

Comparing Self-learning Behavior Of Low And High Scorers With EDIV

Madhuri MAVINKURVE* and Sahana MURTHY

Indian Institute of Technology Bombay, Mumbai, India

*mavinkurve@gmail.com

Abstract: Computer based interactive visualizations have been shown to be effective learning resources in science and engineering for improved conceptual understanding, reasoning and prediction abilities, and experimentation skills. In a prior study, we reported the development of Engineering Design Interactive Visualizations (EDIV), and showed their effectiveness as self-study material in improving students' engineering design competencies. Here, we investigate students' interaction with the EDIVs in order to gain insight into what makes the EDIVs effective. We conducted a qualitative study using screen capture logs to identify behavioural differences between high and low scoring learners as they interact with the EDIV. We found that the high scoring group spent more learning time on interactive activities such as variable manipulation and decision making tasks, while the low scoring group spent more time on reading and concept clarification tasks.

Keywords: Design competency, interactive visualization, learning behaviour

1. Introduction

Computer based interactive visualizations have several known benefits in science and engineering education (Rutten et. al., 2012), such as making invisible things visible, allowing students to build mental models, promoting inquiry-based learning, and improved conceptual understanding and reasoning abilities. Integration of visualizations in laboratories has shown improved prediction ability as well as experimentation skills (McKagan et al., 2009). In this study we focus on interactive visualizations that promote students' engineering design competencies, such as structuring open problems, gathering information, multiple representations, and divergent and convergent thinking. In a prior study, we have reported the development of Engineering Design Interactive Visualizations (EDIVs) that students can use for self-learning (Mavinkurve et. al, 2012). Each EDIV is based on an open-ended design problem in electronics, such as the design of an amplifier. EDIVs contain concepts necessary to design the solution to the problem, as well as activities that students can perform to develop design competencies. The features and activities in the EDIVs are based on principles of formative assessment (Chen, 2012), scaffolding (Fund, 2007) and dynamically linked multiple representations (Ploetzner et al., 2009).

In the previous study, we have shown that students who learn with EDIVs are able to solve open design problems more successfully than students in the control group. While the conclusion was that EDIVs were effective in developing engineering design competencies, the study was not designed to answer how or why the EDIVs were effective. In this study, we directly address the question of what makes the EDIVs effective, by examining students' behaviour as they interact with them. The goal of this study is to identify behavioural differences between learners who scored high and those who scored low on the design problem they attempted after interacting with the EDIV.

We used a qualitative design to address the above research goal. The data source is a detailed log of students' interactions with the learning material, recorded via a screen-capture software. We coded the logs based on students' actions, and compared the learning behaviour of five high and five low scorers. We found that there is a difference in the behaviour pattern of the two groups. High scorers spent more learning time on interactive activities such as variable manipulation and decision making tasks, while low scorers spent more time on reading information and on concept clarification questions. Observed differences in learning behaviour of the two groups of learners indicate that *how* students interact with the learning material affects *how much* they learn.

2. Theoretical basis

Computer-based visualizations have been shown to be effective teaching-learning aids in science and engineering education. Visualizations can represent complex, abstract and invisible concepts (Gordin, 1995). They allow self-paced learning and opportunity for instant feedback. Interactive visualizations have been shown to have a range of benefits, from improved conceptual understanding, higher level cognition abilities, scientific discovery learning, and improved lab related skills of students (Rutten et al, 2012 and references within). However learning gains are seen with visualisation ,when learners actively engage with visualizations (Naps et al., 2002). To promote high engagement level, it is recommended that visualizations offer features that allow learners to explore and interact with the visualizations, such as the opportunity to manipulate variables(Chen et.al, 2012).

In self-learning materials, intelligent self-regulation needs setting of learning goals and tuning thinking process to achieve learning goals (Nicol, 2007). In computer based visualizations, in order to allow learner to set goals and align the learning process, scaffolding strategies are needed to guide the learner (Hmelo-Silver, 2007). One of the scaffolding strategies is the use of question prompts at appropriate stages of learning (Xun & Land, 2004). Feedback in visualizations provided via simulative manipulation helps learners to clarify concepts and leads to improvement in learning gains (Chen et.al, 2012). These studies help to establish the importance of appropriate instructional strategies in learning materials, but do not establish the relation between students' learning outcomes and their interaction with the material.

