SUPPLEMENTAL APPENDIX A. Spectrum of Analysis Methods for Clinical Studies

Analysis methods for clinical studies such as case studies of instructional interactions can be thought of as spanning the spectrum A-D below. More **Generative** and Interpretive Studies fall at stages A and B while more **Convergent**, Confirmatory Studies fall at stages C and D (adapted from Clement[1]).

A. Exploratory Studies: involve the initial construction of new descriptive concepts and relationships while describing what happened in a case study. Although analyses will be interpretive at this stage, reported in a narrative style, and conducted over larger blocks of transcript than in studies falling at stages B-D, analysts who become sensitive to subtle observations may generate key insightful hypotheses about processes that would otherwise be difficult to attain.

B. Grounded Model Construction Studies: Investigators use smaller segments of transcripts as the unit of analysis and begin to tie their theoretical interpretations to specific observations or events in the transcript that support them, triangulating where possible. The pioneering description of this method is Glaser and Strauss.[2]

C. Explicit Analysis Studies: criticize and refine interpretations on the basis of more detailed analyses of cases; develop definitions of constructs that are precise enough to support counting the number of instances of a construct over an entire transcript. Investigators may code transcripts jointly and disputes are used to refine definitions until consensus is reached.

D. Independent Coder Studies: Analysis focuses on low-inference constructs so that coding of constructs can be done by independent coders; inter-coder reliabilities are calculated. Some forms of human activity may not be amenable to analysis at level D since complex, interconnected, or preconscious processes may be very difficult to code at this level.

The present study falls largely at Stage C. It builds on a number of prior exploratory studies (A) and model construction studies (B).

SUPPLEMENTAL APPENDIX B. Selected Gesture Literature

Type and amount of gesture appears to be closely associated with the nature of the subject's internal representation:
Lozano and Tversky[3] found that the type of gesture used to describe navigation information was related to the type of information the subjects later remembered. Spontaneous gesturing by subjects who have been blind from birth, even when talking to other subjects they know are blind, has been documented by Iverson and Goldin-Meadow;[4 5] a more important factor than status as blind or sighted in whether these subjects gestured appeared to be the nature of the internal representation underlying the communication. Iverson and Goldin-Meadow suggest that gesture reflects the manner in which we think about the world.

Representational gesture production, in particular, appears to be associated with visuo-spatial processes:
In Iverson and Goldin-Meadow's[2] study, blind and sighted children were assigned the task of describing a route through their school. Many more gestures were produced when the children (blind or sighted) described the route in terms of spatial directions than when they described the route as a succession of landmarks. Krauss[6] found that gesturing during "spatial content phrases" was nearly five times more frequent than it was for the remaining non-spatial phrases. When Hostetter and Alibali[7] had subjects try to describe dot patterns, they found a significantly larger ratio of gestures-to-words for patterns that were more difficult to conceptualize in terms of geometric patterns. In a review of the literature, Alibali[8] identified no less than 10 different studies providing evidence that speakers use gestures to express spatial information (including the Krauss study just mentioned). Alibali concludes that gestures are a window onto spatial cognitive processes and Hostetter and Alibali[5] propose that the gestures reflect bodily instantiated mental models.

Representational gesture appears to be associated with other imagistic processes:
Feyereisen and Havard[9] found that speakers produced more representational gestures when speaking about topics that were judged to involve visual or motor imagery and more beat (rhythmic emphasis) gestures when speaking about abstract topics.

Evidence suggests that representational gesture is not merely a translation of subjects' verbal meanings, but can reveal unspoken thought:
Goldin-Meadow[10 11] found that the information contained in children's gesture does not always match that contained in their speech; her evidence indicates that such mismatches between gesture and speech reveal that the gesturer has two distinct ideas about a single problem. Goldin-Meadow[9] concludes that gesture can provide the listener access to unspoken thought.

Depictive gesture appears to be a natural way of representing the results of mental animation and conveys information about the animation not revealed in subjects' words:

McNeill[12] has identified a *character viewpoint*, where the gesturer takes the point of view of the actor performing the action, and an *observer viewpoint*, where the gesturer takes the point of view of someone observing the action. He shows that the viewpoint taken can be revealed by a speaker's gestures. Roth[13] recounts where, even though a student did not yet have language to describe events represented in a computer simulation, his gestures allowed him to achieve complex communication that effectively animated the static image on the screen. Hegarty, Mayer, Kriz, & Keehner[14] had subjects solve problems in which they had to think aloud as they inferred motion from static diagrams. These think-aloud participants gestured on 90% of the problems and most gestures expressed information about the animation that was not contained in the words. Hegarty, et al., conclude that gestures are a natural way to express the results of mental animation processes.

