"Show Me" What You Mean: Learning and Design Implications of Eliciting Gesture in Student Explanations

Robb Lindgren, University of Illinois Urbana-Champaign, robblind@illinois.edu
Robert C. Wallon, University of Illinois Urbana-Champaign, rwallon2@illinois.edu
David E. Brown, University of Illinois Urbana-Champaign, debrown@illinois.edu
Nitasha Mathayas, University of Illinois Urbana-Champaign, mathaya2@illinois.edu
Nathan Kimball, Concord Consortium, nkimball@concord.org

Abstract: This paper describes preliminary research conducted on how gestures affect the construction of student explanations of science phenomena. We examine the effect of asking middle school students to "show me" while they construct explanations of critical science topics such as heat transfer and the causes of seasons. Specifically we were interested in whether there were any apparent changes in students' inclusion of unobservable causal mechanisms (e.g., molecular interactions) that underlie observable phenomena such as how heat moves through a metal spoon. To understand these effects, we coded for whether explanations were more mechanistic following the "show me" prompts compared to their previous explanations. Results showed that elicitation of gesturing frequently led to increased attention to, and specification of, the critical mechanisms. We describe a few specific cases to illustrate the ways in which gesturing appeared to alter student reasoning.

Keywords: gestures, explanations, science reasoning, embodied learning

Introduction

Previous research in psychology and the learning sciences has described the critical role that gestures play in thinking and reasoning (e.g., Goldin-Meadow, 2005; McNeill, 1992; Roth, 2001). Frequently studies of gesture and learning have examined how gestures occur naturally in the context of students' reasoning and constructing meaning in areas such as geometry (Kim, Roth, & Thom, 2011), making sense of Cartesian graphs (Radford, 2009), and geology (Singer, Radinsky, & Goldman, 2008). Among other findings, these studies have demonstrated that spontaneous gestures frequently capture a learner's emerging understanding of complex concepts, and that they often precede coherent verbal articulation of canonical ideas. In this preliminary study, we are interested in what happens when explicit attention is given to student gestures through interviewer requests to "show me" as they are in the midst of explaining observable science phenomena (e.g., gas pressure). Leveraging a large corpus of student interviews on three different science topics, we describe how explanations were impacted by gesture prompting. We extracted excerpts of these interviews where gestures were elicited, and we coded these excerpts for whether or not explanations changed from their previous attempt to explain the science phenomenon. Some of the ways that gesturing appeared to impact student reasoning are highlighted through a few illustrative cases.

Gestures and learning

Theories of embodied cognition and embodied learning posit that the composition and activities of our bodies are central to processes of thinking and reasoning (e.g., Glenberg, 2010; Wilson, 2002) and that cognition is "grounded" in simulations of sensorimotor activity (Barsalou, 2008). Gestures are embodied acts that frequently accompany reasoning and problem solving, and several recent studies have shown how gestures play a mediating role in the knowledge-building discourse in authentic learning environments such as classrooms (Alibali & Nathan, 2012; Carter, Wiebe, & Reid-Griffin, 2006; Roth, 2001). Yoon, Thomas, & Dreyfus (2011) describe how gestures performed within a dyad can give rise to new mathematical insights through a space of "virtual constructs," and the authors encourage raising students' awareness of gestures as a learning resource. While studies of gesture and learning are quite prevalent, relatively few studies have examined the effects of explicitly encouraging students to perform gestures while conversing or constructing explanations. In one such study, children who were asked to gesture while working on novel math problems showed stronger performance than their non-gesturing peers (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007). While there seems to be affordances for making student gesturing an explicit component of reasoning and constructing explanations, the different ways that this can occur, and their specific effects on learning, require further exploration.

Study methods and design

This investigation of student gesturing was conducted in the context of a larger project looking at embodied expressions and interactions with science education simulations. The dataset used for this study was a set of individual interviews that were conducted with 37 middle school students from several different schools located in the Midwestern United States. The primary objective of conducting these interviews was to gain insights on student explanations of phenomena related to three science topics: gas pressure, heat transfer, and the causes of seasons. Most students were interviewed about two topics, for a total of 24 interviews on each of the three topics that lasted approximately 25 minutes each. In these interviews students were asked to give explanations multiple times, including an explanation at the beginning of the interview and one at the very end. Over the course of the interviews, students were also asked to make predictions, view computer simulations, and represent their ideas with drawings and gestures. Students were prompted to use gestures in several ways, including being asked to repeat a gesture that they had used previously, or being asked to use a specific gesture (e.g., "let your fingers be the molecules…"). The most common way that gestures were prompted, however, was by the interviewer asking the participant to "show me" while they were in the midst of giving an explanation. Students almost always understood the "show me" prompt as a request to use hand gestures, but if any confusion was expressed the interviewer would follow-up by asking if they could use their hands. The "show me" prompt typically came when students were attempting to describe, or were hinting at the core causal mechanism of the phenomenon. For example, in the gas pressure interviews students were asked to explain why a plastic syringe with the end blocked off could only be pushed down partially, and that when one lets go the plunger pushes back out again to its starting point. Students frequently understood that the air inside the syringe consisted of molecules, but they often struggled with describing what those molecules were doing that led to the pressure that pushes out the syringe.

