Small group reasoning about unexpected sensor readings when scaffolded (or not): One physics lesson, four teachers

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In a physics unit that uses noisy data collected with sensors, many students were observed to respond productively to unexpected data. The four teachers who taught the unit, although dedicated to using inquiry, had different beliefs about what to scaffold, as well as when and how to provide it. We use a case study approach to look at four small groups to investigate what triggered active reasoning about data in each case. The physics unit responds to the call from the NGSS (2013) to engage students in the practice of analyzing and interpreting data. In our experience, many teachers choose lessons with data they know will be clean and predictable, but there is much to be learned from "messy" or noisy data. Manz (2015) argues that building uncertainty into learning environments can establish a need for scientific practices and lead to practices emerging for students during classroom activity. Masnick et al. (2007) found that even in the absence of domain knowledge, students from third grade to college were aware that there is variation in data and that this was something for them to consider in their reasoning. According to Ben-Zvi (2006) and Paparistodemou and Meletiou-Mavrotheris (2008), when using a statistical visualization tool, students from third grade up were observed using an informal process to reason about signal and noise, along with other types of variability in data, without their having been taught the mathematics of statistical inference. Such active reasoning about, and engagement with, data are among the goals of the unit described here.

Design/procedure

The team observed implementations of the unit by four teachers in the fall of 2018. These were in suburban schools in three states in the northeastern U.S. Two of the teachers taught 9th grade physical science and two taught 11th and 12th grade physics. Implementations lasted between 3 and 5 weeks, although these weeks were not necessarily consecutive. All classes were observed and almost 300 focus group and whole-class videos were collected. One activity, the Ball Roll, was selected for a cross-teacher case study analysis. This 2- to 4-day activity involved students measuring the motion of a ball rolling off a ramp and across the floor (Figure 1). It was an appropriate activity to investigate student reaction to noisy data because this was the first time students had seen what data look like when collected with motion sensors, although they had been introduced to the functioning of the sensors in an earlier activity. One focus group per teacher was chosen for analysis. Other than making sure each group had a complete video record, the choices were made randomly from the two focus groups that were videotaped in each class. All videos of the Ball Roll activity for these groups, together with the whole-class videos for these days, were reviewed. The teacher introductions of the activity, the initial data collection and student responses, any subsequent interactions with teacher or observers about these data, and any follow-up whole-class discussion were transcribed in detail. These data were analyzed for such features as type of teacher instruction (was the function of the sensor discussed? was a classroom demonstration of the ramp setup conducted? were recommendations for sensor

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placement given?); type of student response to unexpected data (ask an authority, experiment with sensor placement, reason about real-world causes of the data, etc.); type of scaffolding provided (teacher or observer, information provided, what kinds of questions were asked, were the students left to figure out the answer on their own? etc.); whether the students eventually made sense of the unexpected readings; and type of wrap-up, if any, the teacher provided for the activity.

Findings and analysis

Small Group Responses

Three of the four small groups responded strongly to their initial data collection with the motion sensor, when the live sensor feed on their computer screens showed unexpected patterns in the data (Figure 1).

Table 1 characterizes students' initial reactions to their initial data collection with the motion sensor. Figure 1 includes what the live sensor feed looked like on their computer screens. Students' screens showed unexpected patterns in the data.

Group	**Initial reaction to data collection**	**Teacher Strategies Prior to Data Collection**
T1	Confidence ("*Go. [...] Alright, stop. (looking at data) No, do it again, do it again."*)	1 hour whole class introduction to experiment
T2	Frustration, Confusion ("*Oh wait, wait, stop, stop. That's a very confusing—*")	15 minute whole class introduction to experiment, prior discussion about how sensors work
T3	Humor (S1: "*S1: Oh my gosh. (The graph does not look as expected).* S2: *Is that a good "oh my gosh" or a bad "oh my gosh?"*)	10 minute whole class introduction with real-world examples in discussion
T4	Humor, Confusion (S1: *Mm...that's weird.* S2: *Why?* S1: (laughs) *Uh…*)	5 minute whole class introduction to experiment, 12 minutes to play with sensor setup in small groups, prior discussion about how sensors work

