Improving student problem solving with interactive online tutorials

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Abstract. We have developed a set of 30 Interactive Video-Enhanced Tutorials (IVETs) designed to help students learn effective problem-solving strategies. The IVETs incorporate multimedia learning principles, are adaptive and guide students through an expert-like problem solving strategy while providing different levels of feedback and guidance for different students. They also adapt to students' affect by providing additional guidance to students who indicate they are confused, frustrated, or bored while completing the IVETs. This presentation will showcase the IVETs and present research results from implementing them in large-enrolment physics courses.

Introduction

While there are many products and strategies for delivering active instruction [1], there is a need for online research-based materials that support problem solving in physics. To address this we created a set of 30 Interactive Video-Enhanced Tutorials (IVETs) [2] that span the topics of a year-long introductory physics course. We tested ten of them to see how their educational effectiveness compares to that of passive video instruction.

Theoretical framework

Even students who have learned problem-solving techniques often have not developed the necessary strategies for applying this knowledge [3]. Research indicates that mastery is developed through *deliberate practice* [4]. This involves completing many effortful activities with feedback specifically designed to improve the level of performance, explicitly highlighting how decisions are made for using specific principles, concepts, and procedures [5]. Deliberate practice in an IVET includes supporting students with guidance and targeted feedback throughout the entire problem-solving process [6]. Another important part of the IVET design is the application of multimedia learning principles [7] that are based on research in human learning and memory. For example, students are given control over the pace and mode of presentation (either text or video), which motivates students' engagement and impacts learning [8].

IVET design

IVETs are web-based, self-paced, and short, often taking less than ten minutes to complete. Each is focused on a challenging introductory-physics problem that exemplifies an important concept or principle. They include videos of mini-lectures interspersed with multiple-choice or multiple-select questions, where students must choose the correct answer before moving to the next video segment. Feedback is provided whenever an answer is chosen (either correct or incorrect). The questions and feedback are designed to carefully step students through each stage of an expert-like problem-solving process, while emphasizing the reasoning behind each step. Students who require less guidance can navigate through quickly by selecting text instead of video for the questions and feedback, while students who need more support can choose video summaries that provide extra guidance. Most IVETs are also affect-adaptive, meaning that students are asked how they feel midway through the activity and are then given targeted feedback to encourage and help them if they are struggling.

We developed the *Vignette Studio II* application for authoring IVETS, Interactive Online Lectures and similar assignments. It is available on the project website https://ivet.rit.edu.

Methods and findings

For each of the 10 IVETs that we studied, the IVET was assigned as homework to one section of a physics course, while another section was assigned to watch a passive video solution of the problem. In the passive video the narrator talked through the same problem-solving process and explicitly emphasized key decisions but without the interactive questions. Students in both sections had covered the topic in class, but neither had used these principles concurrently in the same problem. During class after treatment, students were given a follow-up problem to complete individually for a grade, allowing us to compare interactive video (the IVET) with passive video.

As an example, for the Torque and Rotation IVET the quiz scores were put into three groups: Those who completed the IVET (N=73, average score 51%), those who watched the control video (N=66, average score 40%), and those who did not complete either treatment (N=61, average score 32%). A one-way ANOVA yielded a statistically significant difference in the quiz scores for all three groups ($p < 0.05$) with a marginal large effect ($\eta^2 = 0.11$; suggesting 11% of the variance in scores was due to treatment type). The IVET group performed significantly better ($p < 0.001$) than the no treatment group, as well as the video group ($p = 0.013$). Details for this and other tests will be shown in the presentation.

Conclusion

IVETs are relatively effective at teaching problem solving in physics. The IVETs and their authoring application may be downloaded from https://ivet.rit.edu at no cost. (Supported by National Science Foundation grants DUE-1821391 and DUE-1821396.)

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