A study into the effectiveness of studio teaching

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Abstract: There have been a number of initiatives over the past decade or so to introduce information technology, especially multimedia, into engineering education and so overcome some of the problems associated with the traditional modes of teaching. Most of these innovations involve the integration of the lecture, tutorial and laboratory component into some form of integrated approach, along with a significant amount of collaborative learning, group projects and 'student-teaching-student' techniques. This, so-called, studio teaching is a teaching methodology that emphasises co-operative and interactive learning, using multimedia courseware. It is easily adapted to accommodate the increasing diversity in student background, expectation, learning style and pace that had become necessary with the rapid increase in student numbers over the previous five years.

This paper presents the preliminary findings of a three-year longitudinal study of an introductory electronic engineering class given to non-EE students. Each cohort was split into two groups - one taught in the traditional manner, the other in the Integrated Teaching Studio, (ITS). These findings indicate that there are significant differences in understanding and graded results between the two groups, even when there was no significant differences in pre course knowledge or qualifications. It is clear that, even without the laboratory component integrated into the curriculum, students using the ITS perform significantly better than those being taught using more traditional means. When the laboratory component is fully integrated into the ITS-based curriculum there is significant better performance at all levels. It is also clear that students taught in the ITS have significantly more in-depth understanding of the syllabus, as shown by the higher marks in the descriptive component of examinations.

Keywords: Electronic engineering, integrated studio teaching

1. Introduction

Studio teaching was first introduced at Rensselaer Polytechnic Institute, in the USA, in the early 90s, initially in the Physics Department [1] and then in other science and engineering disciplines [2 - 5]. Other universities quickly picked up on the approach and introduced studio teaching into the curriculum, City University of Hong Kong (CityU) being especially vigorous in its adoption [6 - 8].

A typical ITS session would be two hours long and consist of up to 30 minutes of presentation, possibly a short mini-lecture or interactive demonstration, followed by a question and answer session. Again, this may be either pencil-and-paper type or interactive using the workstation available to each individual or pair of students. This may also develop into a small-group discussion, especially when workstations are grouped around each other, as at CityU in Hong Kong [7]. The session may then allow the students to work with some physical equipment or parts and this will allow them to carry out short experiments which are based on the previously presented material. At CityU, the introductory electronics and physics classes are able to carry out experiments where the instrumentation is represented on the workstation screen, although real parts and components are used on the bench [9 - 10]. At RPI most of the studios have fixed bays of standard laboratory equipment that can be accessed by the students by turing their chairs through 180º [11].

Most ITSs have projection screens that can show presentation graphics, animations and web pages, as the instructors' desk, as well as all the student workstations, are not only connected to a LAN but also the Internet. There will also be a visualiser that can be projected onto the large screen(s). This inherent interactiveness, associated with access to the Web, and even VOD, allows the ITS to be very flexible. At CityU, for example, a management or biology class may follow an electronics class.

Of course, normal lecture material, especially that based on overhead projector slides and/or 'chalk and talk', does not fit into an ITS environment. Consequently much thought, effort and money must be put into the preparation of material. Owing to the ubiquitous nature of multimedia there is much material available commercially that can be easily modified for ITS use, although some investment will still be necessary.

The study

Department of Electronic Engineering (EE) at CityU provides a number of 'service' type courses in introductory electronics to several other departments in the Faculty of Science and Engineering. A number of these are provided to the Department of Manufacturing Engineering (ME), who provide degrees in both Manufacturing Engineering (BEME) and Mechatronics Engineering (BEMTE).

CityU established its first ITS in the summer of 1996, with the first courses using the new facility in the first semester (Semester A) of the 1996/7 academic year. It was decided that the introductory electronics course provided for the first year students in ME be one of the first to be converted to the studio environment. At the same time it was agreed that a three-year study of the effectiveness of studio teaching be carried out. Consequently the students enrolled for the two ME degrees were slpit into two groups. One would be taught in the ITS, the other by traditional means. As the entrance qualifications of both groups were similar, and there was the option of students switching between the two degree courses at the end of the first year, the two groups were considered similar in both background and motivation. The only inconsistency in the first year of the study was the large difference in numbers enrolled upon each course. However, this could be compensated for in any statistical analysis.

To minimise as many differences as possible between the two groups, it was decided to use the same lecturer in both the studio and traditional environments. Also, the presentation graphics, and other lecture materials were the same for each group. All assessments were identical, or of similar standard, between and within cohorts - assignments, tests, exams etc. The questions used for tutorial/discussion/examples classes were also identical. Owing to some start up problems in the ITS, the first cohort laboratory work for both groups was carried out in a normal laboratory environment for both groups, although ths problem was overcome in succeeding years. The ITS experimental work covered 90% of that given in the traditional laboratory sessions. The assessment of laboratory work was also similar, especially when marking log books and formal reports.

