

Action Learning Research in Engineering Design Teaching

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Abstract

While teaching mechanical engineering courses, the lecturer realised that the existing course structure and learning environment did not encourage coherent/integrated learning of the subject matter. Furthermore, there was a need to conceptualise real-life elements of engineering; in the other words, it was necessary to bridge the gap between theory and practice. In order to tackle the need for integration, and also the need to improve laboratory-based teaching, the lecturer concerned worked on developing a multi-media teaching system, which employed automation technology to link with the laboratory equipment. Such a learning environment has concrete objects, and visual and symbolic representation presented concurrently. It is envisaged that the combination of multi-sensory stimulation, the organisation of content, and challenging problem-solving will encourage learning and the development of meta-cognitive processes.

This Action Learning Project aimed to extend the multi-media teaching system and to develop an instrument to evaluate and improve the effectiveness of a new teaching/learning environment. A questionnaire was developed to measure the students' responses to the learning environment, their learning experience, and the teacher's role in such a multi-media assisted teaching/learning setting. The questionnaires were administered to both full-time and part-time students who had spent a half semester in the new environment. Although their teaching/learning environments were slightly different, their responses were similar. Furthermore, it appears that the role of the teacher was still the determining factor in the success of the multi-media teaching/learning environment.

Background

After having taught the Mechanical Engineering subjects for a few years, the lecturer concerned identified some major pitfalls/needs in typical engineering education even though the courses were relatively well established.

Inadequate Inter- and Intra-Integration of Engineering Courses

Unlike mathematics, logic, and philosophy, which are mostly concerned with abstract concepts, engineering courses are closely related to the physical world. It is therefore more effective to convey the subject matter by means of physical examples. This is especially true for mechanical engineering design courses because the content concerns the design of real-life engineering components such as bearings and shafts. However, the present teaching format only supports the physical examples to be presented and studied within a laboratory context, which is far removed from the subject matter tuition environment (both mentally and physically). Furthermore, the engineering teaching materials are usually delivered in a sequential manner and the students tend, therefore, to understand the whole course in a sequential but fragmented way. For example, it is very difficult for students to relate the material learnt at the end of the course with that

learnt at the beginning. This can be illustrated clearly by the fact that a lot of materials taught in a second year mechanical design course employs many concepts covered in the first year engineering design and analysis courses. The lecturer in charge has found that students lack the ability to integrate the new mechanical design materials with previously learnt engineering concepts. It is therefore apparent that the integration with the physical world within an individual course, and the integration between different engineering courses, requires improvement.

Inefficient Laboratory Type Teaching

In most engineering discipline teaching, laboratory teaching is a major and usually mandatory feature. However, in laboratory sessions, students are always engrossed in making records of observations of events or objects, transforming these records into graphs, tables or diagrams and drawing conclusions - often without knowing why. Rarely do students deliberately invoke relevant concepts, principles, or theories in order to understand why specific events or objects have been chosen for observation, why they are making certain records or certain kinds of graphs or tables, or why their conclusions from the data are often wrong when judged against textbooks, handbooks or other authorities. In short, students' methodological or procedural activities are usually not consciously guided by the kinds of concepts and theoretical ideas scientists use in their inquiries - there is no active interplay between the thinking side and the doing side of the exercise. As a result, laboratory work is often frustrating and/or meaningless - or to put it bluntly, it is often a waste of time.

In order to tackle the need for integration, and the need to improve laboratory-based teaching, the lecturer concerned has since worked with the Professional Development and Quality Services unit of the university to identify strategies. Education techniques such as Concept Mapping and Vee Heuristic from Gowin and Novak are employed in establishing the strategies, which address the needs in two ways:

- by redesigning the structure of the teaching content;
- by delivering the content in a more integrated and interesting manner.

Furthermore, the excitement generated by new technologies has prompted many academic members to seek assistance to enhance their teaching and improve the quality of learning opportunities for students. Never before have so many academic members been so involved in using technology in their courses (Green, 1997). Unlike previous approaches to using instructional technology, which placed a high degree of structure or control on the learner, the new technology-based instructional applications provide an environment permitting more learner choices (Gillespie, 1998). This fits the new paradigm proposed by Barr and Tagg (1995), whereby we move from a learning environment that is teacher-directed to one that provides for more learner options. Higher education has begun to respond to the challenges of the new instructional paradigm, in part, by developing a strong technology component in its programmes (O'Banion, 1997). Infrastructure is improving, and academics are encouraged to develop on-line courses, with course development tools becoming available. By using the new technology, academics can address teaching and learning issues in several ways. They can enhance quality by enabling students to take a more active role in their learning. They can offer a greater array of resources for their students to use both inside and outside of the classroom. They can provide more opportunities for interactions between and among their students. Perhaps most important of all, they can provide experiences that promote the development of higher order cognitive skills rather than just the transfer of content (Gillespie, 1998).

