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Goin' Up?: Using a Design Task to Teach About Force and Motion

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Abstract: Physics classes often disassociate scientific principles from their real-world applications. This separation ignores the motivation that applications can provide and can also hinder students' ability to use and apply those principles when they need to. We believe that one way of addressing these problems is to present material in the context of a design task which requires that students understand certain principles in order to generate a successful design. In this paper, we discuss *Goin' Up?*, an example of a computer-based, design-centered application which teaches concepts in Newtonian mechanics. We conclude with research questions and planned evaluation methods.

Keywords: science education, learning environments, simulations

An Overview of *Goin' Up?*

Research in physics education has shown that the traditional classroom frequently fails to address student misconceptions (Arons, 1997; Halloun & Hestenes, 1985). Students often learn to solve mathematical problems without making significant improvements on conceptual tests (Hestenes, Wells, & Swackhamer, 1992). Traditional labs, problem sets and exams rarely give students opportunities to reason about or explore physical phenomena on a conceptual level.

We are attempting to overcome these limitations of traditional instruction through educational software that presents scientific principles in a realistic design task. *Goin' Up?* is a goal-based scenario (Schank, 1993/1994), an environment in which students naturally learn a set of skills and concepts in the course of pursuing a defined goal. *Goin' Up?* teaches the basic concepts of force and motion in first-quarter undergraduate physics–linear motion, force, velocity, acceleration, and Newton's Second Law. As in previous GBSs, students' learning is driven by an engaging cover story, a mission, and a structure for completing that mission (Schank, Fano, Bell, & Jona, 1993/1994). In *Goin' Up?*, the student is placed in the role of a novice elevator designer who needs to choose parameters for three different elevators, each with a different set of requirements. The first scenario, for example, asks the student to design the express elevator to the observation deck of a skyscraper. The software presents the students with goals (such as the desired traffic capacity of the elevator and loose cost constraints) and provides relevant data (such as the typical load in the cabin and various speed/acceleration constraints). The challenge in this task is to find a low-cost design with a high traffic capacity–a balanced system which utilizes a relatively small motor to move the cabin at or near the specified limits.

Students create designs by specifying five attributes of the elevator: the capacity of the cabin, the mass of the counterweight, the maximum tension the cable can withstand, the size of the motor, and the motor control (a fixed sequence of forces applied by the motor). Choices for attributes are limited to either a fixed set of options (six different cabin capacities, twenty different counterweight masses) or a possible range of values (a motor force no greater than 100kN). After completing a design, students can test their elevator in a simulation that shows the consequences of their design decisions, accompanied by displays of relevant quantities–forces, velocities, and accelerations. When students encounter difficulties (a cable that breaks, an elevator that doesn't move, an elevator that misses its destination floor, etc.), the system offers guided tutorials for analyzing the elevator system and for predicting the behavior of a design. In addition, students can always ask for demonstrations and explanations of force and motion principles in a multimedia reference database.

As an example, consider a student who tries to get his elevator to cruise at a constant velocity by applying a constant force with the motor. Because a constant (net) force leads to a constant acceleration–not a constant velocity, as the student believes–the student will find that his elevator either exceeds the maximum safe velocity or continues past its destination. In either case, the student must try to understand why his design didn't work and decide how to fix it. At that point, he might ask how to predict the velocity of the elevator. In response, he would see an explanation of the relationship between force, acceleration, and velocity. Applying what he has learned, this student might then specify a motor force that balances the other forces on the elevator, resulting in a constant velocity.

Formative Evaluation and User Testing

Goin' Up? is currently in the late stages of development and is undergoing evaluation. At the time of writing, we have begun to test the effectiveness of *Goin' Up?* with students enrolled in first-quarter physics at Northwestern University. The user tests consist of interviews, short tests which ask students to answer conceptual physics problems, and a recorded think-aloud interaction with the software. In addition, we have administered the Force Concept Inventory augmented by short essay questions, and we will look at student performance on relevant items.

This data collection is designed to provide evidence for a number of hypotheses embodied in the design. For example, we believe that the design of a familiar artifact is motivating because students will understand the nature of the task and have intuitions about the correct behavior of the artifact itself. During pre-interviews, we have asked students to describe what they know about elevators and elevator design, and we will analyze their think-aloud protocol for any use of that foreknowledge while performing the task. We have also asked students to rate their predicted enjoyment of the software (both on an absolute and relative scale) and have then followed up after a session with the software; during the limited testing done so far, we have seen no problems with student motivation.

We also feel that the guided tutorials and reference database enable students to respond to the challenges of the task. Utilizing transcripts of software sessions, we will identify situations in which students have accessed the learning supports and then analyze whether students are then able to improve their designs. Finally, the combination of elements in the software should lead students to develop improved conceptual understanding of force and motion. We will analyze Force Concept Inventory results to determine if *Goin' Up?* leads to statistically significant performance gains on relevant items. In addition, we will administer our own pre- and post-tests which measure students' specific ability to apply physics concepts to a design problem.

The results of these studies will set the stage for the redesign of *Goin' Up?* and the development of a general architecture for the construction of design-centered goal-based scenario software.

References

Hestenes, D., Wells, M., & Swackhamer, G.(1992). Force Concept Inventory. *The Physics Teacher*,3(30), 141-51.

Schank, R. C. (1993/1994). Goal-based scenarios: A radical look at education. *The Journal of the Learning Sciences*, 3, 429-453.

Schank, R. C., Fano, A., Bell, B., & Jona, M. (1993/1994). The Design of Goal-Based Scenarios. *The Journal of the Learning Sciences*, 3(4), 305-345.

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