Two of the groups laughed and expressed surprise while the second group expressed confusion and frustration. Each of these groups spent considerable time figuring out how the graphical patterns related to sensor function (e.g., "Well, [the graph is] flat at the first part because it [the sensor] doesn't register it [the ball] while it's on the ramp."). In addition to their initial reaction, students who expressed confusion and surprise were observed experimenting with the setup,

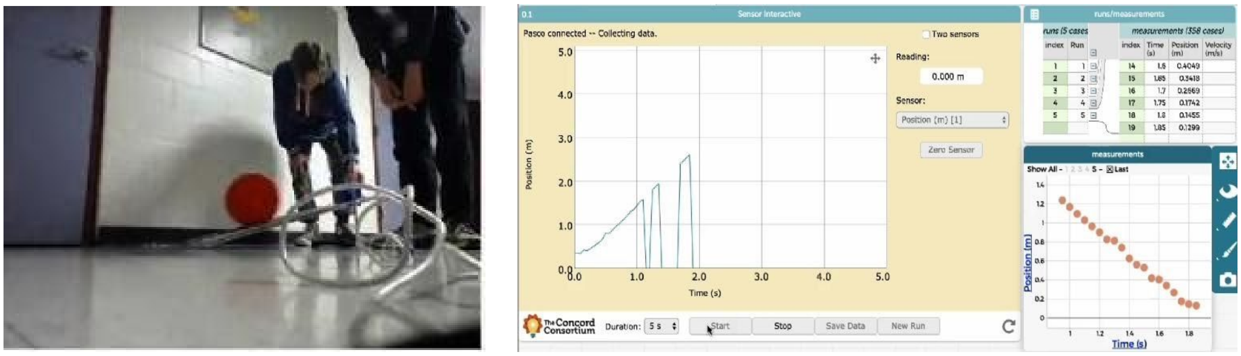

Figure 1. Left: Students rolling a ball down a ramp toward a motion sensor (out of sight). Right: sensor data from that ball roll, with unexpected dips in the position-time data.

adjusting the placement of the sensor, and asking questions from classroom teachers and observers to help them make sense of their collected data.

The first group did not have this kind of revelation, appearing to be confident about the features they were looking for in the graph and ignoring the anomalies. Either they were not interested in what was producing the spikes and dips, or they already understood the underlying causes. This group was in a class where student groups had previously spent more than an hour working with sensors as the teacher scaffolded their activity. Although knowing too much may have blunted the surprise for this group, some understanding of how the sensors worked appeared crucial in allowing the other students to reason productively about the data.

The frustrated group appeared unable to move forward in their reasoning until an observer provided such information. Their initial reading is mostly flat with a few spikes that go offscreen. They experiment with the placement of the sensor, and in spite of generating a good reading, they express frustration ("Uh! It doesn't make any sense!"). In both cases, with the two groups who responded with humor, students were able to work out their initial confusion with help from whole class discussion and teachers giving students agency when they approach the groups during the experiment.

Teacher Approaches

Video analysis revealed ways in which teacher approaches varied. Two teachers focused on how to use the sensors, a third teacher focused on how the sensor uses sound to detect distance, and the fourth gave little guidance, preferring to let students figure everything out on their own.

Limitations

Because this in-depth analysis was conducted on only one group per teacher, we note the difference in instruction as only one possible factor.

Conclusions

We suggest that having students collect their own data can motivate them to spend considerable effort to figure out what those data mean, even if the teacher is relatively hands-off. These students, many of whom were unfamiliar with position-time graphs, reasoned unprompted about graphical features such as horizontal lines, spikes, and isolated points. It can be a challenge to provide just enough scaffolding so that data are puzzling but within reach for most students.

Contribution to the teaching and learning of science

Teachers can be reluctant to use “messy data” in the classroom. In order to support the NGSS call for engaging students in the practice of analyzing and interpreting data, we need to combine supportive materials with simple, organized scaffolding strategies that teachers find easy to adopt. This study contributes to that goal.

Contribution to the interests of NARST members

Anyone who is involved in writing or implementing curricula involving messy data or who wants to encourage more science teachers to engage their students in data practices will be interested in the descriptions of scaffolding strategies and results presented here.

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