Scaffolding a Lesson With Noisy Data: One Physics Lesson, Two Teacher Approaches

A. Lynn Stephens, Natalya St. Clair, Brandi Ediss, and Hee-Sun Lee
lstephens@concord.org, nstclair@concord.org, brandi.ediss@gmail.com, hlee@concord.org
The Concord Consortium

Abstract: When enacting a high school physics curricular unit that involved student investigations with sensors, two teachers were observed preparing their students to engage with noisy data. We use videotape analysis to characterize their scaffolding choices and draw on classroom observation notes to enrich the descriptions. We find that during their introductory whole-class discussion of the investigation, one teacher focused on helping students consider how to construct the physical set-ups to get the data they wanted, while the other teacher focused on having students identify all the variables that could come into play. The teachers differed on what to scaffold and when, including which aspects of set-up design to specify versus which to elicit from their students. Taken together, the scaffolding strategies these teachers used during whole-class guided discussion offer several new ideas for preparing students to engage productively with noisy data.

Keywords: guided inquiry, data analysis, discussion scaffolds, sensors, physics investigations

Major issues

In science, data play an important role in testing knowledge-based hypotheses, exploring new phenomena, and developing explanations of phenomena under investigation. However, science teachers can be reluctant to use noisy data in the high school classroom. The NGSS (NGSS Lead States, 2013) calls for engaging students in the practice of analyzing and interpreting data. However, when a teacher anticipates that classroom data may be "messy" in unanticipated ways, the idea of planning ahead on how to support students in dealing with these data can be daunting. Case studies have shown how individual teachers have supported work with noisy data (e.g., Manz, 2015) but it is not always easy to imagine how a teacher's specific methods could be enacted in a different classroom setting. During InquirySpace 2 (IS2), an NSF funded late stage design and development project, we observed several public high school physics teachers in different schools enact the same physics unit, which employed sensor-based explorations. Preliminary analysis of qualitative data collected during the second year suggests variety and flexibility in the scaffolding strategies these teachers used to prepare students for data collection activities. We identify different teaching strategies used by two of the teachers as they prepared their students to engage with noisy data in the context of a single activity wherein students would engage more deeply with sensor data than they had before.

Potential significance

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 adapt to the needs of their students, to their own teaching styles, and to the logistics and infrastructures of their own classrooms. This study contributes toward that goal by looking at two different IS2 implementations that used the same supporting materials. The examples of scaffolding strategies presented here should be of interest to anyone interested in supporting more science teachers to engage their students in data practices.

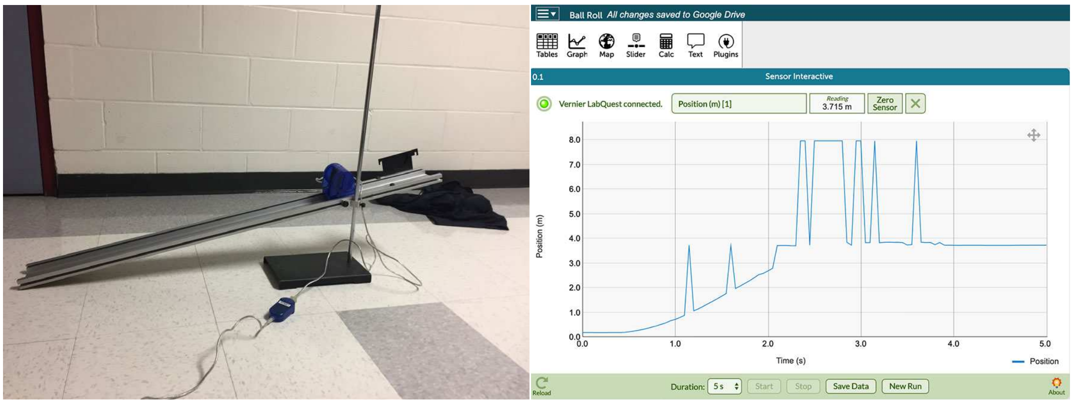
Theoretical framework

The NGSS calls for high school students to design an experiment collaboratively, select appropriate tools for data collection and analysis, and manipulate variables and data in order to improve the experiment (NGSS Lead States, 2013). In our experience, coming up with a final set of data to establish relationships between independent and dependent variables is often not straightforward and can be overwhelming to students, particularly when designing and carrying out experiments on their own. For that reason, formal experimentation in the IS2 physics unit considered here is preceded by a series of investigations that focus on how to recognize and deal with different sources of variation in data. Uncertainty is explicitly built into these classroom activities; this can establish an epistemic need for students to use science practices (Manz, 2015).