At the beginning of semester A, before any teaching began, both groups were given a multiple choice pretest. This covered most of the material that the students were assumed to know before they entered the university as well as some questions based upon material they would meet during the first semester. Some of the questions asked about previous experience with computers, multimedia and other IT related subjects. These more subjective responses are currently being analysed and will be matched with the results of interviews carried out with some of the students involved.

Another multiple choice test was given midway through the semester. At the end of the first semester the students sat an examination which consisted of two parts. The first was a multiple choice section, accounting for 25-30% of the final mark. The rest of the exam was a more traditional one, with students have to answer three questions from four in a more descriptive manner.

The final grading for the semester was based upon a combination of coursework, which included assignment, mid semester test, and laboratory, and examination performance. For the first two years of the study this split was 60:40 examination:coursework changing to 70:30 in the third year.

In the second semester, Semester B, the students sat a mid term test, all questions being descriptive/calculation, followed by a final exam that was of a more traditional style. Again, final grading was based upon a combination of coursework and examination performance, in the same ratio as Semester A. Results for the mid-Semester B exam are still being evaluated and are therefore not indicated in Table 1.

Owing to the nature of the course structure, there are always a number of repeat students in each class. These have been eliminated from the analysis. Similarly some students are given exemption from taking the Semester A course. These students have been eliminated from the analysis of the Semester B results.

The results for these assessments are shown in Table 1. They are given as percentages of maximum marks. Grades have not been shown, as a change in course structure affected the grading system but not the marking system. In Semester A, the final mark is shown in three sections - first, the total mark for both coursework and examination, then as the mark for the multiple choice examination, and then for the descriptive examination. In Semester B, the final mark is shown, first as a total for coursework and examination, and then as examination only. Owing to possible differences between cohorts due to minor changes in the entrance requirements to each course in the change over to the credit unit system, only a detailed intra cohort analysis has been carried out so far. However an inter cohort meta-analysis was carried out at the same time as the intra cohort one. This is shown in Table 2.

Results

Two-sample t-tests assuming unequal variances, checked by single factor ANOVA analyses, were carried out on each assessment result. Initially $\alpha \leq 0.05$, although if the results were inconclusive, $\alpha \leq 0.1$ was used. At the same time, Effect Size has been calculated, and the resulting value of delta is also shown (An Effect Size of larger than 0.5 shows something educationally important is taking place). Table 1 shows the number of students, average score and standard deviation for each cohort and test. Also shown are results of the statistical analyses on an intra-cohort basis.

A meta-analysis was then carried out to ascertain whether there were any significant effects within cohorts and over all three cohorts. Four assessments were used for this analysis; pretest semester A, mid semester A test, final exam semester A, and final exam semester B. The effect size measure was Cohen's d, and Hedges Correction [12] has been used. A meta-analysis program [13] was applied during the calculations. These analyses used mean and standard deviation data shown in Table 1. Also shown are the number of studies in each analysis and the value of P obtained from a two-tailed t-test to ascertain the significance of the finding. The results are shown in Table 2.

First, it can be seen that for all three cohorts, there was no significant difference between the groups according to the semester pre-test. This would seem to corroborate entrance qualification data, although the bare, overall, mark may mask differences in group responses to individual questions. Item Response Theory is currently being applied to ascertain whether this possible difference is significant.

However, by the middle of the first semester significant differences began to show for all three cohorts. The ITS group is consistently performing better than the non-ITS group. In the case of cohort 2 (1997/8) it should be noted that the significance was at the $\alpha \leq 0.1$ level. At $\alpha \leq 0.05$ the results of the statistical analysis were such that the P = 0.06 for the t-test, and $F \approx F_{crit}$ for the ANOVA.

By the end of the first semester the overall grade mark in the final assessment is significantly different for all cohorts, the ITS group consistently performing better than the non-ITS group. If the examination component is extracted from the overall mark, which contains the results of the continuous assessment – lab, assignments, tests etc - the difference between the two groups is even more pronounced. This is especially true when considering the marks for the descriptive parts of the examination; the ITS group clearly shows a more 'in-depth' understanding than the non-ITS group.