Courseware Implementation

A proposal was submitted to the university, which consisted of implementing a new set of courseware employing multi-media technologies, the target platform for the system being primarily the University LAN, and finally, the Internet.

The course content is about vibration, which involves many types of motion. Such mechanical behaviour is very difficult to convey in a traditional textbook manner. An animated ball going up and down with decreasing amplitude (see Figure 1) illustrates the motion of a damped vibration. This allows the student to visualise how the vibration amplitude is decreasing with time. Such visual behaviour is very effective for student learning before they embark on the tedious mathematical equations. The courseware is also supplemented with engineering examples (Figure 2) such that the students can associate what they learn with what they can do in real life. Finally, a vibration experimental rig was specially built to teach a different mode of vibration (Figure 3). The equipment is linked to a PC so that the mechanical behaviour is displayed real-time and the student can draw a strong correlation with what they learnt from the courseware.

Figure 1: The courseware for teaching vibration

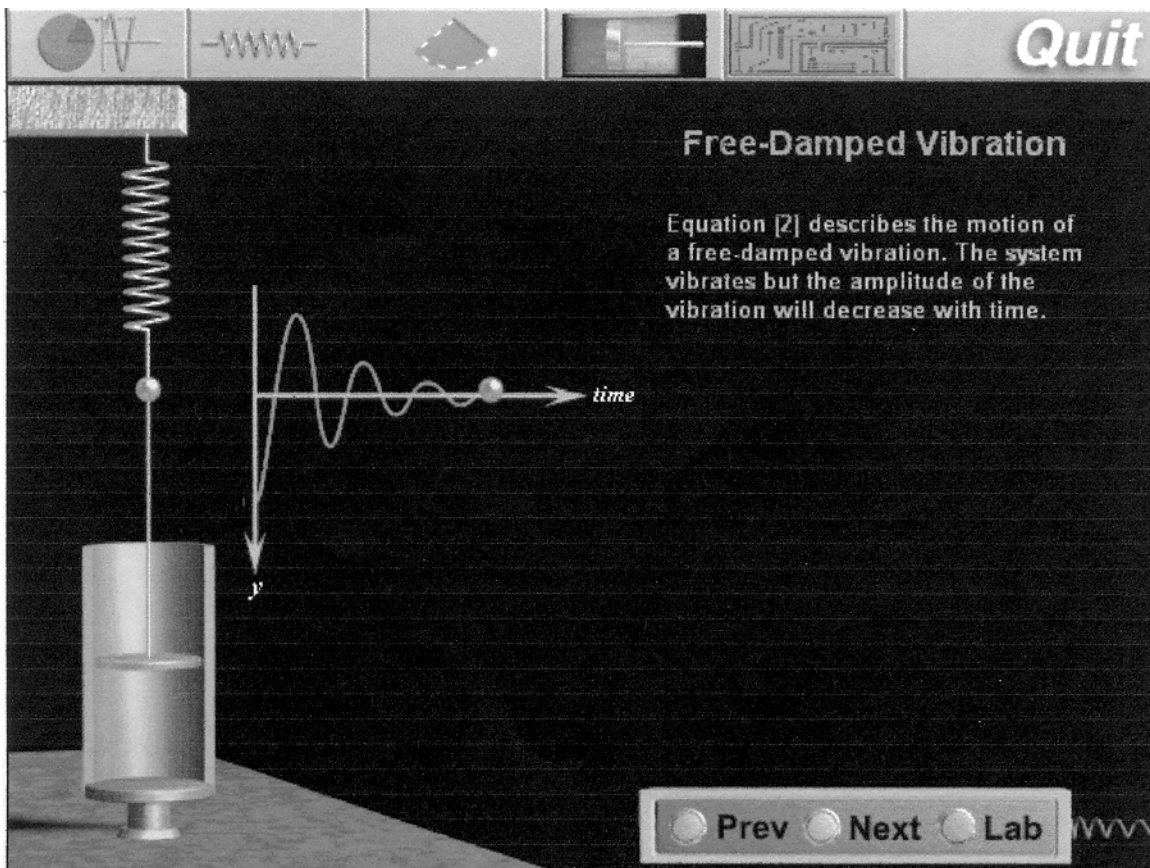
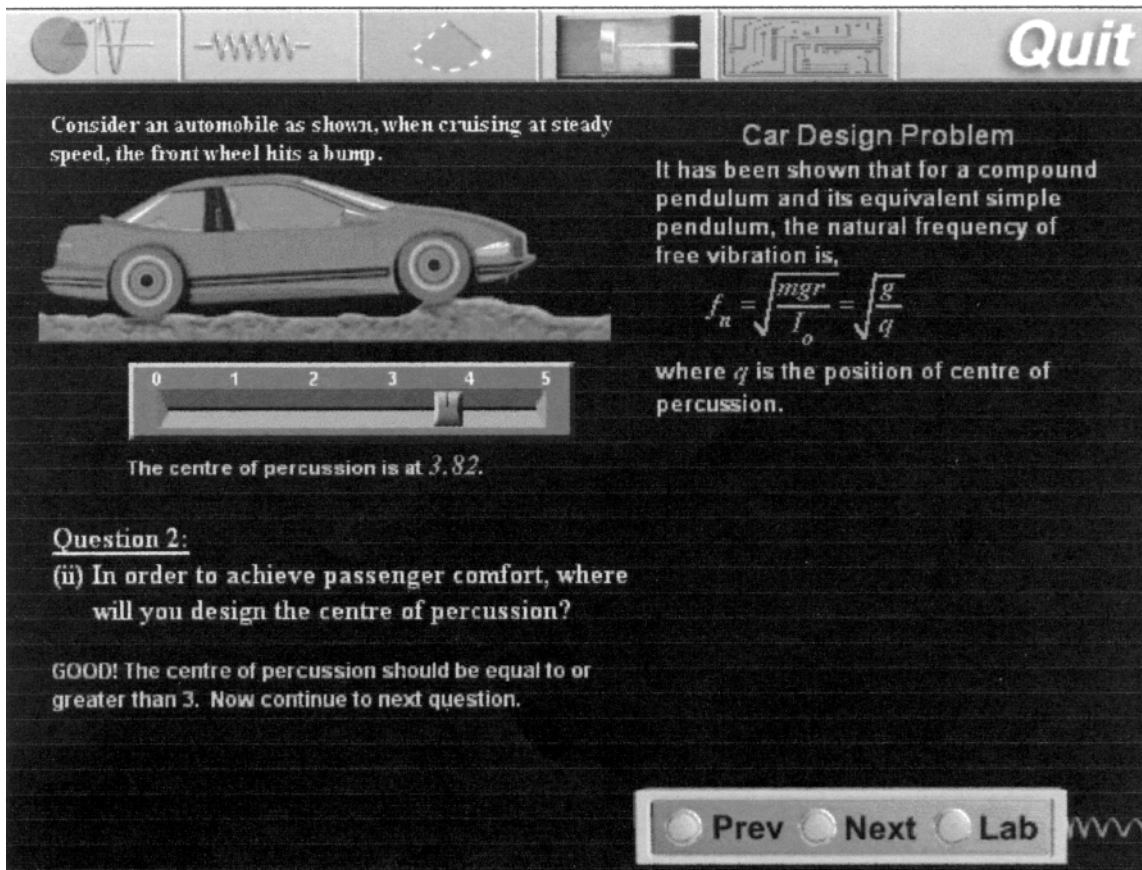
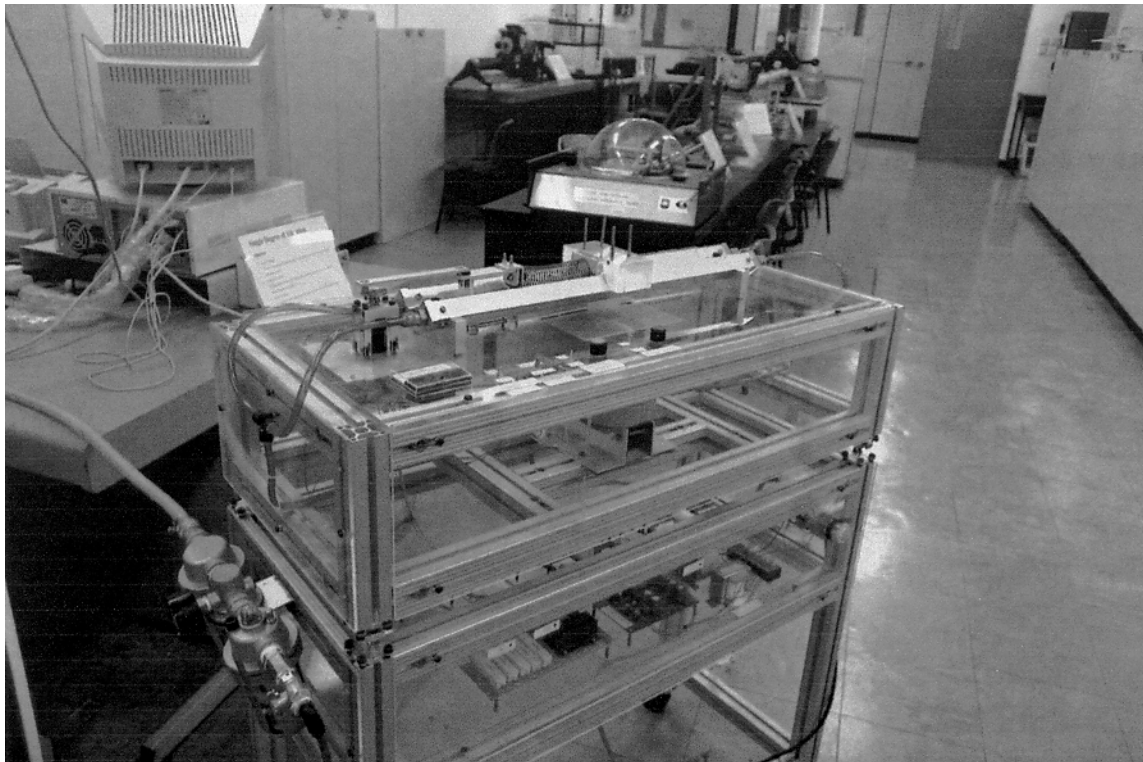


