequisite unit

Most of the students enrolled in Psychology 2 (Study 4) had completed the prerequisite, Psychology 1 (Study 3), in the previous semester. The performance measure investigated was the final non CML examination mark for Psychology 1, so only those students who had done this prerequisite Psychology unit in the preceding semester were included in the analysis. This examination was worth 40% of the unit mark. There was no statistically significant difference found between those students who sat the optional practice ($n= 109$) in the second semester unit and those who did not ($n=184$) based on the final non CML exam mark for their previous Psychology unit (69.5% vs 66.8%, $t=1.69$, $p=.09$).

3. Prior exposure to CML

4.

In the second semester Psychology 2 group (Study 4), 85% of students had also been enrolled in the prerequisite Psychology 1 (Study 3) in the preceding semester. They had prior exposure to CML because they had two assessed tests based on CML in Psychology 1. Table 6 reports some results from Study 4. Of these students, 109 (37%) sat the optional practice test in Psychology 2 and 184 (63%) did not. Of the 70 remaining students who had not done the prerequisite Psychology 1 unit in the preceding semester, 38 (54%) sat the practice test and 32 (46%) did not. As only 37% of students who had used the CML system for their prerequisite unit chose to sit the practice test, it is possible that prior exposure to CML may actually deter these students from sitting a practice test in a subsequent unit.

Table 6: Effect of Prior CML Exposure on Choice to sit a Practice Test

Unit	Psychology 1 previous semester	Practice Test	
		Yes	No
Psychology 2 (Study 4)	Yes	109 (37%)	184 (63%)
	No	38 (54%)	32 (46%)

Discussion

All of the studies we have performed demonstrate that those students who complete a practice test score higher marks on the subsequent assessed test. This effect is seen for students from a number of different subject disciplines.

The practice test may be increasing later performance by alerting the students to the content of the test, but, it may also be that the students are using the external feedback they received to generate their own internal feedback. This could allow them to modify their learning strategy or their approach to the subject matter. The non-practice test group did not have any prior exposure to either the type of questions or the question content and so had no opportunity to receive feedback.

The practice tests in Economics, Accounting and the first semester Psychology 1 unit covered, respectively, 100%, 75% and 50% of the content covered by the assessed test. In the Accounting and Psychology 1 studies the analysis on the assessed test was divided into two parts. Part A covered topics examined by the practice test, and Part B covered topics not previously examined. In both studies students performed better on Part A, that part of the assessed test that reflected material previously examined on the practice test. These results suggest that performance is more likely to be enhanced when the practice test covers similar material to the assessed test, however further study is needed because it was not able to be demonstrated that the parts were of equal difficulty. Also, the number of questions in Part B on each of these tests was different. In the Psychology 1 assessed test Part B contained 15 questions, which was half the length of the test, while Part B on the Accounting test contained only 5 of the 20 questions. The small number of questions covering new material on the Accounting test, and the fact that both practice tests covered material taught earlier in the course may affect our results and so further studies are planned.

In the second semester Psychology 2 unit, we investigated a subset of the group, those students who had used the CML system for their previous Psychology 1 unit. Again, those students who sat the optional practice outperformed their fellow students who did not sit the practice test, even though both groups had previously used the CML system and so were familiar with the system. Both groups were also familiar with the question type and had previously received feedback on CML generated Psychology questions. Further, there was no difference in the ability of the groups as measured by their final non-CML examination mark in the first semester Psychology unit. These findings suggest that feedback is the most likely factor which may enhance later performance on tests of similar material.

Although no student received the same question on the assessed test that they had received on the practice test, they were exposed to the general content area and given feedback on their responses. They also then had time between the practice and the assessed tests to revise areas that were weak. Hence, one possibility for this improved performance of the practice test group

is that prior exposure to the general content area, followed by feedback on errors, allowed students to identify their own weak areas and work on them. Factors investigated to determine student choice to sit a practice test appear to have little effect. No link was found between ability as measured by university entry mark, final exam mark in the current unit or exam mark in the prerequisite unit and student choice to do an optional practice test. If a practice test is optional, an average 55% of students choose to sit it. However, this percentage (see Table 5) varied between 40% and 69% across the subject disciplines we investigated. Further, Table 6 shows that those students who had used CML in Psychology 1 had a lower participation rate (37%) on an optional practice test in Psychology 2. This creates something of a dilemma. If the practice test does enhance performance as these studies suggest, but prior CML exposure has the effect of reducing student participation on a practice test in the same subject area, students may be disadvantaged because they miss the opportunity of the practice test to obtain formative feedback on their performance. If either the lecturers or students believe that the benefit of the practice test lies purely in familiarity with the CML system, and have no regard for the value of formative feedback, then this situation may be detrimental to students' later performance.

Summary

These findings suggest that the CML system when used as a formative assessment tool, can enhance students' performance on later assessments. It appears to have this beneficial effect irrespective of student ability and subject discipline. The effect is seen particularly on those sections of the assessed test that reflect the content of the practice test, however additional research is needed to investigate this aspect. Until further information is available, it appears that all lecturers would be advised to offer students an optional practice test which covers questions from the same content as the assessed test.

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