COMPUTER AIDED INSTRUCTION vs. TRADITIONAL TEACHING: COMPARISON BY A CONTROLLED EXPERIMENT

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ABSTRACT

We present a controlled experiment designed to test the efficiency of Computer Aided Instruction (CAI) in teaching Business Calculus to college freshmen. The following data have been collected: (a) performance in conventional examinations, (b) performance in a concepts test, (c) responses to attitude questionnaires, (d) historical data. Using hypothesis testing, we compare CAI with traditional teaching methods with regard to the following aspects: (a) enhancing the understanding of important mathematical concepts, (b) improving overall performance and (c) making mathematics more interesting for students.

1. Introduction

The American College of Thessaloniki is an English-language Liberal Arts college operating in Thessaloniki, Greece. ACT hosts students from Greece, the Balkan countries, the USA and several other countries. These students have a diverse educational background; in particular, their mathematical preparation and performance varies widely.

Teaching mathematics to such a diverse student body is a difficult task. We must design courses which will impart to the students basic mathematical knowledge (necessary for follow-up courses), we must convince them of the relevance of mathematics and we must keep a fine balance between getting too technical (in which case inadequately prepared students will be alienated) and too simple (in which case mathematically sophisticated students lose interest in the course). The problem is exacerbated because in some of our classes we teach concurrently two groups of students: the first group will major in the Liberal Arts and the second in Business Administration.

2. Past Activities

To remedy the above problems, we have found it necessary to continuously engage in curriculum reform. We have been especially interested in using *computer aided instruction* (CAI) to enhance both the learning material and the teaching process. In the last three years we have experimented with software packages such as Microsoft Excel, MathCad and Scientific Notebook as well as with HTML-based hypertexts. In our efforts we have emphasized conceptual understanding, through the use of graphical and numerical approaches (without however neglecting the analytical approach). In particular, in the Calculus course we have used numerical and graphing experiments (in Excel and in MathCad). We have also experimented with various teaching strategies: we have taught traditional, classroom-based courses, as well as courses almost exclusively taught in the computer lab; we have used collaborative assignments and individual take-home projects.

Our impression is that students are generally attracted to computers; furthermore, computer-phobic students appear less frequently than math-phobic ones. We have also noticed that students are eager to participate in classroom activities in computer-intensive classes. On the other hand, we have found that when teaching a computer-intensive class the students may become quite proficient in the use of computers and mathematical software, without grasping the mathematical concepts in which are ultimately interested.

We should also mention that our colleagues from the Psychology Department have investigated the connection between high school GPA, competence in the English language, self perception and performance in mathematics; they have concluded that self importance is one of the most significant factors in determining mathematics performance **[1, 2]**. We find this result extremely plausible.

3. The Mellon Project in Computer Aided Instruction

In late 1996 we decided to conduct a formal investigation of the themes discussed in the previous section. A Mellon Foundation grant was obtained to support assessment of computer aided teaching of Business Calculus, through a controlled experiment. The experiment was conducted in the Fall 1997 and Spring 1998 semesters; the goal was to evaluate the efficiency of CAI in enhancing the understanding of important mathematical concepts and in making mathematics more interesting / accessible to the students. A total of nine sections (approximately 180 students) were involved: a test group of five sections and a control group of four sections.

Two pilot sections (one test, one control) were taught in Fall 1997. Our main goal during this phase was to familiarize ourselves with the symbolic math software MathCad and with teaching computer lab-based courses. We chose MathCad because of its combination of symbolic math operations with "live" computation (i.e. changes made at some part of a document result in immediate update of the whole document). We found this feature very useful both for demonstration by the instructor and for experimentation by the students.

The main phase of the project was conducted in Spring 1998 and involved 118 students. In this paper we are reporting the results of the main phase. Three control sections (involving 58 students) were taught in the traditional, non-computerized way, with classroom lectures and using a paper textbook. Four test sections (involving 60 students) were taught in the following manner: approximately 50% of the teaching time was spent in the lab, with hands-on experimentation using MathCad; another 25% of teaching time was used for lecturing in the lab, again utilizing MathCad for demonstrations by the instructor; the remaining 25% of teaching time was used for conventional, classroom activities. Hypertext notes (written in MathCad) were prepared by us and used by the students for self study. We also made extensive use of a Web system for distributing course information (e.g. syllabus, weekly schedule and assignments, homework). We have found this to be a very efficient method of information dissemination.

We have collected large amounts of data, which can be separated in four categories.

1. Historical data (e.g. students' high school general and math grades, "desmi" membership, students' GPA and introductory math and CS grades at ACT).
2. Performance in the Math 101 course (final grade).
3. Math concepts understanding (measured by a concepts pre-test and a concepts post-test; these contain material not necessarily taught in class, with emphasis on conceptual understanding and problem-solving).
4. Student attitude (measured by three attitude questionnaires, administered at the beginning, middle and end of the Math 101 course).

