COMP 272: Theory of Computing - A Study on the Learning Effectiveness of Visualizations

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Keywords

Visualization, animation, effectiveness study

INTRODUCTION

In spring 2002 and 2003 we taught COMP272 (Theory of Computing) [2,3], a second-year undergraduate course at the Hong Kong University of Science and Technology (HKUST) on automata theory, using the framework of Just-in-Time Teaching (JiTT) [4,8]. JiTT is a student-centered teaching method, where students are 'forced' to be more active and thus hopefully learn more and learn more easily. Most notably, students must always read the material before coming to class. The course concept has been described in a companion paper at this Symposium [9].

It is widely believed that program visualizations can help students to learn better and understand algorithms more easily [6,7], but few rigorous studies have been undertaken to actually verify this claim. So when we were teaching COMP272 again in spring 2004, we did a study on the effectiveness of visualizations, following the guidelines outlined in [6,7]. Our hope was that seeing visualizations of the (abstract) definitions and playing around with the algorithms would help the students to better understand the course material. Since the study was only approved shortly before the start of the term, we could only do a partial study with four tests. We plan to do another study next year.

THE STUDY

In [6] it was argued that the usefulness of visualizations in teaching strongly depends on the level of engagement of the students. For the tests we adapted publicly available animation applets. Ideally, tests should include the engagement levels of *viewing* (the definitions, step-by-step explanations of the algorithms), *responding* (step exercises), and *changing* (running algorithms on own input data). Due to the aforementioned time constraints, our tests only covered the first two engagement levels.

To measure the effectiveness of the visualizations, we cannot just compare the results of the class quizzes and the final exam with the results from previous years. One reason is that the two previous courses had a rather high deviation in the quiz and exam results, so it may be difficult to get a conclusive result from such a comparison. Instead, we created a control group for each test by randomly dividing the students into a group with access to verbal explanations and visualizations and a group with access only to the verbal explanations.

[7, Subsection 3.3] identified several formative and summative evaluations that might be used to study the effectiveness of visualizations in teaching.

Formative Evaluations

We used pre/post-tests to measure the effectiveness of the visualizations. We did four tests this term. Each test module was available online shortly after the material had been taught in class. Each module started with a pre-test of six questions on the new material. Then the material was explained again verbally. In addition to that, half of the students (randomly chosen) also saw visualizations of the definitions and algorithms. The students could choose to see the explanations and visualizations repeatedly. Each test module ended with a post-test with six questions similar to the pre-test questions. All instances of the questions were randomly generated. We tried to have questions covering the relevant levels of the Bloom taxonomy.

Using access logs we obtained data on the students' time-on-task, i.e., we know the time a student actually spent on the questions and watching the visualizations. We also had a short questionnaire after each test module to get student feedback on the visualizations. At the end of the term we may also do some interviews with a random subset of the students.

Summative Evaluations

Felder and Silverman [1] distinguished four categories of student behavior: sensory vs. intuitive learners, visual vs. verbal learners, active vs. reflexive learners, and sequential vs. global learners. In particular the second category, visual vs. verbal learners, is at the core of this study. We would expect the visual learners to profit more from the visualizations than the non-visual learners. At the start of the term, we classified the students into their different learning types, using a publicly available test [5].

Ethical Questions

In general, students should not lightly be used as guinea pigs for studies. In our study, all students were treated equally. All test modules (with visualizations) were made available to all students after the completion of each module, so that everyone could use them as a self-learning exercise tool. We hope that the exercises and tests will in general be beneficial to the learning progress. Participation in this study was mandatory for all students, although each test was only worth one point. Each test module took about 15 minutes time to complete.

SUMMARY

We did a study on the learning effectiveness of visualizations in the course COMP272 (Theory of Computing). The data from study have not been analyzed yet, but a first inspection of the test results seems to indicate that watching visualizations did not lead to a significant increase in correct answers to the test questions. This is somehow disappointing. The same test will be repeated in a similar course at Soongsil University, Seoul, this summer, when we will have more data to compare. We hope to do another more extensive test next year.

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