Exploring the basics with circuit simulation: Support for self-teaching of electrical engineering fundamentals.

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Abstract: Students enrolled in the first year electrical engineering subject at Swinburne University of Technology were encouraged to use an electronic circuit simulation software, Multisim 10 from National Instruments, for self-teaching while: (i) confirming any qualitatively predicted circuit behaviour, (ii) validating any quantitative results of problem-based activities and (iii) first predicting the cause, then verifying these predictions, for the behaviour of potentially faulty circuit components. The students’ exposure to this software was facilitated, not only by the mandatory purchase of a copy of the software, but by them being timetabled for all their tutorial sessions into a computer laboratory (rather than a conventional classroom) where under academic supervision they were able to work on desktop computers that had preinstalled copies of the said software. Analysis of two surveys and five post-event focus groups clearly revealed general learner acceptance for using the simulation software for self-teaching in both communal and private settings.

Introduction

This study is concerned with the potential use of simulators as a support for self-teaching by students at tertiary institutions. Documented examples of the use of simulators in education include a variety of training programmes in the military and in industry. Modern simulators are currently used to train individuals to control the movement of aircraft, automobiles, and ships, as well as professionals such as air traffic controllers, anaesthetists and ocular surgeons. In manufacturing the use of simulators has enabled efficient product development and debugging. In leisure and entertainment video games and virtual worlds can be viewed as simulations of real and/or imaginary environments.

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 effect outcomes;
- supporting user paced progress in discovery and understanding of issues;
- being a more cost effective implementation of potentially expensive systems;
- facilitating the presentation of “dry concepts” in another way – by the integration of theory and practice.

A major disadvantage of the use of software simulators of physical entities, such as electronic circuits, is that the user is unable to physically handle the circuit components hence some elements of conscious and subconscious learning may not be available.

Theoretical bases of the approach

Even though learners access information through all senses, they generally favour only one which may be visual (by sight), auditory (by sound), kinaesthetic (by moving), or tactile (by touch). 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 a
balanced teaching approach is recommended; one that ideally addresses the learning needs of the student cohort (Felder & Brent, 2005). The use of simulator software in the study of conceptual ideas, such as electrical/electronic circuit behaviour, directly targets the visual, kinaesthetic and tactile learner.

Both the interaction between the student and the content, and the interaction between the student and others about the content “are necessary for efficient, effective and affective learning” (Berge, 2000; Hughes & Hewson, 1998) that has been identified as “deep learning” by Ramsden (2003) and Laurillard (2005).

Underlying most learning style research are the major categories in the cognitive domain attributed to Bloom (1956), namely: knowledge, comprehension, application, analysis, synthesis and evaluation, that is commonly referred to as Bloom’s Taxonomy. In practice this is achieved by providing the “opportunities for students to engage in active processing and questioning of ideas, and practice thinking skills” (Toohey, 1999).

Troubleshooting exercises have been commonly included in the problem sections of recently published textbooks on electronics and circuit analysis. Such problems demand a minimum level of knowledge and comprehension that has to be applied before any conclusion(s) may be analysed then synthesised in order to facilitate the evaluation of the resulting outcome(s) by the student.

Published research papers have established that students “who used the (simulation) software tool perceived a benefit to their study of … electronics concepts” (Banky, 2005; Ronen & Eliahu, 1998) and that simulator-based troubleshooting tasks expose the students to all the elements of Bloom’s Taxonomy as well as confirming Ramsden’s (2003) proposition on effective or deep learning (Banky & Wong, 2007).

“Self-teaching” has been commonly used to describe “learning in isolation”, typically in a distance or an off-campus education context. In Laurillard’s (2002) Conversational Framework, which identifies the necessary activities required to complete the learning process, “reflection” is described as “being internal to the student”, during which the student has to apply, either consciously or subconsciously, various degrees of “self-teaching” in order to make the necessary connections between, and finally understand, the issues being considered.

Teaching and learning details

In the first semester of 2008, the subject HET182 - Electronic Systems, was offered to 117 first year students who were enrolled into the electrical/electronics, mechatronics and communications streams at Swinburne University of Technology. The syllabus covered the introduction to five basic electrical/electronic engineering topics; namely DC circuit behaviour, AC circuit behaviour, electromagnetism, amplification and digital electronics. The students were timetabled for 60 hours of face-to-face contact comprising of lectures, tutorials and laboratory sessions. Each student was required to purchase a Student Version of the simulation software, Multisim 10 from National Instruments, which was bundled with the subject’s “Student Guide”. This “Student Guide” also contained the laboratory manual, the tutorial exercises and the assignment questions for the subject. The student cohort was divided into five tutorial groups that were timetabled into a computer laboratory, rather than into a more conventional classroom, where each desktop computer had a preinstalled copy of the simulator software, thus providing the students with access to it during each tutorial session. In an attempt to regularly expose the students to some of the basic features of the simulator, whenever possible during the lectures the behaviour of circuit elements was also demonstrated with appropriate simulations.

