Increasing students' interest and motivation through effective design of online learning environments

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Abstract: The literature on the use of information and communications technology over recent years has been concerned with best practices for the design of multimedia instructional materials. A range of tools and teaching materials are used to develop students' understanding in different domains. However, evidence addressing the effectiveness of using multimedia, especially interactive elements, remains limited. The present study investigates how the graphics interface of an online environment can be used to effectively present first year chemistry material. In order to conduct this research we developed an online chemistry module with three different versions. Students' performance associated with using these different versions was examined. The information gained from this study will help to improve the graphics interface of online learning environments and is likely to have a significant impact on improving student learning.

Introduction

With the increasing diversity of student populations in higher education, as well as the incorporation of information and communications technology, research has been conducted to investigate best practices for designing multimedia instructional materials and establishing effective e-learning environments. It has been shown that the concurrent presentation of text with animations or pictures can enhance learning (Mayer & Moreno, 1998). Additionally, the inclusion of interactive elements may enhance learning by increasing student interest and motivation and allowing them to be more active learners during the learning process (Craincross & Manion, 2001). However, evidence addressing the effectiveness of using multimedia, especially interactive elements, remains limited.

The present study, following an earlier pilot study (Yeung, Schmid, George, & King, 2007), investigates how the graphics interface of an online environment can be used to effectively present first year chemistry material. In order to conduct this research we developed an online chemistry module with three different versions that can be used as pre-laboratory instruction or stand-alone learning module for 1st year chemistry students. Those three versions were:
- Static version: text and still pictures;
- Animated version: text and animations/simulations;
- Interactive version: text, animations/simulations and interactivity.

The outcomes of this study are of significant interest for tertiary teaching institutions. If one particular method of delivery is more effective than another, then such information is likely to have a significant impact on the design of online materials in the future. Not only can this information help enhance student performance, it can allow the process to be more efficient and cost effective.

Online learning module
A number of design issues were considered when creating the three versions of the online module used in this study. The topic of acids and bases was chosen, because past examination performance and anecdotal evidence suggest that students find this topic difficult, and hold common misconceptions. For example, students often have difficulties understanding the distinction between strong and weak acids, as well as concentrated and dilute acids. These concepts were directly targeted in the module using molecular level graphics – static illustrations, animations and

interactivity were used depending on the version of the module.

Multimedia design principles (e.g. coherence and spatial contiguity principles) were considered when designing the modules (Moreno & Mayer, 1999, 2000). Every effort was made to ensure that the content presented was identical in all three versions, with the only difference being the design of the module, i.e. layout, type of visuals or type of interactivity. Animations and interactivity were only included if the additional features added to the presentation of content and ideas. Otherwise they would simply distract students' attention away from what the content they are meant to learn (Hutchings, Hall &Colbourn, 1993).

Methodology

Participants
Three different groups of first year chemistry students participated in this study at the University of Sydney in 2007. All students were enrolled in a semester 2 chemistry unit of study (UOS) available to students undertaking mainstream science qualifications after completing chemistry in semester 1. These UOS were CHEM1002 (Fundamentals of Chemistry 1B), CHEM1102 (Chemistry 1B) and CHEM1902 (Chemistry 1B – Advanced). All three units cover similar material, but differ in the level of assumed prior knowledge and the level at which material is presented. Generally, CHEM1002 students have either not completed chemistry for the Higher School Certificate (HSC), or achieved comparatively poor results. CHEM1102 students have satisfactorily completed HSC chemistry, whilst CHEM1902 students have achieved a HSC chemistry mark above 80.

Study design
Participation in this study was voluntary. Participants from CHEM1002, CHEM1102 and CHEM1902 were randomly assigned to one of three groups. The study was conducted in an authentic learning environment, i.e. students completed the module in their own time and space. Students completed a pre-test to determine their knowledge prior to working through the module. Each group completed a different version of the online chemistry module, which was delivered via *Moodle*. After completion of the module, students were asked to do a post-test, which used the same questions as the pre-test. Feedback, answers and marks were only given after students had completed the post-test. Marks were recorded for both the pre-test and the post-test associated with the online module. A total of 454 students completed all three aspects of the study (i.e. pre-test, module, post-test) and their results were used in the analysis.

Module survey
Students were asked to complete an online module rating survey after they finished the online modules in an attempt to determine students' views of the module. Specific questions the survey sought to answer were questions related to students' motivational level, students' perception of the modules helpfulness and user friendliness, and how students use the modules to assist their learning.

