

Student Gestures During Shifts from Descriptions to Explanations of Gas Pressure

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Paper presented April 15, 2016 at the annual meeting of NARST

Abstract

The Next Generation Science Standards emphasize engaging students in the practice of constructing explanations using disciplinary core ideas such as the structure of matter. Research has identified that students have difficulty both with constructing explanations and with constructing particulate views of matter, and therefore there is a need to research additional ways to support students in these areas. The present study investigated how students used gestures as they shifted from descriptions to explanations of phenomena involving gas pressure. Using case studies based on student interviews, we found that students used gestures differently when they provided descriptions and when they provided explanations. While giving descriptions, students used gestures to represent observable aspects of the phenomena. While giving explanations, students used gestures to simultaneously represent observable aspects of the phenomena and unseen mechanisms. We conclude that prompting students to use gestures while explaining phenomena may help improve the quality of their explanations by helping them link observable phenomena with underlying mechanisms.

Introduction

Constructing explanations is one of the practices emphasized in The Framework for K-12 Science Education (National Research Council [NRC], 2012) and integrated in the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). Although multiple and varied interpretations of the meaning of explanation exist within the science education community

(Braaten & Windschitl, 2011), the NGSS articulate the role of explanation as providing a causal account of phenomena (Appendix F, NGSS Lead States, 2013). Explanation is distinguished from description in that explanations connect observable phenomena with unseen mechanisms while descriptions focus only on the observable phenomena (Clement, 1989; Glennan, 1996).

The structure of matter is one of the disciplinary core ideas within The Framework and NGSS, and this topic includes the particulate nature of matter (NRC, 2012; NGSS Lead States, 2013). Previous studies suggest that students have difficulty developing concepts related to the particulate nature of matter in general (e.g., Singer, Tal, & Wu, 2003) and the behavior of gases in particular (e.g., Johnson, 1998). Benson, Wittrock, and Baur (1993) found that students spanning second grade through college seldom represent gases as being made of particles. Other researchers have found that even when students do convey that matter is made of particles, most are unable to use a particulate view of matter to explain gas phenomena such as pressure in an enclosed container (García Franco & Taber, 2009).

Interventions to help students construct a particulate view of gases have been documented in the literature for several decades. Studies have been designed to elicit and then challenge student conceptions by presenting phenomena that are difficult to explain using their initial ideas (e.g., Nussbaum & Novick, 1982; Givry & Tiberghien, 2012). While there have been similarities in these studies over the last several decades (e.g., asking students to draw representations of gases), more recent studies have been able to collect data by video recording students, and this has afforded the ability to analyze additional aspects of student reasoning such as their use of gesture.

Prior research suggests that gesture plays an important role in students' explanations of phenomena. Some of the roles that have been suggested include: (a) linking "phenomenal and

conceptual layers of content" (Roth & Welzel, 2001, p. 118), (b) indicating that students are running mental models (Nathan & Martinez, 2015), and (c) distinguishing between descriptions and explanations (Crowder, 1996).

Attending to gesture is also supported by theories of embodied cognition, which suggest the body plays an important role in thinking and reasoning (Glenberg, 2010; Wilson, 2002). Using theories of embodied cognition, Hostetter and Alibali (2008) have developed the gesture-as-simulated-action framework to explain how gestures are produced when people process language. The implication of this framework is that students' gestures can provide insights to how they are thinking about phenomena. Some researchers have argued that gesture is so important that it should be considered along with speech and contextual factors in any analysis of conceptual change (Givry & Roth, 2006).

The present study is motivated by the need to better understand students' gestures in the context of their explanations of phenomena involving gas pressure. Previous research that has used the context of gas pressure to study student gestures has focused on how gesture is a crucial part of students' conceptions (Givry & Roth, 2006). The present study further examines how gestures differ between descriptions and explanations of phenomena. Previous research investigating differences in gesture between descriptions and explanations has used contexts such as seasons and shadows (Crowder, 1996). Based on existing literature we are therefore interested in addressing the following research question: How do students gesture as they change from descriptive to explanatory accounts of phenomena involving gas pressure?

Design/Procedure

This study uses a qualitative approach of analyzing cases. This approach is appropriate because it affords a detailed examination of how students convey their ideas. The data in this

study come from a subset of interviews conducted during the first year of a larger project called Gesture Augmented Simulations for Supporting Explanations (GRASP). The goal of the project is to design simulations that students interact with via gesture interfaces. During the first year of the project, students were interviewed in order to learn what gestures they naturally used while explaining the phenomena of interest. Interviews on the topic of gas pressure were conducted individually with 24 middle school students in pull out and lab settings. The analysis in this paper includes cases from three of these interviews.