3. Learning environment and activities

The learning material is in the form of interactive computer-based visualizations on various topics in basic electronics such as circuit and amplifier design. The primary learning objective of the self-study material is to enable students to learn the ability of 'structure open problem', one of the first steps in designing electronics circuits. In addition to concepts related to the topic, each EDIV contains various activities and features that address the above competencies. These activities have been designed based on the principles of formative assessment, scaffolding and dynamically linked multiple representations. A key activity in the EDIV is a simulation in which the learner can manipulate variables and get visual feedback on the results of a 'virtual experiment' (Fig. 1). In addition, each EDIV contains a number of carefully chosen multiple-choice questions of two types: 1) Conceptual questions to help the learner master the necessary conceptual understanding before proceeding towards the design task, labeled as Concept Clarification Questions (CCQ); and 2) Questions to aid learners in making decisions related to the design task at hand, labeled as Decision Making Task Questions (DMTQ). CCQs and DMTQs provide feedback on learners' choices and guide them towards correct conceptual understanding and suitable design decisions (Fig. 2).

Other features of the EDIVs include multiple representations in the form of waveforms, graphs and equations which work as a hint for design choices, and animations which depict physical processes. The EDIVs also contain Design Tips and Info Boxes, which are scaffolds that appear as supportive text. Design Tips relate to the key decisions learners need to make in order to achieve successful design. An example of a Design Tip is: It is important to choose the Q-point location near the centre of the load line to get faithful amplification. An Info Box contains information necessary to carry out design of a circuit, such as "In the cutoff region of load line V_{BE} is less than 0.7V."

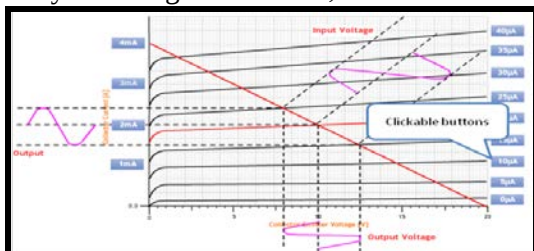


Figure 1. Multiple representations

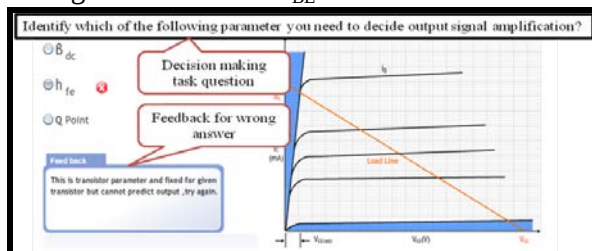


Figure2. Decision making task question and feedback

4. Research Methods

4.1. Sample and procedure

This study is part of a larger project to develop students' engineering design competencies. In prior work (Mavinkurve et al., 2012), we have reported results of a quasi-experiment in which the experimental group learnt with an EDIV on electronics circuit design while the control group received instructional material on the same topic from a traditional lab course. Students in both groups studied the material for 30 minutes without instructor intervention. They then attempted the post-test which contained an open question on the design of an electronics circuit to solve a practical problem. A validated assessment rubric was used to score students' design competencies on the post-test. The experimental group scored statistically significantly higher, leading to the conclusion that the EDIVs were effective in developing students' engineering design competencies.

The sample in this qualitative study is a subset of the experimental group. Out of the 37 participants in the experimental group, 10 were selected in the sample for the current study. The participants are 2nd year Electronics Engineering students in a typical college in Mumbai, India. Purposive sampling was conducted to obtain 5 participants who scored high on the post-test in the control study, and 5 who scored low on the basis of the design competency rubrics. Students with average rubrics scores of 0 or 1 on relevant competencies were identified as low scorers and those with scores of 2 or 3 were considered to be high scorers. However, the two groups were found to be equivalent on previous exams that tested conceptual understanding and traditional problem-solving.

While students studied the material, their screen activities were captured by Camstudio⁶ screen-recording software. These recordings were coded and analyzed to get an insight into students' behaviour when they learn with self-study EDIVs.

4.2. Data Coding and Analysis

Camstudio recordings of each student were first transcribed. The transcripts were segmented by activities in the learning material, and focused on start time, end time, activity in the learning material and the action taken by student while interacting with the content. An example of a transcript is shown in Table 1. While learning from the EDIVs, possible actions of students are: reading (concepts, Design Tips, Info Box), clicking correct or wrong answers, reading feedback to answers, re-trying the question, viewing the animation, and interacting with the variables in the simulation. Based on these actions, we assigned codes to students' interaction with material.

