Using circuit simulator software in the study of electronic circuit behaviour.

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***Abstract**: This paper reports on a pilot research project that investigated the use of a digital circuit simulation software, EasySim, in the study of digital electronics in the first year of an undergraduate engineering course. The ultimate aim of this research, to be completed in 2005, will be to investigate the student experience with such software and its effect on one of their study outcomes (that is their exam results). Students were encouraged to use the tool during their normal learning activities. Those who used the software found it to be helpful. Statistical analysis of exam results for the pilot group indicated a strong relationship between the exam marks obtained and the time spent using the software.*

***Keywords**: Pilot study, simulation software, visual learner, auditory learner, kinaesthetic learner, tactile learner, digital electronics.*

Introduction

This pilot study is concerned with the use of simulators in education. The earliest documented examples of the use of simulators for training, such as tree trunks for practicing sword strokes, are in the military and dates back to the Roman Empire[7]. Simulation for training in the military has continued over the centuries and is still used today. Furthermore, modern simulators are also being used to train individuals to control movement of aircraft, automobiles, and ships as well as to control processes such as air traffic, atomic power generators, and even a patient under anaesthesia. In industry the use of simulators has enabled efficient product development and debugging. In leisure and entertainment video games can be viewed as simulations of real and/or imaginary systems. In education, software simulators of microprocessors have assisted with the detailed understanding of the behaviour of these devices.

The advantages of using simulators include:

- allowing the user to modify system parameters and observe the outcomes without any harmful side effects,
- eliminating component or equipment faults that affect outcomes,
- support user paced progress in discovery and understanding of issues,
- allowing the presentation of "dry theory" in another way.

A major disadvantage of the use of software simulators for physical situations, such as electronic circuits, is that the user is unable to physically handle the circuit components.

Theoretical bases of the approach

Underlying learning style research is the belief, verified by some studies, that students learn best when they can address knowledge in ways that they trust[5]. While each student has a different learning style; most retain a dominant and an auxiliary learning modality. Students usually rely on those modes to process information at an unconscious level however they still may be consciously aware of their preferred mode. The learner accesses information through all senses, but generally favors one. These are visual (by sight), auditory (by sound), kinaesthetic (by moving), and tactile (by touch)[4].

Visual learners prefer seeing what they are learning since images help them understand ideas and information better than explanations. Kinaesthetic learners want to sense the position and movement of what they are working on. Tactile learners want to touch, if possible, the ideas and concepts. Therefore the Golden Rule of teaching may be paraphrased as: "*present information to others as they will best learn*"[4].

The use of simulator software in the study of conceptual ideas, such as circuit behaviour, directly targets the visual, kinaesthetic and tactile learner.

Britain states, in his report for the JISC E-Learning Pedagogy Programme, that: "*Successful teaching involves a variety of strategies and techniques for engaging, motivating and energising students ... There are a number of pedagogical techniques that focus on providing activities for learners to perform either in groups or as individuals that help to create deeper, swifter and more effective learning. These may be in the form of … simulations*"[2].

Teaching and learning details

The simulator was employed in a subject that was timetabled for 60 contact hours per student in the second semester of their eight-semester long course. The subject syllabus covered five basic electrical/electronic engineering topics; namely DC circuit behaviour, AC circuit behaviour, electromagnetism, amplification and digital electronics. Approximately 20% of the contact hours was assigned to the last topic. This material was covered in lectures, tutorials, assignment questions and a laboratory session. In 2004 the approximately 390 enrolled students were divided into three lecture groups each with a different staff member presenting the material. While the software was available to all students and staff, only one of the three lecturers embraced the simulator and used it to additionally illustrate the behaviour of digital circuit elements during the appropriate lecture sessions.

The procedure

In Academic Weeks 9-12 inclusive the digital electronics topic was covered in the lectures and subsequently reinforced in tutorials and assignment questions as well as in one laboratory session. The circuit simulator software, *EasySim*, was made available for all students to download from the University's Blackboard web site. The students were advised to use the software while trying to understand the behaviour of digital circuits, while checking the solutions to problems that students were asked to solve during the tutorial sessions and/or while checking answers to examples in text books.

The students were asked to record the total time spent on studying the digital electronics topic, the total time they used the simulator software and the help, if any, it provided to them. After the exam the students were asked to fill out an on-line survey that provided the researcher with data relating to the students' experiences while using the tool.

