Student Use of Cued Gestures in Explanations of Scientific Phenomena

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Introduction and Theoretical Framework

There is widespread agreement that science education should involve students in developing explanations of natural phenomena (Duschl, 2008), and this practice plays a prominent role in the Next Generation Science Standards (NGSS Lead States, 2013). While the term explanation is defined multiple ways within the field of science education, one category of explanation is the causal explanation in which unseen mechanisms are used to explain observed phenomena (Clement, 1989). This proposal focuses on students’ causal explanations of gas pressure using particulate views of matter, a topic that is challenging for many students (García Franco, & Taber, 2009).

A potential means to address these persistent challenges in conceptual understanding and constructing scientific explanations is through the use of computer simulations. Several recent syntheses of the literature have concluded that using simulations has positive outcomes for conceptual learning (e.g., National Research Council, 2011; D'Angelo et al., 2014). However, these reviews of the literature have concluded that more research needs to be done on specific design features of simulations that elicit new understandings and afford the articulation of canonical ideas.

This study involves learning environments that cue students to use specific conceptually congruent gestures (Lindgren & Johnson-Glenberg, 2013) in order to interact with simulations. Cueing has been suggested to be a useful method for teaching and learning (Lindgren, 2015).
The cued gesture in the current study uses one hand representing molecules and the other hand representing the wall of a container, with the frequency of collisions between molecules and a wall used to generate pressure readings on screen.

This study is based on theories of embodied cognition, which emphasize the role of the body in human thinking (Glenberg, 2010). While there are different interpretations of embodied cognition, there is common agreement that the mind does not operate by processing amodal symbols (Barsalou, 2008). Instead, thinking happens in ways that stem from body-based, perceptual experiences. Researchers have proposed embodied design principles in order to guide the creation of learning environments based on embodied theories (Abrahamson & Lindgren, 2014). This study explores student explanations in the context of a learning environment designed based on these principles.

Given the relatively recent technological capabilities for gesture recognition, little is known about how interventions that use cued gestures support student learning. This study sets out to address two questions:

Q1. To what extent do students use the cued gestures in their explanations of phenomena after using the simulation?

Q2. What are the different ways in which students integrate the cued gestures into their explanations?

**Methods and Data Sources**

This study uses a mixed methods approach. Quantitative analyses are appropriate to address the first research question because the construct of cued gestures is established and thus enables a top-down approach. Qualitative analyses are appropriate to address the second research question because little is currently known about ways in which students use cued gestures in
their explanations. Specifically, we use case study methods because they provide detailed descriptions of student interactions in the learning environment.

Interviews on the topic of gas pressure were conducted individually with 22 middle school students. During the interviews, students were presented with phenomena involving gas pressure¹ and were asked for their ideas before using a simulation. After using the simulation, students were asked again about their explanations of the phenomena. Interviews were video recorded, and audio from the recordings was transcribed. Two researchers analyzed video footage of students’ final explanations and the corresponding transcripts. A closed coding process was used to address Q1, and there was 87.5% agreement on codes with discrepancies resolved by discussion. An open coding process (Saldaña, 2012) was used to generate themes to address Q2.

Results

Q1. To what extent do students use cued gestures in their explanations of phenomena after using the simulation?

Approximately 86% (19 out of 22) of students used gestures when asked for their final explanations of the gas pressure phenomena. Out of these students who gestured, approximately 26% (5 out of 19) initially used the cued gesture as part of their final explanations. Twenty-one students were asked to show what they meant when they gave their final explanation, and 48% (10 out of 21) of these students used the cued gesture.

¹ By pressing on the plunger of a sealed syringe, students observed (a) the air could be compressed, (b) as they pressed the plunger more, compressing the air became more difficult,
Q2. What are the different ways in which students integrate the cued gestures into their explanations?

Students who used the cued gesture did so in three main ways: (a) as a primary resource for communicating an explanation, (b) as a resource for elaborating on ideas, and (c) as a scaffold for sense-making.

Communicating Explanation

When Eliza\(^2\) is asked for her final explanation, she uses the cued gesture to make one of her points, as shown in an excerpt below.

\[ S^3: \text{So there are, in the syringe, there's molecules (uses both hands moving around in random paths). And they're kind of moving around, but they're very, very loose. And when you push on, there's nowhere for them to just move out of the way, and so they have to push back on it (uses the cued gesture; see Figure 1). But more force is being exerted on them so they push back tight (uses one open hand pushing on the other hand). But then eventually they're so tight that they just that they exert enough force back (uses both hands as closed fists with knuckles touching each other), and you can't move it any farther in.} \]

\(^2\) All names are pseudonyms.

\(^3\) We use “S” in excerpts to indicate the student speaking and “I” to indicate the interviewer speaking.
Figure 1. Eliza (pictured right) uses the cued gesture as part of her explanation of the gas pressure phenomena after using the simulation.