Table1. Example of transcript of Camstudio recording

Start time	End time	Content in the learning material	Student's actions
0.47 min	1.31 min	DMTQ1- Question to identify DC circuit For the given CE amplifier circuit identify which is appropriate dc circuit?	• Question read, 2nd option clicked • Feedback read, wrong answer. • Try again button clicked • 3rd option clicked

Our main research goal was to investigate differences in the behaviour pattern of low and high scorers as they interacted with the EDIV learning materials. We characterized this difference on multiple measures. We first analyzed how each student spends his/her time during the self-learning process. We compared the duration of time spent by low and high scoring groups on different activities and features in the EDIVs. To compare behaviours across students who spent different amounts of total time, we calculated the percent of time spent per activity/ feature out of the total learning time. The second parameter we measured was the frequency of visits for each activity/ feature. The time spent on an activity/ feature and the number of revisits indicate the emphasis a student places on different EDIV activities in their learning process. The third measure was to identify the correlation between the post-test scores of students and the time spent for different

⁶ www.camstudio.org

activities and features. Finally, we analyze the chronological sequence of actions of a typical student from each group as a graphical representation of the timeline of their learning process.

5. Results

The time spent by students on the EDIVs range from 8 to 23 minutes, with a mean time of 18.8 min. (SD=4.1min.) by high scorers and 16.04 min. (SD=9.7 min) by low scorers. High scorers spent maximum time on Decision Making Task Questions (4.5 min), followed by reading activity (3.5min), viewing animation (3min) and variable manipulation (2.5min). Low scorers on the other hand spent maximum time on reading activity (3.5 min) followed by Concept Clarification Questions (3min). The largest difference was in the time spent on animation (high – 3min., low – 0.68 min) and variable manipulation simulation (high – 2.5 min, low – 0.82 min). Fig. 3 shows the comparison of time spent on different activities by low and high scorers.

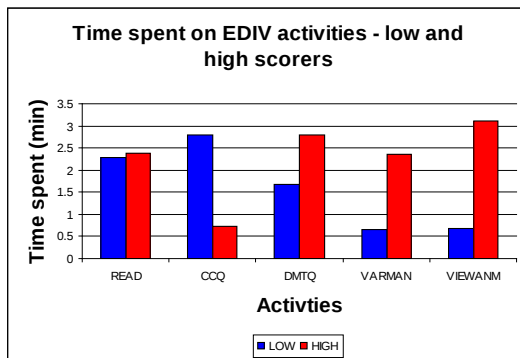


Figure 3. Comparison of total time spent on EDIV activities by low and high scorers

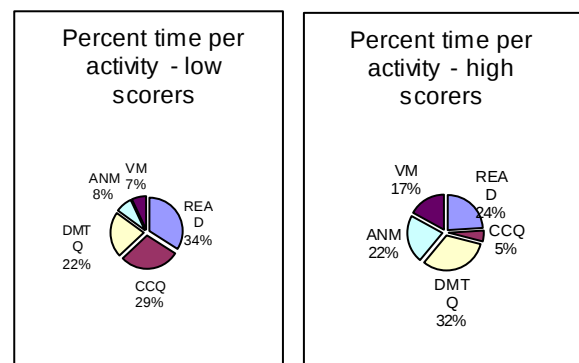


Figure 4. Percent of learning time spent on EDIV activities by low and high scorers

As a percent of total time (Fig. 4), DMTQ is most preferred activity for high scorers; they spent 32% of their learning time on this activity while low scorers spent only 22% of their time. For variable manipulation simulation, high scorers spent 17% time while low scorers spent 8% time. Among low scorers, reading is most preferred activity in which they spent 34% of their learning time while high scorers spent 24% of their time. The second preferred activity for low scorers was CCQ activity, which was 29% of the learning time, while high scorers spent only 5% time in CCQ.

The most frequently visited activity by both high and low scoring students is the DMTQ activity. Reading and viewing animation are the next most frequently visited activities by both groups. The main difference in behaviour of visits is in Variable Manipulation activity, which is visited by high scorers more than low scorers, and CCQ activity, which is more frequently visited by low scorers than high scorers.