4. Assessment

Assessment of the experiment results is still under way; in this paper we present some preliminary results which are based on the above mentioned data and on statistical hypothesis testing. We are generally interested in evaluating differences between the test and control sections in the following areas:

1. Enhancing the understanding of important mathematical concepts.
2. Improving mathematical performance.
3. Making mathematics more interesting to the students.

In addition to the above, we are interested in finding possible differences in the background of the students who participated in the CAI and traditional sections. We test for such differences using standard hypothesis testing (using the t-distribution). The quantities we test are as follows.

1. **M100 Grade (0 to 4).** This is the grade received in the introductory math course, which is a prerequisite to the Math 101 course; it can be taken to reflect mathematical proficiency of the incoming students at the beginning of the experiment.
2. **CS101 Grade (0 to 4).** This is the grade received in the introductory computer science course; it can be taken to reflect computer proficiency of the incoming students at the beginning of the experiment.
3. **M101 Grade (0 to 4).** This is the final grade received in the Math101 course and may be taken to reflect mathematical proficiency (regarding both technical skills and conceptual understanding) at the end of the experiment.
4. **M101 – M100 Grade.** This is the difference between items 1 and 3 and may be taken to reflect *differential* in mathematical proficiency which resulted from taking the (CAI or traditional) course.
5. **GPA.** This reflects the overall academic performance of the students.
6. **Preliminary Concepts exam (0 to 4).** This quantity is the grade received in a *mathematical concepts understanding* exam administered at the beginning of the course.
7. **Final Concepts exam (0 to 4)**. The same as the previous item, but measured at the end of the course.
8. **Prelim. Concepts – Final Concepts.** This is the difference between items 6 and 7 and can be taken to reflect the *differential improvement* in understanding mathematical concepts, which resulted from taking the course.
9. **CS attitude (1 to 5).** This quantity was obtained from an attitude questionnaire administered to the students at the end of the course. It is actually the average of several questions asked regarding the students' attitude about computers.
10. **Math attitude (1 to 5).** This item is similar to the previous one, except that it concerns mathematics rather than computers.
11. **Q: I look forward to coming to class (1 to 5).** This and the next item are questions directly quoted from the attitude questionnaire. They are intended to evaluate the attitude of the students to the particular course (Math 101) rather than to mathematics in general.
12. **Q: I will recommend this class to a fellow student (1 to 5).** See the previous item.

In Table 1 we present the results of the hypotheses tests. In every case we test the null hypothesis (i.e. that the relevant quantity has the same distribution for the student sample coming from the CAI and the traditional sections). In every case we list the average of the quantity for the CAI and traditional section, the corresponding t-value and the corresponding p-value, i.e. the probability that the CAI and traditional samples come from the same distribution.

Item	CAI mean	TRA mean	t-value	p-value
M100 Grade (0 to 4)	2.68	2.52	0.818573	0.414588
CS101 Grade (0 to 4)	3.00	2.83	1.125226	0.262649
M101 Grade (0 to 4)	2.47	1.94	2.469418	0.014894
M101–M100 Grade	–0.21	–0.59	2.166143	0.032213
GPA	2.86	2.51	2.525280	0.012811
Preliminary Concepts exam (0 to 4)	1.41	1.17	1.639328	0.103659
Final Concepts exam (0 to 4)	3.06	2.58	3.073958	0.002594
Prelim. Concepts – Final Concepts	1.65	1.40	1.356195	0.177482
CS attitude (1 to 5)	4.2	3.93	2.114560	0.366093
Math attitude (1 to 5)	4.02	3.84	1.827858	0.070141
Q: I look forward to coming to class (1 to 5)	3.80	3.396	2.319737	0.022104
Q: I will recommend this class to a fellow student (1 to 5)	4.03	3.74	1.635201	0.104718

Table 1

Several interesting remarks (of a preliminary character) can be made regarding the results of the above table.

Attitude to the course. Two questions are relevant here: "I look forward to coming to class" and "I will recommend this class to a fellow student". In both cases, CAI students exhibit a markedly better attitude than traditional ones. This is more obvious in the first question (p-value is 0.022104, so the result is statistically significant); in the second question CAI students again have a more positive attitude which is nearly significant at the 10% significance level (p-value is 0.104718).

General mathematics and computers attitude. It is quite clear that CAI students have a more positive attitude towards mathematics than traditional students (p-value is 0.070141). Interestingly enough, there is no significant difference of attitude towards computers (p-value is 0.366093). It would certainly seem reasonable that students with a better attitude to computers would be attracted to a CAI math course. Keeping in mind that the results presented here pertain to attitudes at the *end of the course*, it would be interesting to compare computer attitude at the *beginning of the course*, as well as to compute *differential attitude* from the beginning until the end of the course. For instance, it is possible that CAI students "overdosed" in computer technology. It would also be interesting to do a follow-up questionnaire (say a year later) in order to investigate how lasting the above attitudes (to both math and computers) are.