Pre- and post-tests
The pre and post-tests sought to test students' understanding of the concepts presented in the module. The multiple-choice questions that were asked ranged from retention questions to transfer questions.

Results

Module survey
The student survey had a number of questions for students to answer on a 5 point Likert scale and some free format questions. Chi square analyses were performed to determine whether significant differences in students' responses exist depending on the version of the module they completed. A summary of the results for selected questions is shown in Table 1. A distinct trend emerged where a larger proportion of students in the animated and interactive groups found the module engaging and

helpful for their learning compared with those in the static group who did not have such positive responses. A larger proportion of students who completed the animated and interactive versions of the module found the explanations very easy to follow. Students in the interactive group, however, required more effort to learn the material compared to the static and animated versions, with a much larger proportion requiring a lot of effort,. These trends are shown in Figure 1 and are consistent across each UOS.

Question	χ^2	df	*p*-value
How helpful was the module for your learning?	26.8	8	0.001
How easy was it to follow the explanations in the module?	36.2	8	< 0.001
How much effort was required to learn the material in the module?	49.5	8	< 0.001
How engaging was the material presented in the module?	32.2	8	< 0.001

Table 1: Summary of results from chi-square analyses of student responses from the module survey
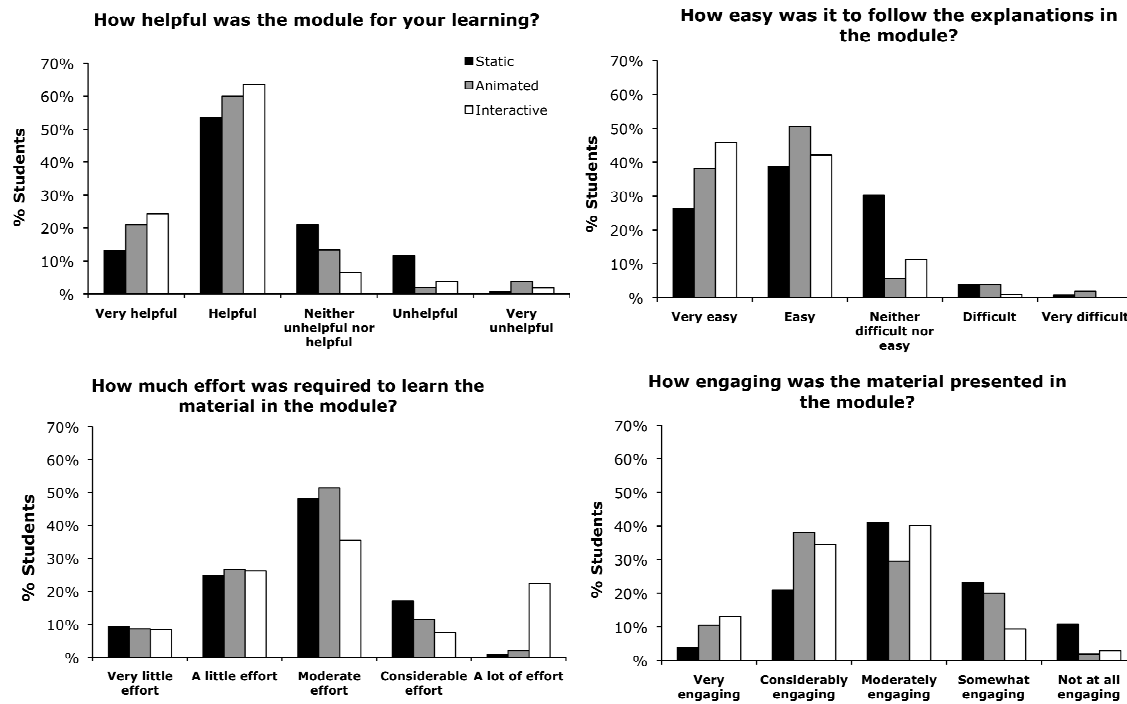

Figure 1: Student responses to the module survey for each version of the module

In addition the free format questions were analysed to see whether differences were evident for responses from students who were assigned to different versions of the module. Students who completed either the animated or interactive versions had *positive* comments about the module, e.g.:
- "I enjoy the online modules as they reinforce lecture material. The animations help me understand reactions which would otherwise be more difficult to visualize"
- "It is more enjoyable than slaving away at a textbook, because it is more interactive"
- "I thought that it was an engaging and perfectly adequate module"
- "The module that I just completed was very well put together and highly useful"

Students who completed the static version made more *negative* comments, and wanted more:
- "Interactivity - not just choosing a multiple choice answer"

- "Videos/interactive diagrams giving a better visual concept of what is happening in chemical reactions".

