An Integrated Studio approach to teaching Basic Electronics to First Year Mechatronics Degree Students

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***Abstract*-- The introduction of studio teaching at City University of Hong Kong allowed for a comparative study of the benefits of this form of teaching. A four-year longitudinal study was carried out using the Introductory Electronics courses designed for First Year Mechatronic Engineering degree students. A similar group in the same department studying Manufacturing Engineering was used as a control.**

It has been shown during preliminary analysis of the data that students using the teaching studio approach acquire a deeper understanding of the subject as well as achieving better grades than those students using the more traditional approaches.

***Index terms*-- mechatronic engineering, integrated studio teaching, interactive learning, introductory electronic engineering.**

I. INTRODUCTION

The introduction of the Honours Degree in Mechatronic Engineering at City University of Hong Kong in 1992 provided a unique opportunity to consider new approaches to teaching mechatronics [1].

One of the objectives of tertiary engineering education is to overcome years of pre-conditioning, and to get the students to think together and to work together. At the same time, introducing experimental work into the curriculum that will be useful training for industry is also important.

The changing face on Hong Kong industry during the past decade has meant that this experience is not now part of everyday life. In the 60s, 70s and 80s, Hong Kong's main employment came from light, low tech, manufacturing. In the 90s this has mostly moved to southern China. Hong Kong is moving towards a management, financial and skills centre for the Pearl River delta. This means that engineering education has to be more aware of these roles [2].

Group based projects, such as micromouse, coupled with inter-disciplinary ones such as robot ping pong [3], are one method of meeting these challenges. The fact that vocational colleges and schools are also participating in mechatronics based project work will enhance the appreciation of evolving and integrating technologies.

Current teaching methodology in Hong Kong is oriented toward lectures and written examinations, and encourages only passive learning and regurgitation. This approach is ineffective for today's students. In addition to specialised knowledge, the current job market often demands skills (communication, co-operation, leadership, and interpersonal skills) that are taught poorly in a lecture-based format.

In 1996 City University of Hong Kong initiated a studio approach to teaching, starting with modules in introductory science and engineering [4]. Studio teaching replaces the traditional large-group lecture, small-group tutorial and separate laboratory work with an integrated approach. A typical studio session consists of a mixture of discussions, mini-lectures, demonstrations, computer simulations, problem-solving activities, and computer supported laboratory exercises. It utilises computer based teaching materials that emphasise multimedia and interactive learning. This paper describes the introduction of studio teaching for introductory electronic engineering for a 1st year Mechatronics Engineering degree course, and an initial evaluation of the effectiveness of this approach over more traditional methods of teaching.

II. STUDIO TEACHING

Studio teaching was first introduced at Rensselaer Polytechnic Institute, in the USA, in the early 90s, initially in the Physics Department [5], [6] and then in other science and engineering disciplines [7], [8]. 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.

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 [9]. 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 [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 180^o [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.

III. COURSEWARE

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.

A number of courseware packages are available on the market that are aimed at first and second year electronic engineering, and related, students. CityU has taken the view that if there are good, well written packages on the market, then it is not necessary to write anything new. After a market survey it was decided that the Electronic Design Education Consortium (EDEC) courseware [12], [13] would cover 60% of the introductory electronics syllabus.

The EDEC courseware only provides a framework for the 'lecture' part of the teaching. Although there are some self-assessment tutorial questions within the EDEC software, it is rudimentary stuff.

Consequently, the tutorial part of a studio session is carried out in a traditional way, with pen and paper, even if the questions are on the screen. Any courseware based tutorials are therefore supplemented by paper exercises.

The EDEC courseware covers about 55% of the first semester course, and 70% of the second semester of the Basic Electrical and Electronic Engineering course. The gaps are in introductory circuit analysis and introductory machines. Packages that can fill these gaps are currently being evaluated, although so far finding any courseware that can compare to the EDEC programs has been singularly unsuccessful.

The modularity of the EDEC courseware, coupled with the ability to customise the presentation sequence of the material, makes it ideal for an integrated teaching studio application.

IV. INTRODUCING LABORATORY CONTENT

The Department of Electronic Engineering (EE) at CityU provides a number of 'service' type courses in electronics to the Department of Manufacturing Engineering and Engineering Management (MEEM), who provide degrees in both Manufacturing Engineering (BEME) and Mechatronics Engineering (BEMTE). The latter started life as a joint degree between the two departments, although it is now a wholly MEEM 'owned' course. Most of the courses in the first year are common to both these degrees, including the introductory electronics course that spans two semesters discussed in this paper. As students are allowed to transfer between the two degrees at the end of the first year, the course content in the BEMTE degree follows very closely on that given by traditional means to the first year BEME students. This means that any laboratory content must be similar, as assessment, including examinations, tests, coursework etc are common to both courses.