Mathematical and computers preparation. While the CAI group has higher grades in introductory courses in both mathematics and computers (and it is plausible to assume that they are also better prepared in these subjects), this difference is *not* statistically significant (p-values 0.414588 and 0.262649, respectively).

Mathematical proficiency. While the CAI group has higher grades in introductory courses in Math100 this difference is *not* statistically significant (p-value 0.414588). Math101 grade difference is statistically highly significant (p-value is 0.014894) and the differential between M101–M100 Grade is also statistically highly significant (p-value is 0.032213).

Conceptual understanding. There is a statistically significant difference between the CAI and traditional groups in their performance at the Preliminary Concepts exam (p-value is 0.079916), as well as at the Final Concepts exam (p-value is 0.002594). The differential performance (i.e. difference in performance at the end and beginning of the course) is *not* statistically significant (p-value is 0.177482).

General Academic Performance. Here we see a statistically significant difference (p-value is 0.012811): CAI students have a higher GPA than traditional ones.

5. Discussion

We will now present some thoughts regarding the results presented above. We must stress that at this point we do not feel we have a complete explanation or analysis of the experiment; much more work and analysis must go into our observations before an explanation becomes available.

Statistically speaking, it appears that CAI did not make a difference as far as *concepts understanding* is concerned. More specifically, CAI students were beter at conceptual understanding both at the beginning and at the end of the course; but, on the average, they improved at the same rate as traditional students. However, CAI *did* make a difference regarding general mathematical performance (as measured by the final grade) both in absolute and differential terms. CAI also made a difference regarding the attitude of the students to the course (i.e. students liked the CAI course better than the traditional one).

Statistics and numbers does not tell the whole story. So it is useful to briefly relate our informal experiences. We definitely felt throughout the course that CAI students were more active and interested than the traditional ones. We believe that an important component of the CAI process is not necessarily related to computers per se, but to the more active part played by CAI students, who had a larger proportion of their classroom time devoted to active participation (e.g. problem solving) than to passively listening to lectures.

We also find plausible (though we cannot at this stage offer hard evidence to support our claim) that computers *did* play a positive role, in "sweetening mathematics" (which, must be admitted is an unpopular course with business students). In other words, the fact that computers played a prominent role in the CAI course, may have taken the students' attention away from mathematics and made them *subliminally* more receptive.

As a converse to the above observation, we have found that, exactly because the CAI classes developed so much momentum, it is particularly important to plan class activities and teaching strategies very carefully so that the learning process does not degenerate into an exercise of computer gaming **[3]**. In addition, we believe that some lecturing is still necessary, even in the CAI course; we do not want to revert to 100% lab course.

Regarding mathematical performance, we did feel that on the average CAI students were better and remained so at the end of the course. Statistical analysis offers a further significant insight: not only were CAI students better in absolute terms, but they also *improved more* than traditional students.

Finally, regarding the understanding of mathematical concepts, we have found that CAI students were better at it than traditional ones. This is substantiated by statistical analysis, which further reveals however, that there was no difference in *differential* improvement. In other words, statistics suggests (and as of now we have no grounds to dispute this), that CAI students were originally better at conceptual understanding and remained so at the end of the class.

A scenario which we find plausible after consideration of the statistical analysis and our subjective experiences is that better students were drawn to the CAI course than to the traditional one. This seems to be supported by the statistically significant difference in GPA between the CAI and traditional students.

In conclusion, we do feel that the CAI course was a useful improvement over the traditional course and we intend to refine and repeat it. Teaching MathCad to CAI students created an overhead, which was partly compensated by spending less time in teaching traditional techniques of differentiation and integration **[4]**. We were able to cover approximately the same material in both the CAI and traditional sections. While we acknowledge that some of the CAI course benefits may not be due to computers but to a more positive attitude (on our and the students' part) to experimentation, it must be kept in mind that we have only taught the CAI course for a couple of years, as opposed to the traditional course, which we teach for over a decade. Taking all of these factors into account, we expect to reap even greater benefits from CAI approaches in the future, as our technique improves.[1]

Finally, let us offer some practical advice to educators who may be interested in introducing a CAI mathematics course. In our experience, computers exert an appeal to students, which eases acceptance of the mathematical content of the course. In addition, students appear to definitely prefer hands-on experience from conventional lecturing in the classroom. Also, we find that the technology enables us to teach mathematics better through demonstration and experimentation. Of course, the active role played by students through computer experimentation is also enhancing the learning process. On the other hand, the instructor must maintain a fine balance between the technical and the conceptual component of a CAI course.

References

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[1] An important consideration to keep in mind is that, if indeed CAI or other experimental courses attract better students, there is the possibility of a diminishing returns effect here.

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