Scaffolding can be defined as support provided by a knowledgeable other that allows students to engage with and learn from activities they would be unable to complete unaided. Scaffolds are gradually removed as students learn. Although Belland (2014) considers one-to-one scaffolding as ideal, Hmelo-Silver, Duncan, and Chinn (2007) describe scaffolding that can be used in certain whole-class contexts. They argue that just-in-time instruction and even mini-lectures can be appropriate forms of scaffold. Martin, Tissenbaum, Gnesdilow and Puntambekar (2019) discuss the importance of both teacher and material scaffolds. Chin (2007) identifies a number of questions that can stimulate productive thinking during whole-class discussion. We argue that discussion-based scaffolds can be effective supports for preparing students to work with noisy data when used in guided whole-class discussions.

Methodological approach

The context of this study is a set of classroom trials of an IS2 physics curricular unit in which the goal is to support students in learning science by doing science. Instead of providing well-established experimental procedures, students are asked questions such as: What can I measure and observe? How can I design an investigation to collect data? Once I have data, how certain am I of the patterns or relationships those data suggest? Do I need to collect more data? Redesign my experiment? The physics module consists of three investigations. The first introduces experimentation and introductory data analysis with the Common Online Data Analysis Platform (CODAP), an open-source online data analysis tool from The Concord Consortium. The second deepens understanding of how to design a set-up, control variables, and deal with noisy data when investigating constant velocity. The third helps students analyze and interpret larger data sets. The units are structured with fading scaffolds and culminate with students designing and conducting their own independent experiments. The investigations include use of motion sensors connected to physical set-ups (Figure 1a). Data are imported into CODAP where they are displayed in multiple representations and can be manipulated and analyzed in a drag-and-drop interface (Figure 1b). Students refine their designs, identify and minimize error sources, and learn how to recognize and deal with unexpected variation in data.



(a) (b)

Figure 1. A set-up for the Ball Roll (a) and a sensor reading with unexpected spikes in position-time data (b).

The team observed implementations of the unit in four suburban schools in three states in the northeastern US during the fall of 2018. All of the teachers had taught an earlier version of the unit the previous year. One activity from the second investigation, 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 1a). This was the first time students had used motion sensors to collect data, although they had been introduced to the functioning of the sensors earlier. Many students were observed to respond productively to unexpected noise in sensor data during the activity (Figure 1b), discussing possible causes with their teammates and engaging in troubleshooting behaviors to identify and deal with sources of this noise.

The present analysis focuses on the opening whole-class discussions used by two 9th grade teachers to introduce the Ball Roll activity. Three team members iteratively coded video of the discussions to identify scaffolding moves, beginning with open coding followed by collapsing and refining codes and descriptors. We also coded other aspects of classroom activity including the learning goals being addressed and the general nature of the activity (teacher demonstration, whole-class guided discussion, etc.). All of the video transcripts were re-coded jointly by the team with the final analytical codes. Here we provide an overview of classroom activity and a partial list of the scaffolding moves.

Findings, conclusions, implications

Earlier in the unit before the Ball Roll activity, students were introduced to the motion sensors (Table 1). They walked in front of the sensors to try to reproduce position-time graphs given to them. Teacher A framed the activity in the context of velocity and motion and wrapped up with a 30-minute whole-class discussion about what the graphs of sensor data meant. Teacher B engaged in little whole-class discussion for this lesson; he briefly showed students the motion sensors and then sent them off to "play" with the sensors.

Table 1: Introduction to Sensors 1-day activity

Teacher A *(1 week before Ball Roll)*	Teacher B *(3 weeks before Ball Roll)*
Whole-class discussion Small group work Whole-class discussion	Whole-class discussion (~2 min) Small group work

After the introduction to sensors, students carried out two activities without this technology: a graph interpretation exercise and a ball roll with manual data collection. These were followed by Ball Roll with Sensors. For Day 1 of Ball Roll with Sensors (Table 2), both teachers introduced the objective of the activity with a whole-class discussion. Students then broke into small groups to set up their ramps and collect a single good run of data. This could take several tries. On Day 2, the objective was for students to improve their procedures to obtain cleaner data. Both teachers concluded the Ball Roll activity with a whole class wrap-up.

Table 2: Ball Roll with Sensors activity (both teachers)

Day 1	**Whole-class discussion (analyzed)** Small group work
Day 2	Alternating small group and whole class work

The portion of video analysis described here is of the introductory whole-class guided discussion on Day 1 of Ball Roll with Sensors. The teachers each spent about 11 minutes on this, soliciting student ideas, providing hints, scaffolding students in linking abstract representations to the real world quantities they represented, and working to activate students' prior knowledge in order to help them apply it to the task at hand.