From this case, we see that Eliza uses several gestures, including the cued gesture, during her explanation. She uses gestures to represent molecular motion, molecular collisions, and equilibrium of forces. Her gestures add information to her verbal explanation, including how the molecules move around and a mechanism for how molecules push a moveable wall.

*Elaborating on Ideas*

When Darwin is first asked for his explanation, he uses gestures to represent the observable walls of the container but not the unobservable molecules. He says that the molecules push the wall back, but he does not give a mechanism for how they push. The interviewer prompts him to show what he means by his explanation.

S: Um, let's say this is the molecule and this is the plunger end (positions hands like the cued gesture, with hands positioned vertically; see Figure 2) so once you push it down, and like once you come to a certain level it's hard to push it down to the end cause the molecules now like have not much space to bounce, so it's going this fast (uses the cued gesture). But that's why once you let it go you can feel, you can see pressure
(uses the cued gesture and moves the open hand back) while it's going back up so you have more space to bounce.

Figure 2. Darwin (pictured left) uses the cued gesture in a vertical orientation after being asked to show his explanation.

When asked to show what is happening, Darwin uses the cued gesture to communicate that molecular collisions provide a mechanism for how the plunger moves. This detail was missing from his initial explanation, but he elaborates on his explanation using the cued gesture. This case illustrates the difference between the first category of communicating explanation, which focuses on initial integration of the gesture into the explanation, and the second category of elaborating on ideas, which focuses on students adding key ideas to their explanations after being prompted to show what they mean.

Making Sense of Ideas

When Erika is asked for her final explanation, she uses the cued gesture as she describes some of the things she saw while using the simulation. Even though she uses the cued gesture, she does not integrate it with a mechanism for her explanation. The interviewer then asks Erika
to show her explanation, focusing on what is happening with the molecules. Erika conveys ideas about molecular motion, but she does not convey ideas about molecular collisions. The interviewer notices this and reminds her of the cued gesture from the simulation.

I: And we were doing this kind of a gesture (shows the cued gesture). When we were doing this, with the simulation, what was your hand, what was your fist?

S: It was, the molecules, and this was the wall, so then it was like (uses cued gesture) because it went back and then, and then if I didn't go, if I just went like that one time it would of went back, but I kept doing it so then the wall kept, compressing to the molecules.

During the student’s response, she pauses multiple times as she conveys what the cued gesture represents, and she recounts causes and effects from using the simulation. Then the interviewer asks her to explain why the plunger of the syringe pops back out.

S: It goes (starts with two open palm hands near each other and rapidly moves them away).

I: And why is it doing that?

S: Because, um, when the air thing is like too much pressure so then when you let go it goes psshh (repeats gesture).

I: But why is it going backwards? Are the molecules doing anything to it?

S: They're pushing the wall.

I: How were they doing that, can you show me?
S: (Uses cued gesture; see Figure 3).

Figure 3. Erika (pictured left) uses the cued gesture after being reminded about using it and discussing what her hands represent.

Even though the student uses the cued gesture when initially asked for her final explanation, it was not integrated with her explanation. Being asked to show her explanation does not seem to help her integrate the gesture with her explanation, but being reminded of the cued gesture is productive for starting to make connections between the gesture and molecular mechanisms for gas pressure.

Discussion

A question that may be raised is why more students did not use the cued gesture in their explanations. It may be the case that some students have abstracted meaning while using the simulations and can convey their ideas verbally afterward. Another explanation is that some
students modify the cued gesture. For example, several students who were interviewed gestured in ways that seemed like modifications of the cued gesture, such as by using their fingertips to represent multiple molecules. This type of gesture was not counted as using the cued gesture, but that is not to say that the cued gesture did not play a role in the development of their explanation. Their modification shows a more complex representation that is currently beyond the technological capabilities of the learning environment. These modified gestures are interesting because students do not usually use them before interacting with the learning environment, and it is rare for students to provide causal explanations before using the learning environment. This suggests that the learning environment may have supported them in using these gestures as part of their explanations.

Another important point is that some students used the cued gesture but had difficulties coordinating it with a coherent explanation. Simply performing the gesture should not be accepted as conveying an explanation. Rather, the use of the gesture should be viewed in the context, including students’ verbal communication.

The issues raised in this discussion suggest that additional investigation into connections between cued gesture use and the quality of student explanations is needed.

Nevertheless, this study has implications not only for the design of digital learning environments but also for pedagogy. Teachers can learn to attend to student gestures as a way to attend to student thinking, and students can feel empowered to use gestures to help make meaning of phenomena. This study shows that you can have productive conversations about a cued gesture when it is congruent, and this is an argument for designing learning environments with congruent gestures rather than arbitrary gestures or mouse clicks. The cued congruent
gestures can be used outside of the learning environment as resources for communicating and making sense of ideas.

References