During the interviews, students were presented with phenomena related to gas pressure and asked to explain the phenomena. Specifically, a sealed syringe containing air was used to help students observe (a) the air inside the syringe could be compressed, (b) the air was increasingly difficult to compress as the plunger of the syringe was depressed, and (c) when the plunger was released, it returned to its original position. Near the beginning of the interviews students were asked to explain these observations. The interviewers asked students to elaborate and reflect on their thinking by asking them to draw pictures, directing their attention to gestures that they used spontaneously, and showing representations of a particulate view of gas using conventional computer simulations. At various occasions throughout the interviews and near the end of the interviews students were asked again to explain the phenomena that they had observed.

Interviews were video recorded, and audio from the video was transcribed. Transcripts were used to identify explanatory segments in which an interviewer requested explanations or when a student spontaneously provided explanations. These explanatory segments were reviewed on video and coded to indicate if students (a) provided unobserved mechanisms, (b) mentioned molecules, and (c) made representational gestures. Two members of the research team coded a subset of six interviews and had an inter-rater reliability of 88%, with all disagreements

resolved by discussion. Gestures were reviewed on video again to gain insights into how students were thinking about the phenomena. We were particularly interested in identifying whether students were describing observable aspects of the phenomena or if they were explaining the phenomena using unseen mechanisms, as well as the differences in gesture accompanying these different ways of talking about the phenomena.

Findings and Analysis

We present three cases of students responding to requests to explain aspects of the gas pressure phenomena that they observed. For each case we first present the student's initial response and accompanying gestures, and then we present the student's responses and accompanying gestures from later in the interviews.

Case 1: Blake

Near the beginning of the interview, Blake is asked to predict if the plunger will be able to be pushed in.

Student [S]: Actually, no. You won't be able to because the air is, uh, pushing it back. The gestures that Blake uses in his response are shown in *Figures 1a* and *1b*. He does not verbally provide a mechanism to indicate how the air would push the plunger. This differed from an interaction near the end of the interview when Blake was asked to show what more pressure would look like.

Interviewer [I]: What is gonna happen when there's more of that pressure?

S: More pressure, the faster molecules goes, hitting the walls. The faster it's, so like, pretend this is how much space you have. Probably it's gonna be like. Like. Just hitting the plunger.

I: And what's the plunger gonna do?

S: The plunger is gonna move back.

The gestures that Blake uses in his response are shown in *Figures 1c* and *1d*. His response included a mechanism to explain how molecules could move the plunger, and his gestures also represented molecules hitting the plunger.

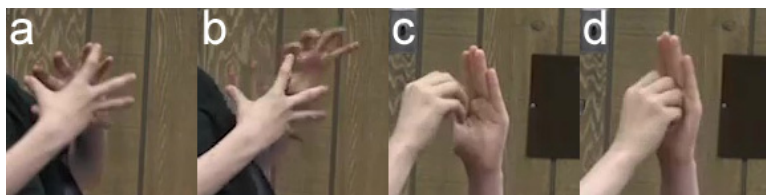


Figure 1. In (a) and (b) Blake makes gestures to represent air pushing the plunger back. In (c) and (d) he gestures to represent molecules moving and hitting the plunger.

Case 2: Sammy

Near the beginning of the interview, Sammy was asked to predict what would happen if she tried to depress the plunger.

S: It would probably be pretty hard because the pressure. There's no way for the air to escape, so it's pressing down on, there's no room for it to take, for the extra air in the place you want to put the plunger into. There's no room for the air to go anywhere, so it's staying in the same place. It's going to be pretty hard to push down.

I: Can you tell me more about why you think it would be hard to push down?

S: The air would be pushing against it, so it would have, umm, more resistance against it. So you wouldn't be just pushing it and the air would move. It would stay in the same spot, so they're pushing against each other.

The gestures that Sammy uses in her response are shown in *Figures 2a* and *2b*. Her response uses a macroscopic perspective of air. Later in the interview she uses molecules to explain a mechanism for why the plunger is harder to depress and why it pops back out.

S: So when you're applying force to the plunger, it presses down on the molecules, so that they're not, they don't have a lot of room left to move. And they're packed down, and there's nowhere else for the plunger to go because the molecules can't move. And when you take off that force, the molecules can push the, um, they're expanding and every time they hit it, it rises, the pressure decreases. So the plunger would push backwards because there's no force on it. The molecules would be stronger than the plunger, and they would press it back up.

The gestures that Sammy uses in her response are shown in *Figures 2c* and *2d*. Her response included molecules in her mechanism, specifically that their collisions with the plunger would cause it to pop back out.

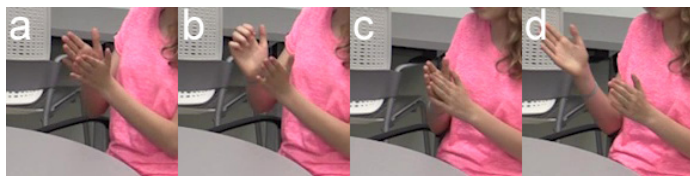


Figure 2. In (a) and (b) Sammy makes gestures to represent it would be difficult to depress the plunger. In (c) and (d) she gestures to represent molecules hitting the plunger and the plunger moving backwards.