Academic Performance

One-way ANOVA was conducted to determine whether there was any difference in performance in the pre-test for the module. Subjects were divided into treatment groups depending on which version of the module they completed: static version, animated version, or interactive version. It was found that there was no statistically significant difference in academic performance between the treatment groups for the pre-test [$F_{2,453}$=0.724, p=0.485] (Figure 2a). Post-hoc comparisons using Tukey HSD confirmed that there were no significant differences between the treatment groups.

To determine the effect of different versions of the module on academic performance, the difference between a student's pre-test and post-test marks was determined. This *gain* gave an indication of the benefit students may have received from the module. Subsequently, one-way ANOVA was conducted to determine whether there was a difference in academic performance between students who completed the different versions of the module. It was found that there was no statistically significant difference in *gain* for the treatment groups [$F_{2,453}$=0.651, p=0.522] (Figure 2b). Post-hoc comparisons using Tukey HSD confirmed that there were no significant differences between treatment groups. This finding was consistent across each UOS.

Since there was no significant difference between the three treatment groups in terms of the *gain* students received, paired-samples t-tests were conducted to determine if there was a difference in students' marks between the pre- and post-test mark for each individual treatment group. Significant differences in marks were found for static group [t_{172}=2.05, *p*=0.0410] and animated group [t_{141}=2.35, *p*=0.0200]. However, no significant difference was found for the interactive group [t_{138}=0.872, *p*=0.385]. This indicates that students in the animated and static groups performed better in the post-test compared with the pre-test, while those in the interactive group did not.
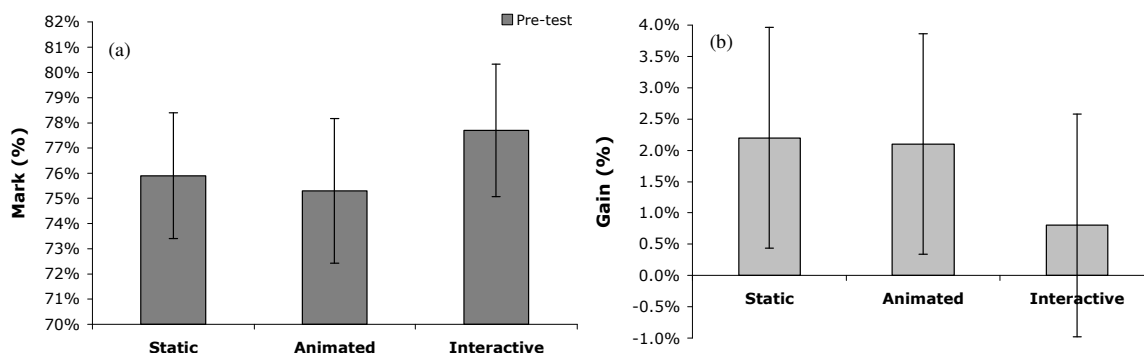

Figure 2: (a) Performance in the pre-test for each version of the module and (b) Mean gain for different versions of the module.

Examination of Individual Quiz Questions

Further analysis was conducted by examining the individual questions asked in the pre- and post-tests to see whether a particular module helped improve student performance for specific types of questions. One question asked students to calculate the concentrations of hydronium and hydroxide ions of a solution at pH 4.3 and 25 ^{o}C. Students who completed the interactive version performed significantly better in the post-test than the pre-test as confirmed by paired t-tests [t_{181} = 1.35, *p* = 0.034]. This is not surprising as the interactive version required students to click and drag correct answers to solve a numeric question. Students would need to be cognitively active when solving this calculation problem as the presentation and delivery of the calculation problem provides a scaffold for students in the interactive group. Students who completed the static version were only presented

with text and completed answers to the calculation problem, similar to a textbook. Since all answers and information were already presented, students are less cognitively active, and so the static version did not help students to improve their performance significantly. Students who completed the animated version were presented with blanks in the calculation problem and were required to press play and watch the answers move into the correct blank spaces. Although students needed to be more cognitively active compared to students in the static version, the animation of correct answers moving to the correct place was still not enough to provide a good scaffold to be associated with a difference in performance.