Each student participant was asked to complete seven "multiple-choice" questions, seven "fill-in-the-blank" questions and one "essay" question. The questions were either open (*fill-in-the-blank* or *essay*) or closed (*multiple choice*) type. A major problem with closed or forced-choice questions is that insufficient alternatives or inadvertent prompting may create a false result; but these are easier to code. On the other hand coding of open type answers may suffer from misinterpretation by the researcher that could result in misclassified responses. In the words of Alreck: "*the choice of open or closed questions depends on many factors such as the question content, respondent motivation, method of administration, type of respondents, access to skilled coders…and the amount of time available to develop a good set of unbiased questions*"[1]. Since this research was only carried out once, an obvious downside to the over all value of the results is that it was impossible to carry out some pre-testing in an attempt to eliminate any biases!

The Results

A total of ten responses were obtained from a pool of about 390 enrolled students. From the three lecture groups the number of responding students was roughly evenly distributed (30%, 40% and 30%).

Student Feedback

The survey results were coded into *SPSS* and this statistical software tool was used to obtain possible relationships between all the questions. Table 1 summarises the mean, standard deviation, skewness and kurtosis for each set of obtained responses for the questions that were scaled (such as hours spent on different activities).

More qualitative outcomes were obtained by looking for trending between all the questions, some of which were responded to by an ordinal (Likert) scale. For this purpose scatterplots were produced as well as both Pearson's and Spearman's correlation values calculated.

For the small group of responding students the following relatively strong positive trends were found:

- The number of hours spent in preparing for lectures, tutorials and laboratory classes and the lecturer taking the lectures.
- The lecturer who used the simulator in lectures and the students who found the software beneficial for understanding digital electronics issues.

		Q2 Hours spent preparing for Lectures	Q3 Hours spent preparing for Tutorials	Q4 Hours spent preparing for Labs	Q5 Hours spent solving problems on own
N	Valid	10	10	10	9
	Missing	0	0	0	1
Mean		6.2000	3.4000	2.5000	2.3333
Std. Deviation		3.91010	2.75681	1.08012	2.00000
Skewness		-.410	1.546	.661	1.701
Std. Error of Skewness		.687	.687	.687	.717
Kurtosis		-1.443	3.516	-1.032	3.978
Std. Error of Kurtosis		1.334	1.334	1.334	1.400

		Q6 Hours spent solving problems with others	Q7 Hours spent revising for exam	Q8 Hours spent using EasySim
N	Valid	10	10	10
	Missing	0	0	0
Mean		.5000	2.2830	2.5170
Std. Deviation		.97183	2.00660	4.82673
Skewness		2.270	.979	2.955
Std. Error of Skewness		.687	.687	.687
Kurtosis		5.356	-.477	9.003
Std. Error of Kurtosis		1.334	1.334	1.334

Table1: Student Feedback to "fill-in-the-blank" questions.

- The number of hours spent by the student preparing for lectures, tutorials and laboratory classes and the usefulness of the software tool.
- The number of hours spent by the student using the simulator and the usefulness of the software tool as an aid for understanding component and circuit behaviour.
- The number of hours spent by the student using the simulator and the number of hours spent by the student revising for the exam.
- The number of hours spent by the student using the simulator and the number of hours spent by the student studying with others.
- The usefulness of the software across all components of digital electronics study.

While for the same small group the following strong negative trends were found:

- The number of hours spent by the student preparing for lectures and the number of hours spent by the student using the simulator.
- The number of hours spent by the student using the simulator and the lecturer who used the simulator in lectures.

The "any comments" question was answered by six participants. These comments provided the following feedback:

- the user interface is unnecessarily complicated,
- the tool should be extended to cover analogue (not just digital) electronics.

Student Performance

Once again SPSS was used to investigate the relationship between the student's exam performance and the time spent using the *EasySim* software tool.

For the whole group of about 325 students who presented for the exam, each student's exam mark (without the digital electronics question) was correlated with the mark obtained for the digital electronics question on the exam paper and found to have a positive relationship. The calculated Pearson Correlation of .580 and Spearman's rho of .578 (both being significant at the 0.01 level) was clearly illustrated in the obtained scatterplot, which is shown in Figure 2. All these statistical processes confirmed that students who did well in the digital exam questions did well in the rest of the exam paper.