Interviews were video recorded, and audio from the interviews was transcribed. Transcripts were divided into explanatory segments, which were portions of the interview when students were asked for explanations or when they offered explanations without being prompted. A subset of the explanatory segments were used as the unit of analysis in this study. Specifically, we selected explanatory instances (a) near the end of the interview when students had been exposed to some resources that may have helped them develop their explanation, and (b) when they were asked to "show" the interviewer what they were trying to convey, or an otherwise explicit request to utilize gestures in their explanations. This resulted in 14 explanatory instances for the gas pressure interviews, 16 instances for the heat transfer interviews, and 17 instances for the seasons interviews. Each of these 47 instances were reviewed on video and independently coded by two members of the research team. Because we were particularly interested in the inclusion of causal mechanisms, explanatory segments were coded for whether or not the explanations were "more mechanistic", "less mechanistic", or if there was no change compared to the most previous explanation that the student had given. By mechanistic, we refer to whether the explanation explicitly describes the causal mechanisms for the phenomenon they are engaged with. For example, with the causes of seasons, we were interested in the degree to which the students described how the Sun's rays came into contact with the surface of the Earth (straight on, at an angle, etc.) at various points in its revolution around the Sun. We took note of the degree to which they discussed how the angle of contact affects the density of the light rays and subsequently the amount of heat transmitted to a given part of the Earth. If this mechanism was made more explicit and stated more clearly relative to the last time they gave an explanation of the same phenomenon, then the instance was coded as "more mechanistic." In their first pass of coding the instances, the two coders had 61% agreement. Discrepancies in coding were resolved through discussion until consensus was reached and all 47 instances were assigned a single code.

Results: Gesture prompting and types of mechanistic changes

In order to get a general sense of whether or not prompting students to use gesture had an impact on their explanations, we tallied how many of these instances resulted in improved focus on mechanism. Table 1 shows the breakdown by interview topic area. Looking across all the interviews a total of 28 or 59.6% of the instances of gesture prompting were deemed to have more mechanistic reasoning compared to their previous explanation. A total of 18 or 38.2% were judged not to have changed, and only one instance was coded as being less mechanistic than the previous explanation. The basic finding from this analysis is that across multiple topics in science, simply prompting a learner to "show me", or to incorporate gesture into their reasoning, frequently led to higher engagement with the core mechanism in their explanations.

The precise reasons why gesture leads to more focus on mechanism is not readily apparent and will require further study, but a few examples provides some insights about the kinds of changes the gesture prompts elicited. In our first example, prompting a student to use gesture seems to lead him to be explicit about the mechanism of heat transfer in a metal spoon (i.e., fast moving molecules speeding up slower moving molecules via collisions). In this example, Harun has just given an explanation of why one end of a metal spoon gets hot

Table 1: Changes in the number of mechanistic elements in explanations after being prompted to gesture

Topic	Explanations became less mechanistic	No change	Explanations became more mechanistic	Total
Gas pressure	1	5	8	14
Heat transfer	0	5	11	16
Seasons	0	8	9	17
Total	**1**	**18**	**28**	**47**

when the other end has been submerged in boiling water. He talks about molecules vibrating and that heat moves through the spoon, but does not say specifically how the heat moves. Later in the interview the following exchange occurs:

> **Interviewer:** So, can you show me with your hands how the heat is going from the hot to the cold [side]?
>
> **Student:** Okay. This is the … hot side. And this is the cold water. And the hot side vibrates starting to travel to the spoon. And then, on the cold tip, when the hot side collides it's starting to get hot.
>
> **I:** So when you were doing this, was this, was your hand a molecule? Or was it, was it something else?
>
> **S:** It was molecules. And when it starts to vibrate because it's heating up then the other ones in the middle start to vibrate too. And then it starts to vibrate until it's completely warm.

When asked to show the spoon, Harun held his hands out in front of him with his right hand representing the hot side of the spoon and his left hand representing the cold side (see Figure 1). As he explained how the hot side vibrated and collided, he shook his left hand and brought it closer to his right hand until they were pressed together and shaking simultaneously. Involving the body in the reasoning process seemed to allow Harun to test his own hypothesis about how changes in the speed of vibration of molecules can propagate over a larger area of molecules. He seemed able to think through the implications of his own prior statements by running a physical, body-based simulation through gesture, and it let him to include the specific causal mechanism in his explanation.