Figure 2: Real life engineering example is used in courseware



The screenshot shows a software interface for a physics problem. At the top, there is a navigation bar with icons for a pie chart, a spring, a pendulum, a car, and a circuit, along with a 'Quit' button. The main content area has a dark background. On the left, a car is shown on a bump, with a scale below it from 0 to 5. Text reads: 'Consider an automobile as shown, when cruising at steady speed, the front wheel hits a bump.' Below the scale, it says 'The centre of percussion is at 3.82.' On the right, the text reads: 'Car Design Problem It has been shown that for a compound pendulum and its equivalent simple pendulum, the natural frequency of free vibration is,' followed by the equation $f_n = \sqrt{\frac{mgt}{I_o}} = \sqrt{\frac{g}{q}}$. Below the equation, it says 'where q is the position of centre of percussion.' At the bottom, there is a 'Question 2:' section with a sub-question: '(ii) In order to achieve passenger comfort, where will you design the centre of percussion?' Below this, it says 'GOOD! The centre of percussion should be equal to or greater than 3. Now continue to next question.' At the bottom right, there are buttons for 'Prev', 'Next', and 'Lab'.

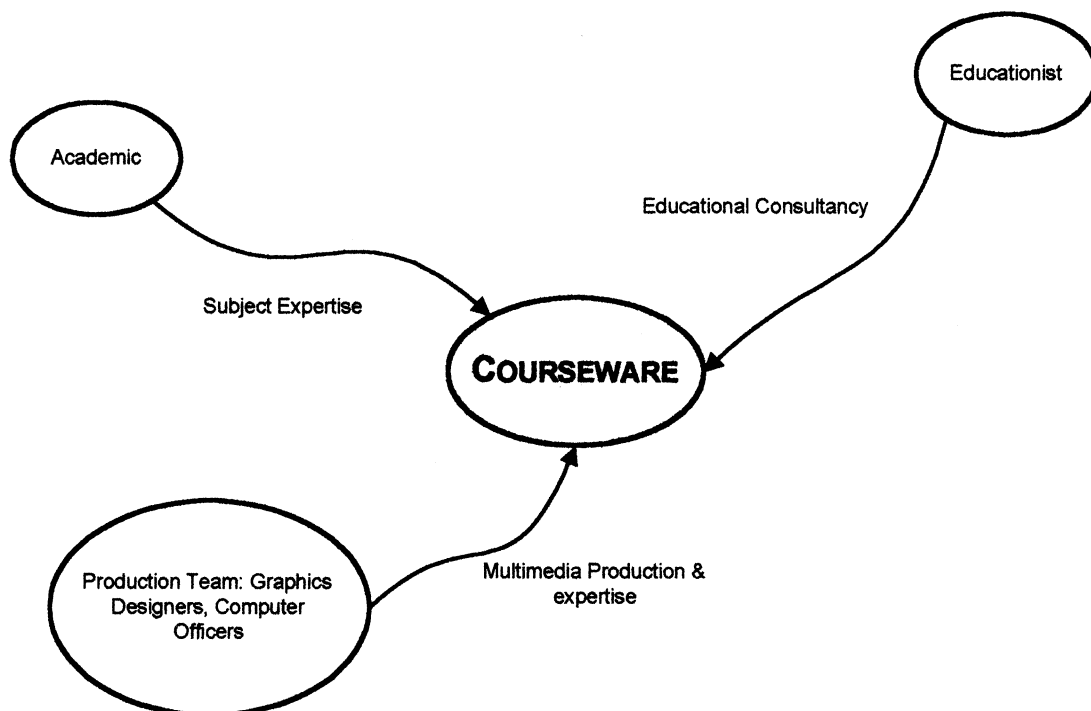
Figure 3: Laboratory equipment is linked to courseware using automation technology



The Action Learning Project later also provided support to improve the courseware and to develop tools to analyse the effectiveness of the system for learning. The funding thus allowed a portion of the engineering teaching content to be implemented in multi-media format and a vibration test rig was modified and interfaced with the teaching system.