A number of institutions involved with the development of laboratory based studio teaching, such as RPI, use 'real' instrumentation to carry out the experiments. At CityU this was not possible, as one of the ITSs is a university resource, the other a faculty resource. As they are not a departmental resource, this means that one lesson may be used for EE, the next for management and the next for physics. Consequently there is not enough time between classes to move large amounts of equipment around, or even have a technician present.

The laboratory course was therefore designed to rely on the only equipment available all the time - the PC. Unfortunately the standard PC does not have the facilities for doing anything useful externally. Some commercially available interfaces, such as the Universal Laboratory Interface (ULI), as used by the Department of Applied Physics and RPI for their laboratory based courseware, make use of the serial port, but this limits the number of items that can be connected at any one time, as well as the bandwidth of any signals used.

Consequently, the laboratory content of the course was designed within a number of constraints. It was quite clear that, with the limitations on current and voltage impose by using an A/D, D/A interface, that most of the experiments in the traditionally taught course would have to be modified or replaced for a course taught in the ITS. For example, the diode used in the diode characteristics experiment would overload the current limit of the D/A as soon as it switched on. Other experiments are just not possible with the a simple pc-based system, for example, the scr and dc machines experiments.

The traditional laboratory manual has been replaced by an online manual. This sits onscreen in a separate window to the instrumentation screen. Some of the hyperlinks in this manual refer to sections of the presentation/tutorial courseware, such as the EDEC modules. It is possible, therefore to link the experimental work screen directly to the lecture and tutorial material.

V. THE STUDY

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 MEEM be some of the first to be converted to the studio environment. At the same time it was agreed that a four-year study of the effectiveness of studio teaching be carried out. Consequently the students enrolled for BEMTE would be taught in the ITS, the students on the BEME course 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.

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.

VI. 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 test for the first 3 cohorts. 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 [14] has been used. A meta-analysis program [15] was applied during the calculations. These analyses used mean and standard deviation data shown in Table 2. 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 also shown in Table 2.

Also, 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 Table 1.

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.

Results of assessments: ITS vs non-ITS students cohorts 1-3 (repeats and exemptions excluded)

All marks are scaled to give percentages

Test			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	39	59	39	48	39	multiple choice only
		avg	59.91	60.21	54.37	53.80	58.81	58.82	
		stdev	15.73	7.93	13.38	11.35	14.04	7.74	
			no sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.05$		
			$\delta = 0.030$		$\delta = -0.043$		$\delta = 0.157$		
Mid A		n	108	38	58	37	48	37	multiple choice only
		avg	79.04	83.98	77.93	80.81	79.13	89.01	
		stdev	5.48	4.63	10.41	7.75	17.66	10.18	
			sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.05$ sig diff $\alpha \leq 0.1$		sig diff $\alpha \leq 0.05$		
			$\delta = 0.897$		$\delta = 0.277$		$\delta = 0.559$		
Final A		n	85	33	55	37	46	37	includes c/w
	total mark	avg	50.69	58.69	53.39	57.05	37.25	45.38	
		stdev	7.51	8.22	8.97	12.56	7.28	9.52	
			sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.05$ sig diff $\alpha \leq 0.1$		sig diff $\alpha \leq 0.05$		
			$\delta = 1.063$		$\delta = 0.408$		$\delta = 1.127$		
	total exam	avg	38.52	48.76	53.61	57.00	27.56	36.90	exam only
		stdev	9.87	9.08	11.70	14.96	8.36	12.28	
			sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.1$		sig diff $\alpha \leq 0.05$		
			$\delta = 0.937$		$\delta = 0.298$		$\delta = 1.117$		
	m-c	avg	60.31	75.97	70.40	77.30	51.27	54.16	m/c component
		stdev	12.33	9.06	12.71	11.78	11.22	11.22	
			sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.1$		no sig diff $\alpha \leq 0.1$		
			$\delta = 0.937$		$\delta = -0.086$		$\delta = 0.258$		
	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	18.15	13.98	
			sig diff $\alpha \leq 0.05$		no sig diff $\alpha \leq 0.05$ sig diff $\alpha \leq 0.1$		sig diff $\alpha \leq 0.05$		
			$\delta = 0.873$		$\delta = 0.443$		$\delta = 0.895$		
Final B		n	84	39	55	37	44	37	includes c/w
	total mark	avg	53.96	52.27	40.16	40.61	37.97	44.09	
		stdev	9.65	9.04	9.84	12.15	12.06	13.19	
			no sig diff $\alpha = 0.05$		no sig diff $\alpha \leq 0.05$		sig diff $\alpha \leq 0.05$		
			$\delta = -0.175$		$\delta = 0.046$		$\delta = 0.507$		
	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 $\alpha \leq 0.05$ sig diff $\alpha \leq 0.1$		no sig diff $\alpha \leq 0.1$		sig diff $\alpha \leq 0.05$		
			$\delta = 0.351$		$\delta = 0.061$		$\delta = 0.605$		
Comment			(Lab work done in lab - both courses) Exam p/w = 60:40		(Sem A lab in ITS Sem B lab in Lab) Exam p/w = 60:40		(Sem A and most Sem B lab in ITS) Exam p/w = 70:30		

