Student Use of Scaffolded Inquiry Simulations in Middle School Science

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ABSTRACT

Interactive simulations can help students make sense of complex phenomena in which multiple variables are at play. To succeed, these simulations benefit from scaffolds that guide students to keep track of their investigations and reach meaningful insights. In this research, we designed an interactive simulation of a solar oven design and explored how students utilized the simulation during learning and how scaffolds functioned to alter the learning experience. We used a table for recording trials and guiding questions to scaffold students' interactions with the simulation. We employed data mining techniques to analyze student interactions for use of the control of variables strategy and other approaches. We found that the control of variables strategy may not be as beneficial for learning as an exploratory strategy.

Keywords

Interactive Simulations, Science Education, Inquiry, Log Data

1. INTRODUCTION

Simulations can be powerful tools for allowing students to engage in inquiry, especially in science disciplines. To succeed, these simulations generally benefit from scaffolds that guide students to keep track of their investigations and reach meaningful insights [6]. In this study, we examine guiding questions and recording of trials in a table as scaffolds. We use a simulation of a solar oven that allows students to investigate the multiple variables at play in energy transformation and gives representation to invisible phenomena.

We used the knowledge integration framework to create the curriculum about solar ovens, because the framework focuses on building coherent understanding [4]. This framework offers instructional design principles to enhance connections between design decisions and scientific principles. The knowledge integration framework has proven useful for design of instruction featuring dynamic visualizations [8] and engineering design [1, 6].

Various scaffolding methods are often used with interactive simulations. Often, these scaffolds are implicit, or built into the system with the simulation [7]. For example, guiding questions are used with inquiry simulations to direct students' attention toward certain features of simulations [2]. Other tools, like concept maps and note-taking spaces can also assist students in making sense of inquiry simulations [3].

Using log files from student interactions with the curriculum and output from the automatically generated tables (simulation scaffolding), we use feature engineering to identify how students use the model and whether these uses have an impact on learning.

2. CURRICULUM

This research focuses on a curriculum about solar ovens that is run using the Web-based Inquiry Science Environment (WISE). During this curriculum, students design, build, and test a solar oven. Students use an interactive computer simulation to test the different materials in their oven during the design process.

This curriculum takes between 10-15 hours, and students complete the project in groups of 2 or 3. Students also complete individual pretests and posttests.

2.1 Interactive Computer Simulation

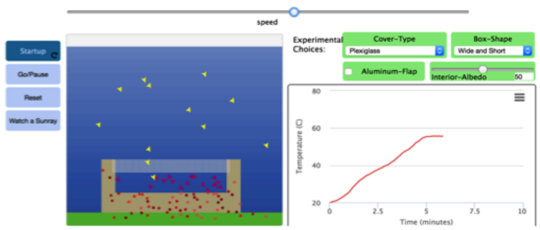
The scaffolds we developed for the interactive simulation are twofold; short response style questions direct students to investigate capabilities and limitations of the simulation and an automatically generated table helps students to keep track of trials they have run. The table includes information about all of the settings used in that trial, as well as the results of the trial at certain time points.

3. DATA

This data comes from 635 students across three schools and five teachers. These students formed 255 teams. After dropping students who did not complete significant portions of the curriculum, there were 558 students and 246 groups or partial groups remaining.

4. DESCRIPTIVE STATISTICS

Of the 246 groups who participated in the curriculum, 216 (87.80%) of the students used the computer model to pro-



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1	Wide and S	None	No	50	20	24	30.2	31.5
2	Skinny and	None	No	50	20	26.2	29.7	31.1
3	Wide and S	Plexiglass	No	50	20	25.6	55.4	53.4

Figure 1: The interactive simulation used by students to test solar ovens and visualize energy transformation; below the table simulation is output from the automatically generated table

duce at least one row of data during the first design iteration. We consider each row of data produced to be a trial. As seen in figure 2, many groups do not use the simulation scaffolds at all and produce zero rows in the automatically generated table. Still more students produce only 1 row in the table, which may mean they are confirming their ideas for a solar oven that they have already discussed and planned prior to using the simulation and without any evidence outside of their intuitions.

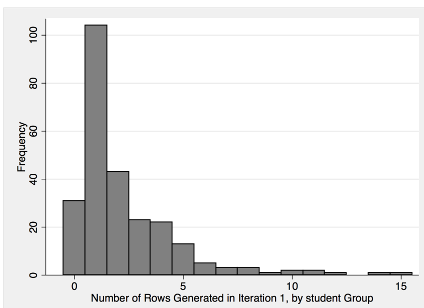

Figure 2: Histogram depicting the frequency of the number of trials run by a group of students during the first iteration of using the simulation (Mean: 2.27)

5. CONTROLLING VARIABLES

We define a control of variables strategy as changing a single variable at a time. We use feature engineering to develop a variable, *COV Trials*, that represents the number of trials a student ran using the control of variables strategy. Overall, 137 (55.69%) of the 246 groups employed a control of variables strategy. There were 216 groups that used the table scaffolds to generate at least one row of data. Of the groups that generated at least two rows in the table (115), 103 of them (89.56%) employed a control of variables strategy.

6. EFFECT ON LEARNING

Using pretest and posttest scores we aimed to understand the effect of actions with the simulation on learning. We found that the number of rows generated during the simulation was a significant predictor of learning (b = 0.10, t(546) = 2.68, $p < 0.01$). However, simply employing a control of variables strategy was not a significant predictor of learning. There were also two short response scaffolding questions. We generated a variable based on the number of questions students answered (0, 1, or 2). This was predictive of learning (b = 0.10, t(546) = 2.56, $p = 0.011$).

Overall, evidence suggests that students should be encouraged to experiment with the model and guided to produce at least two rows of data in the table to improve learning outcomes and use the short response questions. Perhaps changing more than one variable at a time in this type of environment indicates that students are spending more time thinking about possible outcomes.

7. LIMITATIONS

While we have found simulations to be beneficial for student learning in previous work [5], it is important to note that not all student learning is due to interactions with the simulation. While there is likely some difference between students who generated one row versus those who generated two or more rows, it is difficult to understand the differences between using a control of variables strategy and generating multiple rows of data in the table.

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