Table 1

Results of assessments: ITS vs non-ITS students 1996/7-1998/9 (repeats and exemptions excluded)

All marks are scaled to give percentages

Test	Year	Cohort 1		Cohort 2		Cohort 3		Comment
		ME (non ITS)	**MTE** (ITS)	**ME** (non ITS)	**MTE** (ITS)	**ME** (non ITS)	**MTE** (ITS)	
Pretest	*n*	111	36	59	38	46	39	
	avg	59.91	60.21	54.37	53.80	56.61	58.82	*multiple choice only*
	stdev	15.73	7.93	13.38	11.35	14.04	7.74	
		no sig diff α ≤ 0.05		*no sig diff α ≤ 0.05*		*no sig diff α ≤ 0.05*		
		δ = 0.030		δ = −0.043		δ = 0.157		
Mid A	*n*	108	36	58	37	46	37	
	avg	79.04	83.98	77.93	80.81	79.13	89.01	*multiple choice only*
	stdev	5.49	4.63	10.41	7.75	17.66	10.18	
		sig diff α ≤ 0.05		*no sig diff α ≤ 0.05* *sig diff α ≤ 0.1*		*sig diff α ≤ 0.05*		
		δ = 0.897		δ = 0.277		δ = 0.559		
Final A	*n*	95	33	55	37	46	37	
total mark	*avg*	50.69	58.69	53.39	57.05	37.25	45.36	*includes c/w*
	stdev	7.51	6.32	8.97	12.56	7.20	9.52	
		sig diff α ≤ 0.05		*no sig diff α ≤ 0.05* *sig diff α ≤ 0.1*		*sig diff α ≤ 0.05*		
		δ = 1.065		δ = 0.408		δ = 1.127		
total exam	*avg*	39.52	48.76	53.51	57.00	27.56	36.90	*exam only*
	stdev	9.87	9.08	11.70	14.96	8.36	12.28	
		sig diff α ≤ 0.05		*no sig diff a ≤ 0.1*		*sig diff α ≤ 0.05*		
		δ = 0.937		δ = 0.298		δ = 1.117		
m-c	*avg*	68.31	75.97	78.40	77.30	51.27	54.16	*m/c component*
	stdev	12.33	8.06	12.71	11.78	11.22	11.22	
		sig diff α ≤ 0.05		*no sig diff a ≤ 0.1*		*no sig diff α ≤ 0.1*		
		δ = 0.937		δ = −0.086		δ = 0.258		
desc	*avg*	28.08	38.87	45.21	50.91	19.52	32.04	*descriptive component*
	stdev	12.04	12.68	12.86	17.07	10.15	13.99	
		sig diff α ≤ 0.05		*no sig diff α ≤ 0.05* *sig diff α ≤ 0.1*		*sig diff α ≤ 0.05*		
		δ = 0.875		δ = 0.443		δ = 0.895		
Final B	*n*	94	29	55	37	44	37	
total mark	*avg*	53.96	52.27	40.16	40.61	37.97	44.09	*includes c/w*
	stdev	9.65	8.04	9.84	12.15	12.06	13.19	
		no sig diff α = 0.05		*no sig diff α ≤ 0.05*		*sig diff α ≤ 0.05*		
		δ = −0.175		δ = 0.046		δ = 0.507		
exam	*avg*	47.84	52.62	35.38	36.16	33.50	42.92	*descriptive only*
	stdev	13.61	13.52	12.66	14.67	15.57	17.31	
		no sig diff α ≤ 0.05 *sig diff α ≤ 0.1*		*no sig diff a ≤ 0.1*		*sig diff α ≤ 0.05*		
		δ = 0.351		δ = 0.061		δ = 0.605		
Comment		*(Lab work done in lab - both courses)* *Exam:c/w = 60:40*		*(Sem A lab in ITS Sem B lab in Lab)* *Exam:c/w = 60:40*		*(Sem A and most Sem B lab in ITS)* *Exam:c/w = 70:30*		

Table 2: Comparison of effect sizes within cohorts, and for all cohorts

Cohort	1	2	3	All
No of studies	4	4	4	12
Total no of students	542	376	332	1250
Average effect size	0.562	0.145	0.58	0.43
P value of effect size	0.095	0.186	0.03	0.002

For the final assessment at the end of Semester B, other than an anomaly with cohort 2, the ITS group performs better in the examination compared to the non-ITS group, even though the overall grade marks are similar, especially for cohorts 1 and 2. It is possible that the second cohort is in someways unrepresentative because the introduction of the laboratory component into the ITS group did not go smoothly and was abandoned near the end of the Semester A. This disruption may have affected concentration and the coursework mark for this group. However, it is significant that the ITS group scored significantly higher in the descriptive part of the Semester A final exam, even though this was not true for the Semester B final examination.

One point to note is that when laboratory work was introduced into the ITS in Semester B (with cohort 3), the ITS group performed better in both final grade mark and examination, compared with cohorts 1 and 2, where Semester B laboratory work was carried out in traditional laboratory for both groups.

