Exploring middle school students' sense making of a computer simulation about thermal conduction

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Abstract: In this study, we explored how students used a computer simulation to construct mechanistic explanations of thermal conduction. We analyzed the interviews of fourteen students and developed a rubric to characterize verbal explanations. We compared the quality of explanations before engaging with the simulation, while engaging with it and again at the end. Results suggests that students with higher prior knowledge tended to mention fewer aspects of the simulation than those with lower prior knowledge.

Keywords: computer simulations, student explanations, heat transfer, conduction, technology, design

Introduction

Simulations have been shown to support student learning as they are flexible, adaptable, have greater accessibility, actively engage students in inquiry-based learning, and they can simplistically represent complex and abstract phenomena (Hilton & Honey, 2011). However, the effectiveness of a simulation depends upon several factors such as the simulation's design features, the role of the teacher in providing support, and the level of students' prior content knowledge (Smetana & Bell, 2012). In this paper, we explore how students made sense of a simulation and how a facilitator helped them construct sophisticated explanatory models about thermal conduction. We define a simulation as a "computer generated, dynamic model of the real world and its processes" (Smetana &Bell, 2012, p. 1338) and a student's explanatory model as an *imagistic mental model* in which the student visualizes the interactions of unobservable elements such as molecules to explain why observable phenomena happen (Ahn, Kalish, Medin, & Gelman, 1995). Our hypothesis is that students who had higher levels of prior knowledge before seeing the simulation will use it to confirm their predictions and those with lower levels of prior knowledge will use simulations as a primary resource to construct their explanation. The ICLS theme of Transforming Learning, Empowering Learners aligns with our work because of our efforts to develop effective learning environments.

Methods

For this study, we interviewed fourteen (9 males and 5 females) middle-school students of different backgrounds from the surrounding area of a large Midwestern University in the United States. We designed a semi-structured interview with three phases. In the first phase, we engaged students in a real world situation about a metal spoon getting hot, we had them draw molecular models, gesture and make predictions. Next, we showed them a simulation depicting a molecular representation of conduction and ended with a request for explanation. The interviews and computer screen were recorded and audio was transcribed. For the analysis, we constructed a canonical explanation of conduction and identified seven necessary explanatory elements. They are (1) The spoon is composed of molecules, (2) Molecules are dynamic, (3) Molecules interact with each other (touch, bump, push, etc.), (4) Hot means faster moving molecules, (5) Cold means slower moving molecules, (6) Fast moving molecules bump into slow moving molecules, and (7) Chain reaction of molecular collisions occurs along the spoon. While reading a transcript, we marked these codes whenever the student explained conduction. For example, we coded 1, 2, and 4 for the following response: 'The spoon's molecules (1) are wiggling (2) and the hot side wiggles more (4)'. A student was judged to have higher levels of prior content knowledge if they mentioned more elements than the first three codes, before interacting with the simulation. To check for reliability, two of the researchers coded two student's transcripts for the presence of these codes. We obtained an inter rater reliability of 87%, discussed and resolved discrepancies before we coded the rest independently.

Findings

Overall, there was an increase in the total number of explanatory elements across the three phases of the interview for 14 students. There were 42 elements mentioned in the pre-simulation phase, 47 mentioned while engaging with the simulation and 58 mentioned in the final explanations. Therefore, students developed more canonical explanations for thermal conduction over the course of the interview. Figure 1 shows a scatter plot comparing the number of elements each student stated before the simulation and while engaging with it. On examining this plot, there seems to be a negative trend between having higher prior knowledge before the simulation and engaging with it.

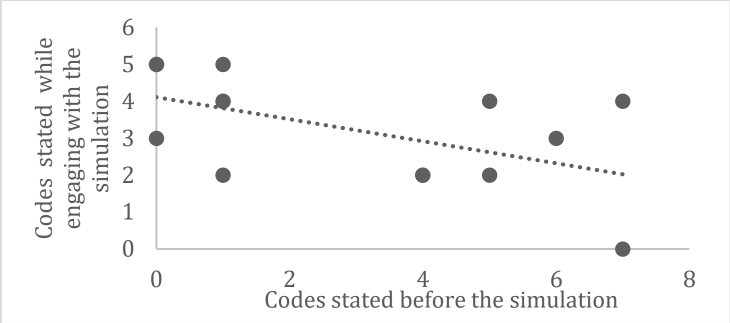

Figure 1. Scatter plot of codes stated before the simulation to the codes states while engaging with it.

A possible reason for this might be that students had qualitatively different discussions with the interviewers depending upon their level of knowledge. To check for this, we examined a student from each case, Naveen (pseudonym) who is point (7, 0) in the above plot and Sanford (pseudonym) who is (0,3) on the plot.

We found that, before watching the simulation, Naveen had already constructed a canonical explanation of thermal conduction. He explained the mechanism by comparing molecular collisions to pool balls. He also drew a molecular model of the spoon that was consistent with canonical representations. However, when viewing the simulation Naveen's interest shifted away from the mechanism to the way the simulation represented equilibrium of temperature. He seemed to be investigating another concept for himself, which he knew was not required for conduction since he did not include this idea in his final explanation. On the other hand, Sanford did not have much prior knowledge about heat or about molecules when he started his interview. When he watched the simulation, he spent more time describing what he saw. After viewing the simulation, Sanford talked about molecules moving and used his hands to describe molecular interactions. He used more elements from the simulation to construct an explanation for heat transfer. The interviewer's encouragement to use his hands helped him further develop his ideas. Therefore, there was a clear difference between the ways Naveen and Sanford used the simulation. While Naveen quickly confirmed his predictions and moved on to investigating other ideas, Sanford spent more time describing, expressing and connecting the elements of the simulation to the case of the spoon.

Conclusions and implications

Results suggest that the simulation was a useful resource for constructing mechanistic explanations of thermal conduction. Moreover, it was helpful because it catered to the diverse needs of the students. Students with higher levels of prior knowledge tended to verbalize fewer explanatory elements depicted in the simulation than those with lower levels of prior knowledge. However, in both situations, the interviewer played a significant role as an instructor and a guide to their explorations. In Naveen's case, the interviewer obliged his explorations in other areas, but for Sanford, the interviewer guided his attention to specific depictions within the simulation and encouraged description through verbal and gestural cues. This shows that appropriate guidance can make a significant difference to student learning. This preliminary work highlights the need for more research on the forms of guidance provided to learners using simulations.

References

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