The Procedure

For each group, the first tutorial session was devoted to an introduction of the simulator with an overview slide show presentation that was followed by two exercises designed to highlight the software’s possible use as a self-teaching aid, as well as an alternative checker of solutions to quantitative problems. During the subsequent tutorials, following the usual communal discussions of the problems and their solutions, the students were given the opportunity to validate for themselves
any of the resulting options by appropriate simulation(s). If time did not permit this, the academic with the aid of a data projector would demonstrate the simulation(s) for the benefit of the group. Further, in order to encourage deep learning, at least one of the already discussed problems was usually revisited within a “troubleshooting” scenario, that the students were then asked to analyse in order to try and predict a likely cause which they subsequently validated with a suitable simulation.

On two occasions, once at midpoint and then at the end of the semester, the students were asked to complete the same survey that attempted to gain information about the student’s:

- perception on the usefulness of the various study aids available within the subject,
- use of the software for self-teaching.

Each survey required the student participants to complete four “multiple-choice” questions, thirteen Likert-type questions and eight “fill-in-the-blank” questions. These questions were either open (fill-in-the-blank) or closed (multiple choice or Likert) type. A major problem with closed or forced-choice questions is that insufficient alternatives or inadvertent prompting may create a false result; but the upside is that these are easier to code. The scale with the five response alternatives is based on the proposal by Likert (1932) that was not intended to be a summated scale. However, “Likert scaling presumes the existence of an underlying (or latent or natural) continuous variable whose value characterizes (sic.) the respondents’ attitudes and opinions” (Clason & Dormody, 1994). The resulting ordinal scale should be analysed with acknowledgement of the consequential discrete nature by comparing the proportions of the responses in each category.

Since the survey did not give an opportunity for the respondents to contribute with an “essay” question, an attempt was made to rectify this by asking each tutorial group to participate in a post-event focus group to expand and/or introduce their ideas on the issues covered by the surveys. These focus groups were conducted by another academic, thus maintaining student anonymity and perhaps facilitating more unguarded participant contributions.

During each session, the students’ opinions on three questions were canvassed; namely:

- have they used the simulator software during the semester;
- for what purpose did they use the simulator software;
- which other learning resources did they use during the semester?

The focus group transcripts and the moderator’s notes were analysed and compared to the statistical outcomes from the surveys in order to triangulate the results. Coding of open type responses is problematic, since misinterpretation by the researcher could result in them being misclassified.

**The Results**

A total of 170 survey responses (consisting of 95 from the first and 75 from the second survey) were obtained from the pool of enrolled students. Additionally, 78 students (in four groups of approximately the same size and one twice as large) participated in the post-event focus groups.

**Student Survey**

The survey results were coded into SPSS and this statistical software tool was used to evaluate the responses to questions asking the students to indicate their perception of the help with understanding the subject material that they possibly received from thirteen identified “study aids”. For the purpose of analysis, as seen in Table 1, the multinomial Likert responses were “binomialised” by obtaining the percentage of “disagreed” and consequentially “not disagreed” responses.

By inspection, for the two surveys the following trends were found:

- for all but one of the “study aid” options (Laboratory experiments) both the percentage of “not disagree” and the number of “valid responses” were lower for the later survey;
- the same “study aid” option (Doing the assignments) received the highest percentage of “not disagree” in both surveys;
- established options (such as Lecture attendance, Tutorial attendance, Attempting tutorial problems, Referring to text books, Asking questions, Laboratory exercises etc.) were consistently perceived as being similarly beneficial;

- chi-squared analysis confirmed the null hypothesis that for each surveys the “not disagree” percentages were from the same distribution at the 95% significance level;
- approximately two-thirds of the student body used *NI Multisim 10* for private self-teaching.