As far as the production of the multi-media courseware is concerned, apart from finance, the main problem was in using IT for education development. It is accepted that one can hire a research assistant to develop courseware, and the academic can carry out the programming work and produce first-rate courseware. In our case, the courseware development was based on a team model (Figure 4) to demarcate tasks to the most suitable member, rather than in finding a single person who could handle every aspect but only marginally satisfactorily. There were three players in this model. The academic was the subject expert who was also the final user of the courseware. He defined what was required of the courseware and he also provided the subject details. The second player was the educationist who gave advice on instructional design and knowledge representation. The educationist/instructional designer worked closely with the academic, using the carefully planned concept maps, to translate the subject content into a special document - usually known as the storyboard - which has specific guidelines for the purpose of producing multi-media materials. The third player in the production team consisted of graphic designers and multi-media system developers. They used the script provided by the academic and the educationist to create media elements such as audio, video and graphics/animation as required.

Figure 4: Courseware production team model



Questionnaire Relating to the Courseware

Effort was made to pilot test the courseware amongst engineering students. A questionnaire (Figure 5) with 23 items was administered to the class of about 30 part-time students. They were mainly mature students who were teachers in schools during the daytime. The group pilot-tested

the courseware for two hours. They also used the courseware in their study where it was viewed positively.

Figure 5: Questionnaire on courseware

Multimedia Package Evaluation Questionnaire

	Rating		-3	-2	-1	0	1	2	3
Your Learning									
<i>To what extent did the multimedia package assist, or allow, you to:</i>									
1	change your knowledge of the subject								
2	changed your understanding of the topics presented								
3	allow practice to change your performance								
4	Get appropriate feedback on your performance								
5	correct any errors								
6	get to know the structure of the subject matter (the content)								
The Instruction (teaching/ tutoring)									
<i>How well did the multimedia package:</i>									
7	present sequenced activities								
8	challenge your thinking								
9	encourage problem-solving and application of knowledge								
10	arouse your interest in the topic or the subject matter								
11	prompt the “tutor” to work with the class (or with yourself)								
12	act as a teaching tool in this situation								
Affective (feelings)									
<i>From your experience, did you feel the package to be:</i>									
13	stimulating/ attractive								
14	motivating/ interesting to use								
15	satisfying/ feel good to use								
Technical									
<i>How would you rate the multimedia package for:</i>									
16	quality of screen presentation								
17	ease to use								
18	computer problem – glitches, bugs, technical problems								
19	navigation (easy of knowing where you were in the program)								
General									
<i>Overall, what is your opinion about:</i>									
20	Using this program again								
21	recommending it to your fellow students								
22	the organisation of “laboratory” experience								
23	how worthwhile the activity/experience was								

Some appropriate descriptors for the SEVEN POINT SCALE (-3, -2, -1, 0, 1, 2, 3)

- 3 (most negative) Greatly decreased/ much lower, Very Low, Unsatisfactory, Strongly Disagree, Worthless/ useless
- 2 (more negative) Decreases/ much lower, Low, Very Poor, Firmly Disagree, Unacceptable
- 1 (negative) Slightly decreased. Lessened, Slightly below average, Poor, Slightly Disagree, Unsatisfactory
- 0 (middle area) Same as before/ unaltered, Average, Generally Acceptable, Neutral, Satisfactory
- +1 (positive) Slightly increased/ little better, Slightly Above Average, Good, Agree Slightly, Quite Satisfactory
- +2 (more positive) Increased/ noticeably improved, High, Very Good, Firmly Agree, Outstanding
- +3 (most positive) Greatly increased/ significantly improved, Very High, Highly Satisfactory, Strongly Agree, Brilliant

The questionnaire was divided into the following aspects:

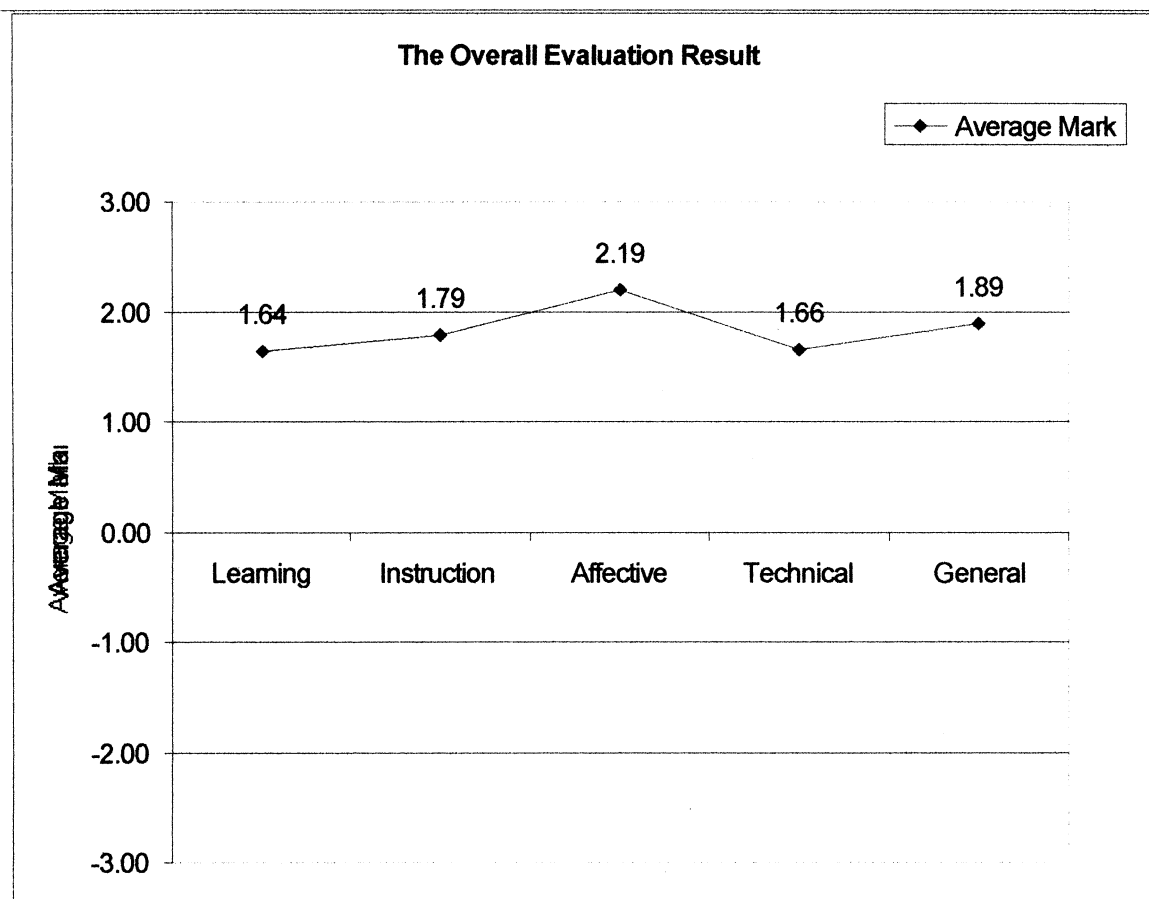
- Learning – this concerned the impact of the courseware on such areas as knowledge, understanding, practice, and feedback.
- Instruction – this was to ask how much the learning/teaching environment affected areas such as thinking, application of knowledge, interest stimulation.

- Affection – this was mainly concerned with how attractive and motivating the courseware was considered to be.
- Technical – this concerned the user friendliness of the courseware.
- General – in this section, users were asked whether they would like to use the courseware again, whether they would recommend others to use it, and whether it was a worthwhile experience.

The average score for each aspect is shown in (Figure 6). On the seven point scale, 3 = strongly positive, 0 = neutral, and -3 = strongly negative. It can be seen that the overall feedback viewed the courseware favourably. Amongst the five aspects, the technical side rated the lowest, which is to be expected for the pilot set of courseware, while the score for affection rated the highest.

To summarise, the overall attitude towards the courseware was positive. It was seen, therefore, to be worth pursuing its use in teaching activities.

Figure 6: Survey results on courseware



Survey Related to Teaching and Learning

A new questionnaire (Figure 7) was designed to find out more about the learning environment, learning experience and the role of the teacher when using such multi-media courseware. The questionnaire was administered near to the end of the project.

Figure 7: Questionnaire on learning and teaching

Questionnaire on Courseware Evaluation

The questionnaire intends to find out how the vibration computer courseware, which is integrated in the course, affects your learning experiences.

Please use HB pencil to mark the answer in the survey form according to the following categories.

A = strongly disagree B = disagree C = agree D = strongly agree

On learning environment:

1. Computer-aided tutorials are useful for my learning.
2. The computer courseware was useful in tutorials.
3. I've found that the self-accessed computer courseware through the LAN is useful for my study.
4. The computer courseware was well integrated in the lectures.
5. There was enough opportunity to use the equipment – Vibration Test Rig.
6. The computer courseware was well integrated in the tutorials.
7. The computer courseware was useful in lectures.

On student learning experience:

8. I like learning through interacting with the computer software.
9. I think that the computer courseware helps me to understand concepts better than the text-script handouts.
10. As a result of learning through the computer courseware, I developed new interests in the topic.
11. Having gone through the computer courseware, I could apply the principles learned in new situations.
12. The computer courseware stimulated me to raise questions in tutorials.
13. I need to refer to the handouts frequently for revision, although I have gone through the computer courseware.
14. I still have unsolved problems about the topic, although I have gone through the computer courseware.
15. I prefer more hand-on laboratory work than learning with the animated computer courseware.
16. The computer courseware stimulates me to discuss problems with my classmates.

On teacher's role in the tutorials when courseware is available:

17. The lecturer made me feel welcome to ask questions.
18. I think that the lecturer has made good use of examples and illustrations from the computer courseware to help his explanation.
19. I think that the lecturer was willing to provide individual guidance when students had problems in understanding the concepts.
20. The lecturer encouraged us to discuss between classmates.
21. The lecturer gave clear guidance in using the computer software.
22. The lecturer provided feedback on students' performance.