Table 1. Results and statistical analysis of first three cohorts performance

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

Table 2. Meta-analysis of results - comparison of effect sizes within cohorts, and for all cohorts

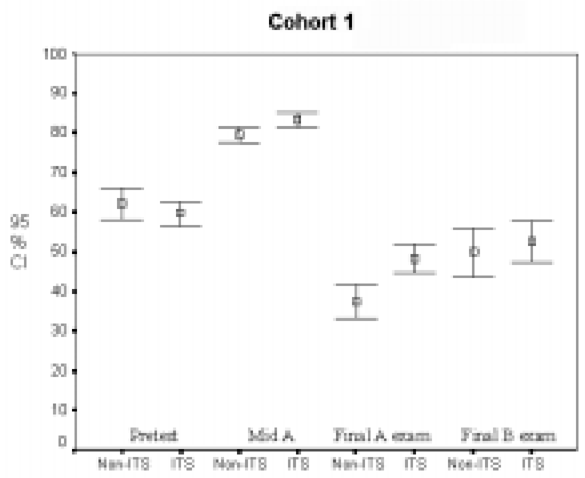

Chart 1. Mean scores and 95% CI for cohort 1

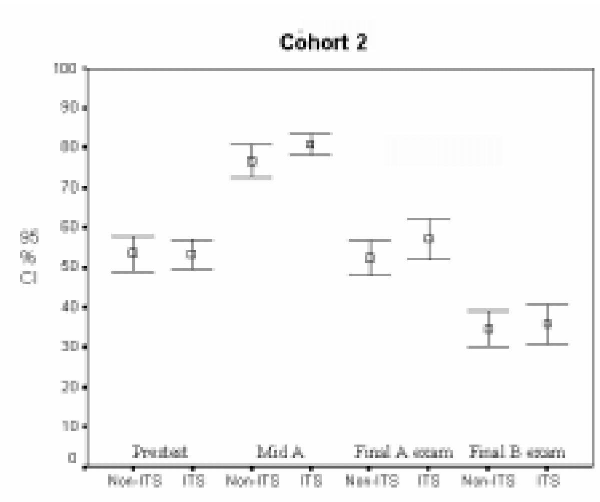

Chart 2. Mean scores and 95% CI for cohort 2

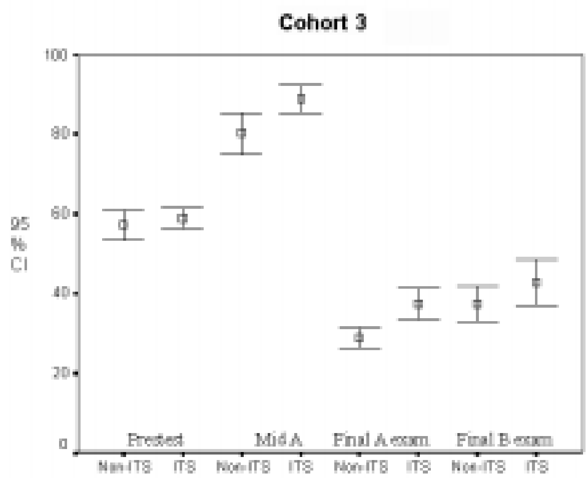

Chart 3. Mean scores and 95% CI for cohort 3

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.

VII. CONCLUSIONS

It is clear that, even without the laboratory component integrated into the curriculum, as occurred with cohort 2, 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 currently being evaluated is the effect of placing most of the teaching material on the Web. The interactive courseware has now been made available to the non-ITS students via the web, and it will be interesting to see, when analysis of the current cohort is complete, whether this affects the results reported here.

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