It is possible to plot the pure exam results for the four tests for each cohort. However this would not show the precise statistical relationship between the results. Charts 1-3 show mean scores with error bars for the results for a 95% confidence interval. This clearly shows, in graphical form, the relationships outlined in the table above.

The results of the meta-analysis bear out some of the conclusions drawn above which are based on the raw statistical data. It can be seen that there is a significant effect overall for cohorts 1 and 3, with no significant effect for cohort 2. However, the meta-analysis for all three cohorts quite clearly shows that when measured over three years the effect is significant.

Chart 1
Cohort 1

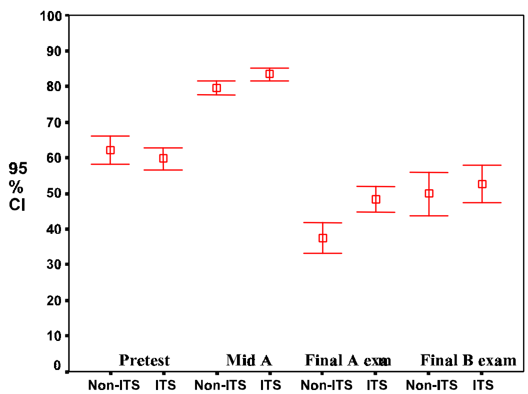


Chart 2
Cohort 2

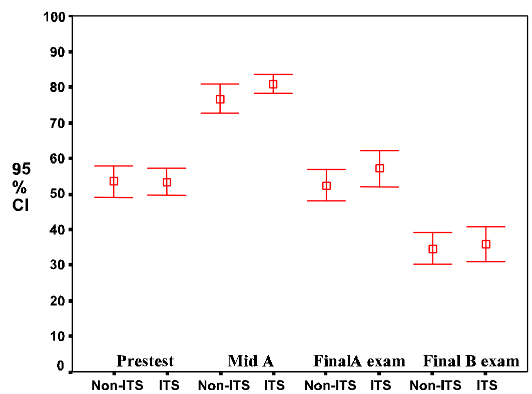
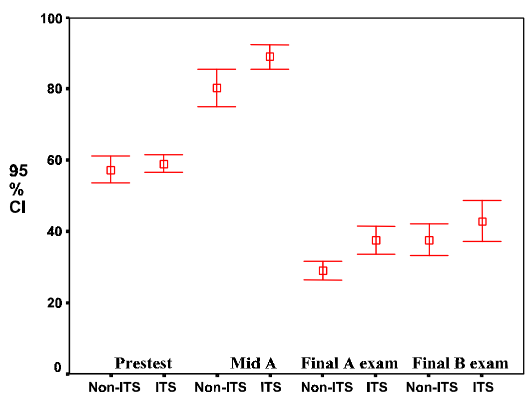


Chart 3
Cohort 3



Conclusions

It is clear that, even without the laboratory component integrated into the curriculum, students using the ITS perform significantly better than those being taught using more traditional means. When the laboratory component is fully integrated into the ITS-based curriculum there is significant better performance at all levels. It is also clear that students taught in the ITS have significantly more in-depth understanding of the syllabus, as shown by the higher marks in the descriptive component of examinations.

On a more subjective basis, it is also noticed that students are more interested in learning in an ITS environment than in the traditional lecture-based one. Attendance records show this for the three cohorts examined in this paper. Whereas average attendance rates at lectures and tutorials/examples classes for the non-ITS groups were around 50-60%, those for the ITS groups were around 95-100%. Attendance is not compulsory at lectures and tutorials/examples classes for the courses in this study. There is however a 75% attendance requirement for laboratory work, and attendance for this has been discounted.

Feedback from students using the ITS, which is still being collected and evaluated, seems to indicate that most, once they get used to the environment, are very happy with learning this way. Some do have problems, especially those who come from a more traditional learning background and who are still expecting to be told what to learn, as at school.

Another area of ongoing discussion is the attitude of the teaching staff. As a form of team teaching approach is taken in the ITS, and because planned schemas may be changed depending on the immediate feedback form students, those teaching staff more used to traditional methods sometimes have great problems adapting. This may, in some ways, undermine many claims for the efficiency, in terms of both staff and capital investment that are often made for studio teaching. In the period of this study the same number of academic staff hours were used for both groups; the only significant difference was the far smaller amount of laboratory time and resources, including technician involvement, compared to traditional laboratory sessions.

One aspect of further work that will be considered in future is the effect of placing most of the teaching material on the Web. At the moment the interactive courseware is available for use by students on the student LAN at the university, and in the two ITSs, which are open for student use when there are no classes scheduled. The LANbased courseware has been accessed by both ITS and non-ITS students, the latter being exposed to it when it used for presentations in the traditional lectures. Further data from future cohorts will factor this access into the ongoing study.

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