23. **Please write your comments about your learning using the courseware on the back on the survey form.**

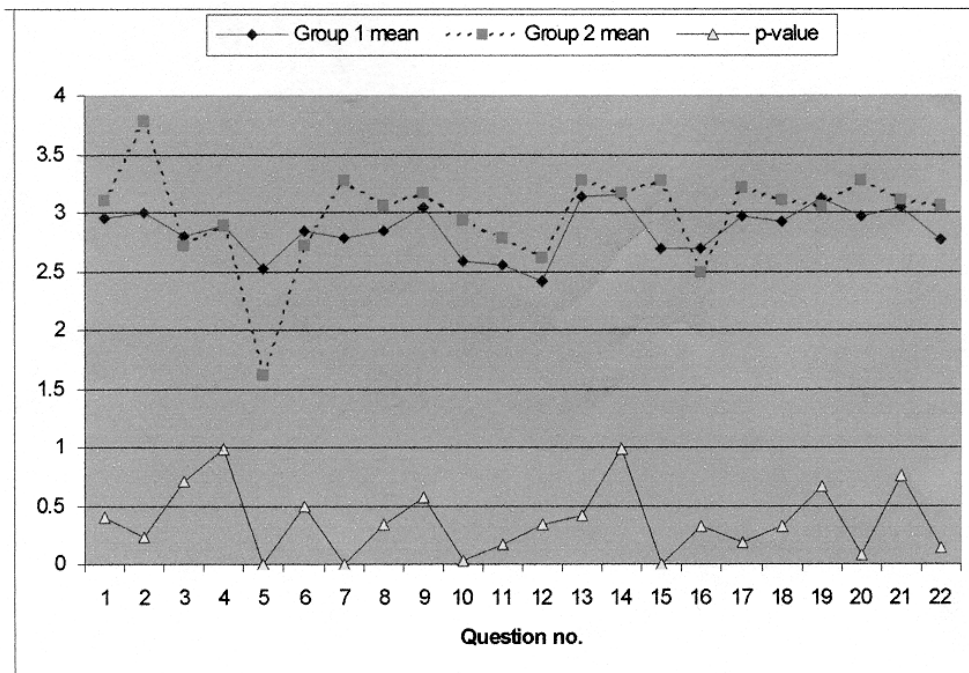
End of Questionnaire & Thank You

The target students were from two groups. The first group (group 1, n=74) consisted of full-time students who had access to the courseware in both the tutorials and the computer service centre, in their own time. Due to the large number of students in the group, the courseware was shown on a large screen in the lecture theatre during lectures. The second group (group 2, n=18) were mature part-time students. The number of students were fewer than 30, therefore the courseware was used

fully in both lectures and tutorials. It was conducted in the same room equipped with a computer terminal and a large screen for computer display in the front of the room. A summary of the findings is shown in Figure 8.

Figure 8: Comparison between group 1 and group 2

Question no.	Group 1 (n = 74)		Group 2 (n = 18)		Differences of means	t-statistics	95 % confidence interval of the difference		p-value
	Mean	SD	Mean	SD			Lower	Upper	
1	2.96	0.6912	3.11	0.5830	-0.1517	-0.859	-0.5026	0.1993	0.393
2	3.00	0.6621	3.78	0.8085	0.2222	1.222	-0.1391	0.5836	0.225
3	2.80	0.7019	2.72	0.9538	-0.0751	0.377	-0.3202	0.4703	0.707
4	2.89	0.5630	2.89	0.7584	-0.0030	0.019	-0.3127	0.3187	0.985
5	2.53	0.7257	1.61	0.7775	0.9159	4.737	0.5318	1.3001	0.000
6	2.84	0.6199	2.72	0.6691	0.1156	0.699	-0.2131	0.4443	0.486
7	2.78	0.6253	3.28	0.4609	-0.4640	-3.145	-0.8061	-0.1819	0.002
8	2.84	0.8281	3.06	0.9376	-0.2177	-0.975	-0.6614	0.2260	0.332
9	3.05	0.7745	3.17	0.7071	-0.1126	-0.562	-0.5106	0.2853	0.575
10	2.58	0.5970	2.94	0.6391	-0.3634	-2.285	-0.6793	-0.0474	0.025
11	2.55	0.6245	2.78	0.6468	-0.2298	-1.389	-0.5586	0.0990	0.168
12	2.42	0.7586	2.61	0.6978	-0.1922	-0.978	-0.5825	0.1981	0.331
13	3.14	0.6889	3.28	0.5745	-0.1426	-0.812	-0.4918	0.2066	0.419
14	3.16	0.7407	3.17	0.7859	-0.0045	-0.023	-0.3958	0.3868	0.982
15	2.69	0.7572	3.28	0.7519	-0.5886	-2.962	-0.9834	-0.1938	0.004
16	2.70	0.7569	2.50	0.8575	0.2027	0.996	-0.2016	0.6070	0.322
17	2.97	0.6819	3.22	0.8085	-0.2492	-1.340	-0.6187	0.1202	0.183
18	2.92	0.6975	3.11	0.8324	-0.1922	-1.009	-0.5707	0.1863	0.316
19	3.12	0.6183	3.06	0.4162	0.0661	0.429	-0.2396	0.3718	0.669
20	2.97	0.6615	3.28	0.6691	-0.3048	-1.749	-0.6510	0.0413	0.084
21	3.05	0.6387	3.11	0.8324	-0.0571	-0.319	-0.4119	0.2978	0.750
22	2.77	0.7173	3.06	0.8269	-0.2917	-1.467	-0.6869	0.1035	0.146
S1	2.83	0.3949	2.73	0.5606	0.0980	0.865	-0.1271	0.3231	0.389
S2	2.79	0.3430	2.97	0.3745	-0.1831	-1.995	-0.3654	-0.0008	0.049
S3	3.00	0.4580	3.17	0.5623	-0.1700	-1.350	-0.4204	0.0803	0.181