A correlational analysis between post-test scores and activity time shows that there is positive and significant correlation (Spearman rank coefficient $\rho=0.67$) between post-test scores and time spent on DMTQ as well as time spent on animation ($\rho=0.65$). We also found positive but non-significant correlation between post-test scores and time spent on VM activity (0.6). CCQ activity time is significantly negatively correlated with post-test scores ($\rho=-0.73$).

Table 3-Correlation coefficient for activity time and SOP scores (* significant at 0.05 level)

Post-test scores	Total time	DMTQ	ANM	VM	CCQ
	0.485	0.674*	0.654*	0.6	-0.734*

We illustrate the learning pattern of students interacting with EDIVs, with an example each of a typical low and high scorer. Figure 5 shows the timelines of behaviour for a low and a high scoring student. Time is presented from left to right (in minutes), and each row represents a different activity in the EDIV. When a student spends time on an activity, a block is placed on the row for that activity for the duration of time spent. The length of the block is proportional to the amount of time spent for

that activity. This representation is adapted from the analysis in (Atman et. al., 1999) and is similar to the chronological representation of discourse (Hmelo-Silver et. al., 2009).

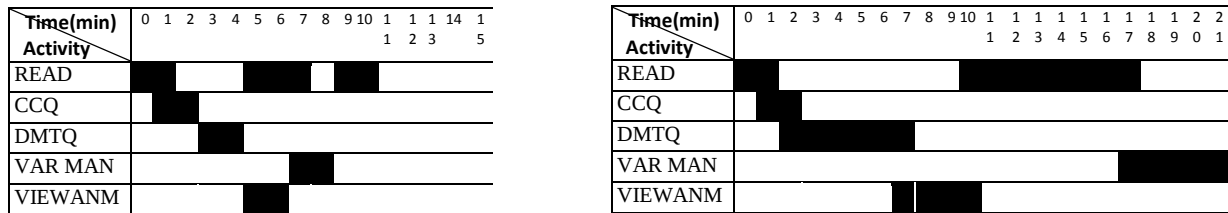


Figure 5. Activity timeline for low-scoring student (A, left) and high-scoring student (B, right)

As shown in Figure 5, Student A (left), a low scorer, (post-test score = 2.5/ 12) spent 9 minutes on the learning material, most of it on the reading activity. In CCQ and DMTQ activities, student A clicked the correct answer and proceeded to the next activity without reading feedback. In the variable manipulation activity, student A interacted with the simulation for only one value of the parameter. For the other values, he advanced through the material without viewing the feedback. Student B (right), a high-scorer (post-test score =11/ 12) spent 21 minutes on the EDIV. She spent the least time in reading the material (1 minute) and proceeded to CCQ activity. In DMTQ activity, she first attempted the first question correctly and proceeded to next DMTQ for which selected the wrong answer, read the feedback and attempted the question again. This time she selected the correct answer. For the third DMTQ she selected the correct answer and then read the feedback for all answers, spending a total of 6 minutes on this activity. When interacting with the simulation, student B changed the values of all available variables, observed the corresponding changes in the circuit.

6. Discussion

Comparison of self-learning behaviour of low and high scorers showed differences in all the measures we used. High scorers mainly focused on interactive activities such as experimenting with variables in the simulation and Decision Making Tasks Questions. They not only spent more time on these activities but also revisited the activity multiple times. On the other hand, low scorers spent the largest fraction of their learning time reading material and attempting concept clarification questions. Learning time spent on variable manipulation simulation is low for this group. In terms of similarities between the two groups, there was no significant difference in the total time spent on learning material. Similar behaviour for both groups was also observed in the reading of concepts, Info Box and Design Tips. While the number of visits to DMTQs was seen to be nearly equal for both groups, the fraction of learning time spent on these activities is different. Overall, students who scored low on the engineering design competencies seem to have used the learning material in a more traditional manner, mostly as reading information and clarifying concepts. Since there is no significant difference between prior knowledge levels between two groups, it is unlikely that a low entry level knowledge led to this behaviour of the low scoring group.

Our motivation for conducting this comparative study was to try to get an insight into the relation between learners' behaviour as they interact with self-learning material, and the quality of their learning. Naps et. al. (2002) recommend that interactive visualizations will be beneficial if the learner is active in the learning process. We find that the high scorers in our study employ an active learning process in which they are engaged with the visualizations at a high level. On the other hand, the engagement level of low scorers is lower, with reading being the primary mode of interaction.