<table>
<thead>
<tr>
<th>My understanding of the material covered in this subject has improved because of:</th>
<th>Survey 01</th>
<th>Survey 02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not disagree (%)</td>
<td>Valid responses</td>
<td>Not disagree (%)</td>
</tr>
<tr>
<td>(a) Lecture attendance</td>
<td>87.4</td>
<td>95</td>
</tr>
<tr>
<td>(b) Preliminary reading of the lecture slide show printouts</td>
<td>76.6</td>
<td>95</td>
</tr>
<tr>
<td>(c) Tutorial attendance</td>
<td>92.6</td>
<td>94</td>
</tr>
<tr>
<td>(d) Attempting the tutorial problems</td>
<td>95.8</td>
<td>95</td>
</tr>
<tr>
<td>(e) Doing the troubleshooting exercises in the tutorials</td>
<td>90.5</td>
<td>95</td>
</tr>
<tr>
<td>(f) Using the <em>NI Multisim 10</em> software in the tutorials</td>
<td>83.0</td>
<td>95</td>
</tr>
<tr>
<td>(g) Using the <em>NI Multisim 10</em> software to check my work</td>
<td>79.8</td>
<td>94</td>
</tr>
<tr>
<td>(h) Doing the assignments</td>
<td>97.9</td>
<td>94</td>
</tr>
<tr>
<td>(i) Referring to the text book</td>
<td>90.5</td>
<td>95</td>
</tr>
<tr>
<td>(j) Asking questions from fellow students</td>
<td>88.4</td>
<td>95</td>
</tr>
<tr>
<td>(k) Asking questions from academic staff</td>
<td>83.0</td>
<td>94</td>
</tr>
<tr>
<td>(l) Laboratory preliminary work</td>
<td>80.6</td>
<td>93</td>
</tr>
<tr>
<td>(m) Laboratory experiments</td>
<td>83.9</td>
<td>93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I have used <em>NI Multisim 10</em> to check my calculations for assignment and/or text book problems.</th>
<th>Y(%)</th>
<th>N(%)</th>
<th>Y(%)</th>
<th>N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey 01</td>
<td>62.1</td>
<td>34.7</td>
<td>58.7</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 1: Summary of survey results

**Post-event focus groups**

A review of the session transcripts and the moderator’s notes for the five focus groups that were conducted at the end of the semester revealed the following:
- a significant majority used the software to check assignment submissions and laboratory results;
- the majority found it useful and would “rather have it than not”;
- respondents ranked text book or peer-help more preferable than the software simulator for self-teaching;
- the need for “user training” and/or “more simulated examples” was voiced by some students;
- a few indicated a clear preference for more tutorial problems over the troubleshooting exercises;
- the mandatory requirement of purchasing the software was an issue to at least one student.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>12</td>
<td>15</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>Number who used simulator</td>
<td>13</td>
<td>12</td>
<td>15</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Number who found it useful</td>
<td>13</td>
<td>11</td>
<td>12</td>
<td>(majority)</td>
<td>(majority)</td>
</tr>
</tbody>
</table>

Table 2: Summary of results to some focus group issues
Conclusions

A review and analysis of the results led the researcher to the following conclusions:

- assessable components (such as Doing the assignments, Tutorial attendance, etc.) returned more favourable responses since students feel more encouragement to participate thus affecting their perception of such activities as being more helpful;
- as the semester progressed student participation and perceptions altered with a downward trend, except for one option (Laboratory experiments) that had an assessable component at the three-quarter mark of the semester thus perhaps further supporting the premise that assessable components tend to be seen as preferred self-teaching aids;
- the unsuccessful attempt at triangulating the result for simulator use may be an indication that the type of data collection tool, secret ballots (surveys) or open ballots (focus groups), can have an effect on a person’s responses to issues being canvassed;
- a particularly narrow-focused aid (such as using a circuit simulation software) will be perceived as beneficial by only some learners (in particular the visual, kinaesthetic and tactile learner) thus typically scoring lower preferential percentages than the more universally targeting aids (such as referring to the text book, attempting the tutorial problems, etc.);
- using the results for the more established options as a benchmark, both the troubleshooting exercises and the NI Multisim 10 software were relatively well received as confirmed by the chi-squared test performed on the tabulated percentages.

The research results are encouraging enough to continue with further examination of this self-teaching aid for the study of electrical engineering fundamentals. An aspect that deserves examination is whether any change of perception will be detectable if the need for the simulation software is integrated into an assessable option hence ensuring that an increased number of students are exposed to using it. For example this could be to mandate that submissions for both assignment solutions and preliminary work for laboratory experiments must include not only any calculations but appropriate confirming simulations as well; or allowing the completion of and then the submission for assessment any unfinished laboratory experiments using the simulator.

Finally, in other engineering disciplines, the use of appropriate simulation software for the task of self-teaching should also be investigated.

References


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