Reliability Measures

The Cronbach Alpha was used to check whether the students' answers were consistent throughout a scale. For example, were the students answering each of the questions in 'On learning environment' in a similar pattern? Alpha is a value from 0 to 1 in which the higher the value, the higher is the reliability.

Scale	Alpha
On learning environment (S1)	0.7380
On student learning experience (S2)	0.6041
On teacher's role in the tutorials (S3)	0.6793

The alpha values obtained as shown above were quite high which indicate that the students' answers on each of the above-mentioned scales were consistent. Therefore, we can compute aggregate scores on each of the scales and investigate the relationship between these three aspects.

Comparison between the Scales

Aggregate scores were computed by summing the responses on each of the questions within a scale divided by the total number of questions included in that scale.

Pair	Mean of the 1 st Component (SD)	Mean of the 2 nd Component (SD)	Correlation (r)	Mean of the differences	t-value	p-value
S1 & S2	2.808(0.428)	2.823(0.360)	0.497	-0.053	-0.519	0.604
S2 & S3	2.823(0.360)	3.027(0.481)	0.483	-0.2041	-0.6314	0.000
S1 & S3	2.808(0.428)	3.027(0.481)	0.448	-0.2193	-0.6223	0.000

It can be seen from the table above that there was no significant difference between the average scores given by the students between S1 and S2 but there was a significant difference between S3 with both S1 and S2. In particular, we can see that the students' average scores on the 'teacher's role in the tutorial' were significantly higher than both the 'learning environment' and the 'student learning experience'. Contrary to the notion that computer-aided learning is often a solitary affair, it appears that the students, both full-time and part-time, preferred the presence of, and assistance from, the teacher when using the courseware. However, this was not conclusive.

Comparison between Group 1 and Group 2

The line chart (Figure 8) demonstrates the following observations of note.

- In most of the questions, there was no significant difference between the students of group 1 and group 2.
- The questions which showed significant changes in students' attitudes have been highlighted in the above table. The corresponding p-value was smaller than 0.05.
- The significant differences of question 5 were positive, meaning that the average scores given by the students of group 1 were significantly higher than those of group 2. (This is obvious

since resources could not be allocated for group 2 to use the equipment at length in this semester.)

- The significance differences of questions 7,10 and 15 were negative indicating that the average scores given by the students of group 2 were significantly higher than those of group 1. The response to question 15 is to be expected following the finding from the above point. It is interesting to see that the part-time students actually liked having the courseware to hand during lectures – perhaps the reason being that the situation provided more interactions between student and student, and student and teacher. Additionally all the technical details were ready on the computer screen. As far as question10 is concerned, it seems that the effectiveness of the courseware can be maximised in a small-group teaching environment, given enough terminals.
- For questions 8-16, 'student learning experience', average scores of the group 2 students were significantly higher than those of group 1. This further supports the notion that the courseware was more effective for learning if it was used in a small group which provided for more interactions between different parties.

Conclusions

A new courseware, which utilises the multi-media technology, was developed, the system being integrated with real-

life examples and laboratory equipment. The courseware has now been used for two semesters. In the pilot test, a questionnaire was administered, the results showing that the students were generally very positive about the courseware. However, there were still a number of technical 'hiccups' which needed to be addressed.

After the second trial, which was on a much larger scale, with both full-time and part-time students, a new questionnaire was designed to evaluate the learning and teaching when using the system. It was found that the system was used effectively in a small group and an interactive environment. Interest in the subject was raised as a result of using the courseware. Finally, it was interesting to see that the influence of the tutor was much higher than either the students' experiences using the computer courseware, or the learning environment. Therefore, the role of the tutor cannot be ignored in such multi-media teaching/learning environments.

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