The development of the Engineering Design Interactive Visualization learning materials was based on recommended principles from educational research such as formative assessment. Activities in the EDIV, such as DMTQs promote self regulated learning through the feedback, which not only indicates the correct or wrong answer, but guides the learner from the actual performance towards the desired performance (Nichol, 2007). We found that time spent by learners on the DMTQ activity is correlated with post-test scores which indicates the usefulness of DMTQ activity in self learning material. High scorers also spent more time on variable manipulation wherein for every change in the variable, visual and textual feedback is provided. According to Chen et. al. (2012) such 'simulative

manipulation' activities help the learner to acquire knowledge through process of experimentation, exploration and reflection.

One limitation of this study is in the small sample size, especially in drawing conclusions based on the correlation results. We chose a qualitative research design with a small sample to gain a deeper and fine-grained understanding of learners' behaviour. While this research design is suitable for our initial research goal, one would need to conduct a study with a larger sample for a correlation study. A second limitation could be that the pattern we observed was due to the choice of topic in the learning material. This limitation can be addressed by repeating a similar study with EDIVs in different topics.

7. Conclusion

Our study has identified the differences in learning behaviour of high and low scoring students as they interact with EDIV learning material - interactive visualizations on engineering design. The primary difference is the level of engagement with the learning materials, wherein high scorers are more actively engaged than low scorers. Our study indicates a correlation between the pattern of learning behaviour and the students' development of engineering design competencies measured by the post-test on solving an open design problem. This study points to the need for further research to test the hypothesis that the behaviour pattern of learners is responsible for their success in learning to solve open design problems through the EDIVs.

Further, this study confirms that the activities and features included in the EDIV learning materials are beneficial to learners. One implication of this research is for instructional designers of such learning materials. The activities and features that are frequently used by high scorers indicate that these should be included in the learning materials. Secondly, if these learning materials are being used with instructor mediation, this study indicates that instructors should encourage students to spend time on the interactive activities, instead of spending time merely on reading. In future work, we aim to identify strategies to promote higher engagement levels with EDIVs for all learners.

References

- Atman C. J., Chimka J.R., Bursic K.M, and Nachtmann, H.L. (March 1999). A comparison of freshman and senior engineering design processes. *Design Studies* , 20(2).
- Chen, Y. L., Hong, Y. R., Sung, Y. T., & Chang, K. E. (2011). Efficacy of simulation-based learning of electronics using visualization and manipulation. *Educational Technology & Society*, 14 (2), 269–277.
- Fund, Z. (2007). The effects of scaffolded computerized science problem-solving on achievement outcomes: a comparative study of support programs. *Journal of Computer Assisted Learning*, 23(5), 410–424.
- Gordin, D. N. (1995). Prospects for scientific visualization as an educational technology. *Journal of the Learning Sciences*, 4(3), 249-279.
- Hmelo-Silver, C. E., Duncan, R. G., Chinn, C.A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, *Educational Psychologist* , 99-107.
- Hmelo-Silver, C., Liu, L., & Jordan, R. (2009). Visual representation of a multidimensional coding scheme for understanding technology -mediated learning about complex natural system. *Research and Practice in Technology Enhanced Learning*, 4, 253–280.
- Mavinkurve, M., Murthy, S. (2012). Interactive Visualizations to teach design skills. 20th International Conference on Computers in Education, ICCE 2012, Singapore.
- McKagan, S. B. (2009). A research-based curriculum for teaching the photoelectric effect. *American Journal of Physics*, 77(1), 87-94.
- Naps, T. L., Rößling, G., Almstrum, V., Dann, W., Fleischer, R., Hundhausen, C., et al. (2003). Exploring the role of visualization and engagement in computer science education. *ACM SIGCSE Bulletin*, 35(2), 131-152.
- Nicol, D. J., Macfarlane, D.D. (2007). Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. *Studies in Higher Education* , 199-218.
- Ploetzner, R., Lippitsch, S., Galmbacher, M., Heuer, D. & Scherrer, S. (2009). Students' difficulties in learning from dynamic visualisations and how they may be overcome. *Computers in Human Behaviour* 25(1), 56–65.
- Rutten, N., Van Joolingen, W. R. & Van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers and Education*, 58(1), 136-153.
- Xun, GE & Land, S. M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *ETR&D*, 52 (2), 5-21.