Case 3: Ulani

Near the beginning of the interview with Ulani, she is asked to predict what would happen to the plunger once it is pressed in and then released.

S: It will come right back.

I: Oh, interesting. And why do you think it will do that?

S: Because, there is so much force in the air all right here. And, when there is more pressure pushing on it, it will travel and try to hit right back on.

The gestures that Ulani uses in her response are shown in *Figures 3a* and *3b*. Her response includes a macroscopic view of air pushing the plunger back. Later during the interview Ulani discussed increased pressure when the syringe was pushed more, and she was asked to explain the increase in pressure.

S: Because of the fact that it's less space to move so they try to hit it even harder and harder and with more speed.

I: (Noticing and drawing attention to gestures the student used) Can you show me that again? So what are your fingers? What do they represent there?

S: The molecules, and this is the little white part right here. Like this is the box and this is hitting and hitting.

...

I: What is it [the plunger] going to do?

S: Just pop.

The gestures that Sammy uses in her response are shown in *Figures 3c*, *3d*, and *3e*. Her response includes molecules in a mechanism showing that their collisions with the plunger cause it to pop back out. Her gestures show multiple collisions against the plunger.

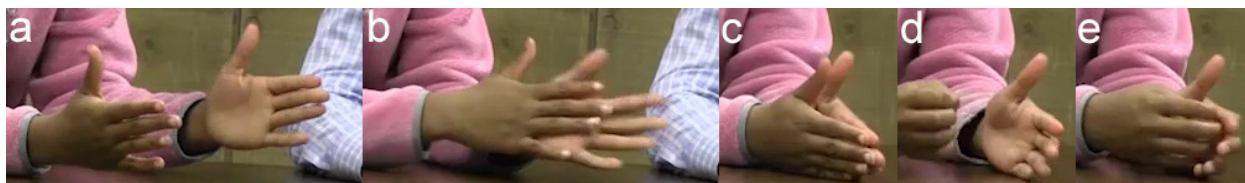


Figure 3. In (a) and (b) Ulani gestures to represent pressure on air and air moving the plunger. In (c) she gestures to represent decreased volume in the syringe, and in (d) and (e) she gestures to represent molecules repeatedly colliding with the plunger.

Discussion and Conclusions

In all three of the cases, students initially provided descriptions of air pushing the plunger without referencing molecules. This is consistent with previous research indicating that students often do not use a particulate view of matter in their explanations (Benson, Wittrock, & Baur, 1993). Students' initial responses were descriptions rather than explanations because they did not use unseen mechanisms to provide a cause for the observable phenomena. Interestingly, all three students used similar gestures with open palms and space between their hands as shown in *Figure 1a, 2a, and 3a*. Blake and Sammy maintained that space throughout the duration of their gestures (*Figure 1b and 2b*), but Ulani brought one hand in and made contact with the other hand (*Figure 3b*), possibly hinting at intuitive ideas about a mechanism.

All three students later transitioned to explanations of the gas pressure phenomena that they observed, and they used different gestures during these explanations. All students used a particulate view of matter to construct explanations that linked observable phenomena with unseen mechanisms involving molecules. As shown in *Figures 1c, 2c, and 3d*, all three students used gestures to simultaneously represent the observable plunger and the unseen molecules. These uses of gesture support Roth and Welzel's (2001) claim that students use gestures to link "phenomenal and conceptual layers of content" (p. 118).

Viewed from a perspective of the gesture-as-simulated-action framework, the gestures that students used could indicate their mental representations of causes for the phenomena (Hostetter & Alibali, 2008). The changes in gesture could signal conceptual changes that occurred for students (Givry & Roth, 2006). Another view is that gesture use could have promoted dynamically emergent concepts (Brown, 2014). Take the example of Ulani who spontaneously used gestures, and, upon having attention drawn to them, reflected on what they

meant. She then elaborated on the role of molecules in the mechanism that she was providing and thus improved her explanation.

Implications of this study include the possibility helping students transition from descriptive to explanatory accounts of phenomena by prompting them to use and reflect on their gestures. This can help all students learn science in two main ways. First, it enables students to use multiple resources (i.e., not only language) to communicate their ideas, and this could be especially helpful for English Language Learners. Second, prompting students for gestures could facilitate thinking about unseen mechanisms, making the practice of constructing explanations accessible to more students. Future research should investigate the extent to which prompting students to gesture during instruction can play a role in the development of explanatory accounts of phenomena. This research should explore various sources of prompting such as teachers and technology-mediated learning environments.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. DUE-1432424. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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