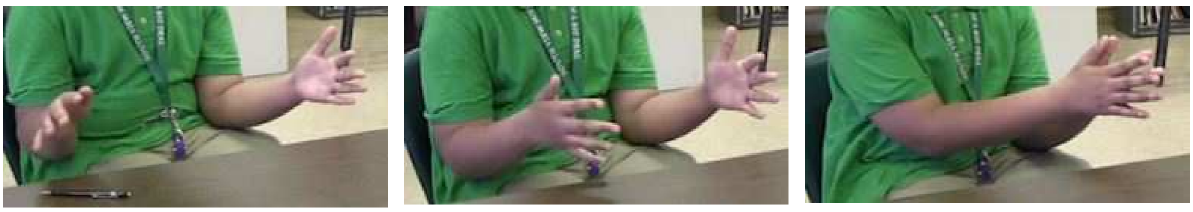

Figure 1. Harun gestures to show vibrating molecules along the length of a spoon.

In our second example, the student appeared to already have the basic causal mechanism of air pressure. Myrna states that the reason that the plunger in a syringe with a closed off end pushes back after it is pressed in, is because the air molecules are "pushing" against the wall of the syringe. However, it is not clear from her initial explanation why the molecules push more when there is less space in the syringe. Later in the interview when she was trying to explain it again, the interviewer used the "show me" prompt, and she says the following:

> **S:** When they have a really big space, and this is the plunger, then they're just occasionally hitting it and then hitting this wall and this wall, and hitting it again. And then when you try to push it in, they're hitting it, like, more often like this. Until they're all just hitting it at once, like that. And then, they're all hitting it and then when you let go now it's like that. Until they're just barely hitting it.

As Myrna is saying this, her hands are flailing all over when she describes the syringe as having a "big space", but her movements are quicker and more compact when it is "pushed in." Unlike her initial explanation, she is conveying that the frequency in which the molecules are hitting the plunger has increased, which strengthens her explanation for why the plunger pushes more when it is compressed.

In our final example, both of Lisa's initial and final explanations of why we have seasons are basically correct. What is interesting, however, is that using gestures changes the perspective that she takes in her explanation. Initially her explanation is focused on what is happening in a particular place on Earth, but when asked to gesture she takes a more holistic view, representing the Earth in relation to the Sun with her hands (see Figure 2). Here is Lisa's initial explanation, and then the one she gives in response to the "show me" prompt:

S: The way that the Earth is tilted in the summertime where we are gets more direct sunlight even though we get sunlight every day, but the Sun's rays are a…they come from a different angle in the winter so we get the light and heat less intensely.

S: Like so this fist is the Earth and upright is like this, but it's kind of tilted normally so the Sun is always shining like this, but it's flowing out like a spotlight that is stronger in the center and gets the light...it fades more when it gets towards the outer sides of the circle…it goes around the Earth like this and the angle that it's at doesn't change, so if it's here and we're here it would be less intense

Figure 2. Lisa showing the Earth tilted (left) and sunlight shining on the Earth "like a spotlight."

In this case the gesture prompting seemed to switch Lisa's explanation from a "ground" view to a "space" view, which may have different affordances for communication and for solidifying her own understanding.

Conclusion

We have shown in this preliminary study that requesting students to use gestures in the explanations of science phenomena frequently alters the degree to which the student engages with the causal mechanism. Often the gestures seems to lead to more mechanistic explanations, or they change the perspective from which the mechanism is described. These findings suggest that both classrooms and new technologies may find success in improving student explanations through explicit elicitations of gestures.

References

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences, 21*(2), 247-286.

Barsalou, L.W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–645.

Broaders, S. C., Cook, S. W., Mitchell, Z., & Goldin-Meadow, S. (2007). Making children gesture brings out implicit knowledge and leads to learning. *Journal of Experimental Psychology: General, 136*(4), 539–550.

Carter, G., Wiebe, E. N., & Reid-Griffin, A. (2006). Gestures: Silent scaffolding within small groups. *Journal of Classroom Interaction, 41*(1), 15-21.

Glenberg, A. (2010). Embodiment as a unifying perspective for psychology. *Wiley Interdisciplinary Reviews: Cognitive Science, 1*(4), 586–596.

Goldin-Meadow, S. (2005). *Hearing gesture: How our hands help us think.* Cambridge: Harvard University Press.

Kim, M., Roth, W., & Thom, J. (2011). Children's gestures and the embodied knowledge of geometry. *International Journal of Science and Mathematics Education, 9*(1), 207-238.

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought.* Chicago: University of Chicago Press.

Radford, L. (2009). Why do gestures matter? Sensuous cognition and the palpability of mathematical meanings. *Educational Studies in Mathematics, 70*(2), 111-126.

Roth, W. (2001). Gestures: Their role in teaching and learning. *Review of Educational Research, 71*(3), 365-92.

Singer, M., Radinsky, J., & Goldman, S. R. (2008). The role of gesture in meaning construction. *Discourse Processes: A Multidisciplinary Journal, 45*(4-5), 365-386.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625-636.

Yoon, C., Thomas, M. J., & Dreyfus, T. (2011). Gestures and insight in advanced mathematical thinking. *International Journal of Mathematical Education in Science and Technology, 42*(7), 891-901.

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