Another question asked students to choose the correct representation of a concentrated weak acid. Significant differences were found between pre- and post-tests of students who completed the interactive [$t_{180} = 2.95$, $p = 0.004$] and static versions [$t_{194} = 2.72$, $p = 0.034$] of the module. The students in the static version were presented with molecular level images of strong/weak and dilute/concentrated acids, as well as illustrations at a molecular level of strong and weak acids before and after ionisation. The interactive version included an animation of the ionisation of the different types of acids, which students could control with either a slider bar, or multiple movie control buttons such as stop, play, back, etc. Students in the interactive treatment group are able to stop and look at specific parts of the animation when they need to in order to help them visualise specific parts of the ionisation process. The clear snapshot pictures in the static version and the student-controlled animations seem to provide the detail students require in assisting them to improve in the post-test for this question. Those in the animated group did not perform significantly better in the post-test compared with the pre-test [$t_{166} = 0.631$, $p = 0.529$]. The reason for this may be that they were not able to control the animation or focus on the parts they needed to.

A third question asked students to select the strongest acid from a table given the pH and concentration of each acid. This question was initially done poorly as shown by low pre-test marks. Students often find this type of question very difficult, however, students who completed the static [$t_{194} = 4.86$, $p < 0.001$], animated [$t_{166} = 4.38$, $p < 0.001$], and interactive [$t_{179} = 3.81$, $p < 0.001$] versions of the module performed significantly better in the post-test. The improved performance was independent of the version of the module they completed. A specific task in the module guides students through the process of how to solve this type of problem. Such scaffolding may be associated with the improved performance.

Discussion

This study shows that there are differences in student rating for different versions of the online learning module. Those who completed the interactive and animated version overall had much more positive responses in the module survey compared to those who completed the static version. Student comments in the free response section of the survey also indicated that students who completed the animated and interactive version had a very positive experience compared to students in the static group. While it is clear that the static version was not preferred the situation is less clear for the differences between the animated and interactive versions.

The preference for and higher engagement with the animated and interactive versions of the module compared with the static version does not translate into improved academic performance. This result is in conflict with results from the module survey, as one would expect that students who are more engaged will perform better (Scott, 2001). This is consistent with the limited research investigating the comparison between animations and static graphics (e.g. Tversky, Morrison & Betrancourt, 2002). Although some research findings suggest that animations are superior to static images,in many cases, animations do not provide benefits over static images (Narayanan & Hegarty, 2002; Schnotz & Grzondziel, 1996; Wu & Shuh, 2004).

It was only after examining each individual module that some significant differences emerged. Paired t-tests indicated that students in the animated and static groups performed better in the post-test, while those in the interactive group did not, suggesting that the interactive version is not as beneficial as the other versions. Highly interactive elements, or animations require much more cognitive processing power, which consequently overloads working memory and accounts for the smaller gains of the interactive versions. Since working memory is limited, if too much attention is allocated to extraneous processing, there may not be enough attention remaining for intrinsic and germane processing required for learning. This is demonstrated by the greater amount of effort our students felt they needed to understand the material in the interactive version. For this reason, static media may be more effective than dynamic images in line with *the static media hypothesis* (Mayer, Hegarty, Mayer & Campbell, 2005).

Examination of individual questions revealed that each version of the module is beneficial for different types of questions. For example, the interactive version was effective for viewing animations at a molecular level. The added controls allow students to stop and focus on a particular image of the animation, which allows them to process and interpret what is presented to them. Without these controls, students may suffer from cognitive overload by trying to interpret a dynamic image (Chandler, 2004), which is more complex than its static counterpart (Tversky, Morrison & Betrancourt, 2002). When viewing molecular level diagrams, static images were equally as valuable, for the reason that they require less cognitive load to interpret than animations that students cannot control. The interactive version is also useful for presenting calculation type problems where students click and drag correct numerical answers into place. This type of presentation mode provides a scaffold to assist students in using formulas and arriving at the correct answer.

Conclusion

The aim of this study was to determine the most effective graphical format of an online chemistry module to enhance student learning. This study has shown that students have a preference for and are more engaged with the animated and interactive versions of the online chemistry module that we have designed, compared with the static version. However, this did not translate into improved performance and differences between the animated and interactive versions could not be determined.

This research has found that no one module is better than another, as no significant differences in *gain* were found. Instead, findings reveal that each version is effective for different types of questions and presenting different concepts. This information should be taken into consideration when designing online materials in chemistry. Instructors need to know what material is to be presented and the concepts students are required to understand. This will then allow instructors to decide which graphical features need to be used to enhance learning. Using specific features shown to assist students in particular areas, should improve their performance, and will also be cost effective.

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