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UNDERSTANDING STUDENTS' SENSE-MAKING PROCESSES WHEN FACED WITH UNEXPECTED DATA: A CASE STUDY IN HIGH SCHOOL BIOLOGY

Examining a lesson in a high school biology unit that utilized noisy sensor data, we sought to understand the ways students engaged in active reasoning about the data and the factors that influenced this process. Video analysis centers on one small group of students as they learn to use sensors to collect data on osmosis, focusing particularly on their reactions to variation within and across experimental runs. Our observations indicate that discussion with peers and classroom observers was most productive in facilitating understanding of noisy data when accompanied by hands-on trial and error with the sensor, supported by teacher scaffolding and onscreen instructions provided by the curriculum. Our results lead to several suggestions for educators who are interested in exploring inquiry-based science investigations using sensor data.

Keywords: Educational Technology, Scaffolding, Inquiry-based teaching

INTRODUCTION

Research in science education suggests that many students, particularly those in traditional science classes, feel disconnected from conventional laboratory experiments, leading to difficulty in linking their experimental data to the concepts (Hardy et al., 2020). In these classroom settings, students are often asked to carry out procedures rather than design and implement their own investigations. In the project described here, students are asked to take the first steps designing their own investigation, which makes use of osmosis pressure sensor data. This case study describes the results of the implementation of this biology activity, focusing on the experiences of a single small group.

Importance

It has been known for some time that the United States needs more workers with strong backgrounds in science, technology, and engineering (National Research Council, 2012, p. 1). High school biology is often viewed as a "gateway" subject for ninth grade students towards STEM careers (Cunningham, Mulvaney, & Sparks, 2015). It is a required subject in many American high schools and has a potential to reach many students. White and Frederickson (1998) showed connections between seventh, eighth, and ninth grade students' science content performance and their inquiry skills (p. 69). While their studies were in physics, they recommend developing a curriculum designed to scaffold the development of students' inquiry, metacognition, and modeling skills in biology and other experimental sciences as well (White & Frederickson, 1998, p. 92). We agree with Hardy et al. (2020) that students should think of data collected in biology classes as produced rather than collected, and that a science classroom that allows students agency for design and implementation of experiments using sensors and probeware allows space for perceived ownership of data. Our units have been structured to support student perception of ownership and perception of a need to use science practices (Manz, 2015).

Context

[The Project] is developing a set of curricular materials for high school physics, chemistry, and biology teachers. Our goal is to create a set of research-based design tools that students can use to learn how to design and carry out their own investigations. The project includes a software environment that integrates a set of probeware, an online data analysis platform, and a set of instructional materials that, along with teacher scaffolds, can help students explore their data. Involving learners in the planning and design of

scientific experiments and using their own data produced through probeware is at the heart of the investigations in this project. In our work, we have observed students producing data and making sense of noisy sensor data across topics in biology, chemistry, and physics. These datasets are allowed to be noisy by design; our research focuses on how students react to this kind of data and how they come to resolve making sense of the data within experimental runs.

An important difference in biology, compared to other subject areas, is that a run of data collection can be arbitrarily long. Previously, we analyzed four physics groups and the scaffolding offered by four different physics teachers to those groups (NARST 2019). The physics sensor runs in this context were approximately 5-10 seconds long, whereas the biology sensor runs lasted from 5-10 minutes.

Figure 1. The potato osmosis lab setup. A potato with a pressure sensor attaches to the laptop (left). Data was displayed in real time on the computer screen as students produced data from the pressure sensor, which was then exported into the data analysis software (right). These students have not rescaled their graph and so the signal appears as a horizontal line; the slope is not visible.

The osmosis unit responds to a call from *A Framework for K-12 Science Education* (National Research Council, 2012) (a foundation for K-12 science and engineering standards widely accepted within the United States) to engage students in the practice of analyzing and interpreting data. In our experience, discussion-based scaffolds can be effective for preparing students to deal with noisy sensor data *[Authors, 2019, 2020a,b]*. The curricular unit was designed by the *[project]* curriculum team with input from the teacher to engage students deeply in their first experiences with noisy data. The sequence of activities from the *[project]* curriculum is designed to include fading scaffolds over time, leading to a final independent project where students design their own investigation with the teacher available for suggestions, feedback, and materials. In this pilot investigation, students measure changes in pressure over time to demonstrate how molecules transmit through a potato cell via osmosis.

RESEARCH QUESTION

Our overall motivating question for this study was: ***How do students engage with noisy sensor data in a partially scaffolded biology investigation?***

RESEARCH METHOD AND DESIGN

We use qualitative case study methods to investigate how one group of students reacted to noisy sensor data in the potato osmosis unit. This exploratory study focuses on a single small group to exemplify aspects of student interaction we observed in 65 videos and 40 observational note documents. These represent a portion of the 400 videos collected as part of a larger study. Video data was selected for instances of students working with noisy sensor data, possible scaffolding moves by the instructors, and moments that had been flagged as interesting in classroom observer notes. After organizing field notes from the classroom and video data, research team members watched and transcribed tape recordings to identify themes.

FINDINGS

1. Students reacted to the data with confusion. Throughout the experiment they were not sure if they should be producing a straight line or different shape.
2. The teacher underspecified the procedure by not telling students explicitly how deep to bore the potato.
3. Students had a tendency to engage in side talk during the 10-minute sensor runs when they did not have another task to work on. However, students made productive use of class time when instructed to work on another aspect of the task while the sensors were running.
4. By the end of the unit, all student groups engaged with their data productively.

DISCUSSION AND IMPLICATIONS

Our case study findings raise questions about how to design classroom time around runs of data collection in the biology classroom, which are fairly long, taking about 10 minutes each. On the first day of data collection, the teacher had asked students to write down their experimental procedures while collecting data. However, once given the chance to do additional runs, students had a tendency to engage in side talk while collecting data. Also, on the second day of data collection, students remained unsure what the data should look like as they waited for the runs to take shape.

We then considered this data along with results of a study of students in two freshmen physics classrooms from the same project. Video coding conducted as part of that study *[Authors, 2019, 2020a]* did not reveal large amounts of side talk. However, runs of data collection in the physics context lasted only 5-10 seconds as opposed to minutes. Both investigations used fading scaffolds and underspecified aspects of the procedure. We hypothesize that because the runs were so much shorter in physics, those students were allowed more opportunities to interact with the equipment, revise their experimental set-ups, and engage in sensemaking conversations around noisy data. Other factors that could explain the differences include differences between the individual students as well as variations in hardware and activity structure.

CONCLUSIONS

The group of students we observed had a tendency to veer off topic during their data collection runs. In spite of this, they did make productive use of this time, especially on the first day when they wrote down their procedures while they were waiting to complete a run of data. Although the students reacted with confusion to the noise in the sensor data, it appeared that purposefully underspecifying the procedure helped stimulate conversation around procedures for experimental runs.

Further research is warranted to explore how length of data collection runs affects student sensemaking as they work with sensor technology. Additionally, there needs to be more research about the challenges teachers face when scaffolding students to engage in this kind of data collection. One suggestion is that planning an activity for small groups to do during longer runs may help students stay engaged.

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