Teacher A initiated discussion by asking the students to *reflect* on the ball roll they had conducted the previous day, in which they had gathered position-time data for a rolling ball using the rather cumbersome analog method of running after the ball and manually marking its position each second. Though this reflection lasted only 2 minutes, it engaged students in identifying problems they had experienced when trying to gather meaningful data in this way. Next, Teacher A spent several minutes asking the class how they could improve their data collection procedures. He *invoked the goal of the investigation as a design constraint*, "So we want to make sure we can make a system that's going to produce the same velocity each time. So the way we're gonna do that is, rather than rolling the ball, what might be better?" At times, he *specified certain materials* they would need in order to focus attention on other aspects of design, "(Y)ou guys are going to be making ramps with books and stuff like that. But if we roll it down a ramp, what's going to happen now? [...] How are we going to come up with better results?" He spent most of the last five minutes of the introduction previewing the online activities, making sure students understood the objective of the activities on each page and walking them through technical aspects of CODAP. This teacher deferred an extensive discussion about the key variables involved until the next day, after students had completed their first data collection. This first day, he *focused on the outcome*--the fact that their objective was to try to set up a system that could produce a clean velocity measurement each time the ball left the ramp.

Teacher B began the class by reviewing graphing homework. He then engaged the students in a *discussion about links between graphical elements and real world quantities*, using a position-time graph he drew on the board. For instance, one student identified the slope of the graph as "how fast it [the ball] is moving." The teacher may have chosen to begin this way because these students had not engaged in much whole-class discussion about graphs during the earlier sensor activity (Table 1). Teacher B *invoked the goal of the investigation to help guide the discussion*. However, instead of framing this goal in immediate terms as trying to collect clean velocity data (as Teacher A did), he framed it in terms of the goal of a future activity they were planning: being able to kick a ball when blindfolded after a classmate had set the ball in motion. In response to his question about what they would need to know in order for their kick to make contact with the ball, a student responded, "Time." Teacher B confirmed this, "Time! When it's released. So we have to know that, don't we. So the person blindfolded somehow has to have a sense of when it [the ball] is released, doesn't he?" Teacher B spent only 1½ minutes scaffolding the development of data collection procedures, doing so at the very end of the discussion. Instead, on this first day, he *focused on scaffolding students' identification of the key variables* involved rather than deferring this discussion until the second day as did Teacher A.

The lesson materials suggested that teachers try to *underspecify the procedure* so that students would have agency in designing their set-ups to collect clean data—and so that they would produce noticeably different results from group to group (a different level of noise). This difference could be used on the second day to initiate a class discussion about control of variables. Teacher A implemented this by specifying that the students were to use four books to build their ramps, but he did not indicate which books. Instead, he gestured toward cabinets that contained a variety of textbooks of different thicknesses. Teacher B, on the other hand, did not facilitate any discussion at all about procedure when introducing the activity. He did *elicit suggestions of materials from the students*, then made it clear which materials to use. Restricting the materials also restricted the options for assembling them, but questions such as where to place the sensors were left open. Although teacher responses to the particularities of their classrooms and the needs of their students, influenced by their own pedagogical inclinations, led to different decisions about how to scaffold the activity, there were a number of strategies that both teachers used. During the whole class discussion (~11 min) they

- used the discussion to set the stage, elicit prior knowledge, and diagnose student readiness;
- solicited student ideas wherever possible;
- scaffolded class identification of key variables: what to vary, what to hold constant, and what to measure (although Teacher A did this the second day);
- scaffolded partial development of a data collection procedure to be fleshed out by each small group;
- invoked the goal of the investigation as a constraint, allowing students agency in designing their procedures to get clean data, even during one of the more heavily scaffolded activities in the unit.

This analysis is of two introductory discussions led by two teachers from a larger cohort. These whole-class introductions, suggested by the teaching materials, appeared to play an important role in preparing students to encounter noisy data. Analysis indicates that teachers used these to tailor this preparation according to their own teaching styles and level of knowledge of their students. Even though both teachers provided extensive scaffolding in this early encounter with noisy data, using the goal of the investigation as a constraint created room for student agency. This was enabled by an IS2 investigation that combined sensor use with an online data analysis environment, supported by a unit written to facilitate guided inquiry. Analysis of the larger cohort is ongoing, including identification of moment-to-moment teacher strategies for dealing with unexpected data. We suggest that there are an interesting variety of strategies that can provide students both agency and support as they work with noisy data and that identification of more of these would be of use to the field.

References

Belland, B. R. (2014). Scaffolding: Definition, current debates, and future directions. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 505-518). New York: Springer.

Chin, Christine (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44*(6), 815-843.

Hmelo-Silver, C.; Duncan, R.; Chinn, C. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99–107.

Manz, E. (2015). Resistance and the development of scientific practice: Designing the Mangle into science instruction. *Cognition and Instruction, 33*(2), 89-124.

Martin, D., Tissenbaum, C., Gnesdilow. D., & Puntambekar, S. (2019). Fading distributed scaffolds: The importance of complementarity between teacher and material scaffolds. *Instructional Science, 47*, 69–98.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. www.nextgenscience.org/next-generation-sciencestandards.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. IIS-1147621 and DRL-1621301. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.