Are well-designed Web sites efficient for learning mathematics at the undergraduate level?

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Abstract

We conducted an experiment in order to examine the effectiveness of an educational Web site, which provides resources to undergraduate students in mathematics. The participants' task was to solve 18 questions about differential equations. Students in the paper condition outperformed those in Web site conditions. There was no difference between the original and an improved Web site version. Moreover, students in all conditions preferred working with the paper resource. Practical and theoretical implications are discussed.

Key-words: Web sites, educational design, mathematics, undergraduate level

Introduction

The use of electronic technologies for teaching and learning at the university has increased tremendously in recent years. But what do we know about their pedagogical effectiveness? The first literature reviews indicated that the benefits of educational technologies were quite limited. Recent studies, however, show that it is possible to optimize learning through the use of appropriate educational design (e.g., Mayer, 2003; Van Merrienboer et al., 2002).

Our research investigates the efficacy of a set of Web-based resources for undergraduate mathematics learning. We address the following questions: can students efficiently search mathematical information in a Web site? Are they motivated by this resource? Is it possible to increase usability with design guidelines? Based on the notion that usability improves the ease of use of a Web site, we used a set of ergonomic guidelines (Scapin & Bastien, 1997) to evaluate and modify an educational Web site used at the undergraduate level in a French university. Our hypothesis was that the revised version would improve learning outcomes.

Method

Our experiment consisted of a learning session. Students were asked to solve a number of questions on the topic of differential equations and look for related information on a Web site. Participants were 122 undergraduate students in life sciences (75% female; mean age=18.8). They completed a pre-test about their experience with computers and the Web, initial knowledge of the study topic, and socio-demographics.

Materials were a questionnaire with 18 questions on differential equations and a set of documents (6000 words). For each question, there was one page in the set of documents containing relevant information (target-page). These materials were presented in one of four formats: (G1) original Web site; (G2) modified, design, Web site; (G3) paper; (G4) control (questions only). Students' learning outcomes were measured through the number of correct

answers and perception of usability and satisfaction. We also measured participant's workload (with an adapted version of the NASA-TLX), time spent in each question and number of pages visited.

Students were assigned to one of the four experimental conditions. They worked individually for 1 1/2 hours. At the end of the session, students worked with their tutor on a related subject, and finally were dismissed.

Results

We found that groups differed in their learning outcomes ($p<.001$). Post-hoc analysis showed that participants in G3 correctly solved more questions than any other group. The control group solved less questions than any other group, and G1 and G2 did not differ among each other. The effect of group explained 36% of the variance.

The time spent to solve the questions, the number of pages visited, and the mental workload were not different in G1 and G2. Thus, the modified Web site was not more efficient for learning. However, time spent was correlated with learning outcomes ($r=.39$, $p<.01$), with the number of target-pages found ($r=.36$, $p<.01$), and with Web experience ($r=-.38$, $p<.01$). Only a trend in the expected direction existed for the correlation between mental workload and learning outcomes ($r=-.10$, $p>.05$).

Students' perceived the menu (table of contents) as "simple and easy to use" to a greater extent in the G3 (94.4%) than in G2 (63.2%) and G1 (51.2%) ($p<.05$). While no student felt "tired to read on paper ", 42.1% of the students in G2 and 37.2% in G1 felt "tired to read on screen" ($p<.05$). Finally, more students were satisfied with the aesthetics of materials in G1 (69.8%), than in G2 (50%) and G3 (55.6%) ($p<.05$). Overall, students declared that they prefer to use the paper rather than the Web site to study, mainly if they had been assigned to the paper condition in the experiment (48.8% in G1, 52.6% in G2, 61.1% in G3).

Discussion

We did not find evidence that a "well-designed" Web site can promote learning. Although we applied design guidelines to construct a modified version of an existing Web site, we did not succeed in demonstrating its superiority for reading and searching information. This result could be due to our type of task (differences in cognitive load may not appear in the context of an exercise, cf. Paas, 1992); to an effect of familiarity with the original Web site; or an inappropriate use of the guidelines. However, we observed significant differences in learning outcomes between the Web sites and a paper version of the same materials. Not only did the paper lead to higher scores but it also received the students' preference as a media for learning. Perhaps, as Martin and Platt (2001) write, the function of the computer is to give access to information, but it delivers information to students that are used to carry books and take notes on paper.

Our results have practical and theoretical implications. At the practical level, we suggest that institutions should consider the problems of delivering pedagogical information online and promote evaluations of their materials. At the theoretical level, our results sum up to studies showing the limitations of on screen legibility (eg. Mayes et al., 2001) and contribute to theories of cognitive load (eg. Van Merrienboer et al., 2002). In the perspective of developing new educational technologies, our results suggest that cognitive factors, but also individuals' perceptions, should be taken into account.

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