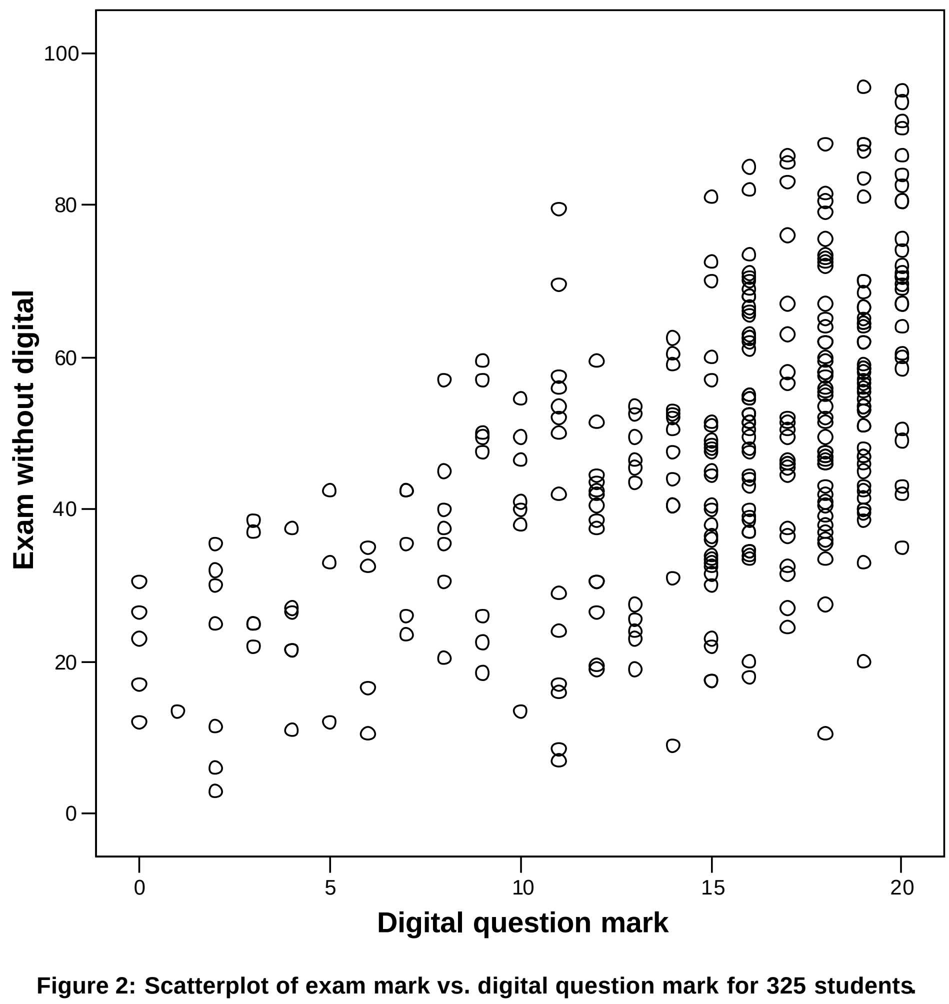

Figure 2: Scatterplot of exam mark vs. digital question mark for 325 students.

When analysing the responding group of ten students, once again scatterplots and Spearman's, rather than Pearson's, analysis was used since it is a non-parametric technique that is recommended for very small samples[6]. The obtained results support the earlier findings for the correlation between all students' digital circuit's exam question mark and the mark for the rest of the exam paper. This suggests that the small sample of students who used the simulator obtained little or no benefit while answering the exam questions; an outcome that will need to be explored further in a large group study.

There is a weaker trending between the time the student spent using *EasySim* and the mark obtained in the exam for the digital circuit's question; while the trending with the exam mark for the rest of the paper is more significant. The possibility that students who did well only because they spent time on the subject was ruled out after looking at the trending between the exam results and total time spent on studies, which is very weak and surprisingly negative. Even if this is false, the earlier results still suggest that, at worst, the students using the software package were motivated to study more and have the opportunity to reap the benefits in the overall exam marks they obtained.

Conclusion

In summary, even though the sample size of this pilot study was small and probably biased, in that only interested students responded to the survey, there is enough strong trending to suggest that within the small group of students those who used the software tool perceived a benefit to their study of digital electronics concepts.

Also there was a strong trending between the times spent using *EasySim* and the exam results for the students who responded to the survey. Further for the whole subject group of students those who did well in the digital electronics exam question also did well in the rest of the exam paper. Since this relationship was also found for the responding group, it may be concluded that in answering the exam questions there is no benefit to the students who used the software simulator as a study aid.

There is enough evidence to support further investigation by repeating this research in 2005, ideally using a more comprehensive simulation software tool, probably *Electronic Workbench*, with a larger participating group of students who will be using the software for a longer period of time (about 14 weeks) and more often (for assignments and laboratory preliminary submissions as well as for private study) in order to try to establish any statistical significance in the observed trends.

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