For educational research using gesture analysis, see reviews by Roth[15] and Scherr.[16]

SUPPLEMENTAL APPENDIX C. Coding for spontaneous student use of expert reasoning processes in two classroom discussions

TABLE C-I(a). Book on Table

Transcript Line #	**Episodes in which at least one non-formal reasoning process was observed**	**Gesture Codes**	**Reasoning Codes**		
11	S15: if you think about it, when…the **[G]** book is on the table, that the **[G]** surface of the table gets **[G]** warped a little bit….If you imagine building a table out of…uh, **[G]** a balloon…	Gesture Shape, Force indicat.	Analogy		
13	S15: …the balloon gets **[G]** pushed down…				
14	T: I hear you saying my table gets warped?				
15	S15: …**[G]** and responsible for some of the force pushing the book up.				
57	S15: (W)e build the table out of something pliable…		Analogy jointly construct-ed		
58	S3: …like plywood…				
62	S15: …or cardboard…				
64	S15: …or paper…				
65	Sx: Bounty.				
85	S15: To me, if the table is perfectly rigid, does not move at all, then I don't see how…	Gesture Force indicat.		Extreme C	
87	S15: …if we had an ideal table that did not move at all…				
89	S15: …then I don't see how it could be pushing up on the book.				
91	S15: I don't see how [an ideal table] **[G]** pushes on the book.				
98	S12: If the table is perfectly rigid, you could almost call it part of the ground…. If the table isn't there, [the book is] gonna hit the **[G]** ground. But you could always dig a **[G]** hole, right?.... (Y)ou're going to say the **[G]** ground is moving, too? … You could go **[G]** right through to China, [the book] keeps **[G]** falling.	Gesture Shape, Motion indicat.		Extreme C	Gedanken

TABLE C-I(b). Book on Table

Transcript Line #	**Episodes in which at least one non-formal reasoning process was observed**	**Gesture Codes**	**Reasoning Codes**	
109	S14: So it's like the river. [Cancellation case discussed in an earlier class, where velocity of a current was equal and opposite to the velocity of a boat.]	Gesture Motion indicat.	Analogy	
112	S14: The book is pushing down with the velocity of the [boat] engine, it's **[G]** pushing down. And the table is pushing up with the velocity of the current. If you take the current away, then the engine [moves], if you take the **[G]** force of the table pushing up away, then the book would just fall **[G]** down.			
114	S15: But by the same analogy then, if gravity disappeared…**[G]**...the book would just **[G]** fly off into space [due to the upward force from the table on the book]. [In fact, the table would unwarp.]	Gesture Force, Motion indicat.		Gedanken
123	S14: That's like if the engine…**[G]**...is greater than the velocity of the current…	Gesture Motion indicat.	Extreme C	
125	S14: …(L)ike the river's coming **[G]** down at 3 and the boat's going **[G]** up at 5, or 7, or whatever…then the boat is moving upstream, so the [garbled] is greater. So that's like what we're saying about the elephant sitting on the table. [The elephant will move down even though the table is pushing up.]			
135	S15: [S14's] idea is compatible with the warped table theory. The idea is that the **[G]** elephant sitting on the table is too much **[G]** for the material that the table is made of, and it **[G]** punctures the thing, it **[G]** warps it too much.	Gesture Shape, Force indicat.	Extreme C	

TABLE C-II(a). Gravity

Tran-script Line #	**Episodes in which at least one non-formal reasoning process was observed**	**Gesture Codes**	**Reasoning Codes**		
9	S9: If you put a ping-pong ball beside an elephant, it would probably [move] the elephant [due to mutual grav forces].			Extreme C	
12	S9: There's no **[G]** movement. You don't feel the attraction. But in order to see [movement], you'd have to have a really, really tiny mass and a really, really huge mass.	Gesture Motion indicat.		Extreme C	
40	S5: Well, I just think that gravity has nothing to do with rotation, but maybe with **[G]** rotation [of Earth] like, [points to drawing of stick figure near equator] that guy is trying to get **[G]** thrown off the Earth. So he's getting **[G]** pulled at the same rate [as if there were no rotation] but he's also getting **[G]** pushed away.[a]	Gesture Force indicat.			Gedanken
49	S7: I think of [rotation and gravitational forces] as being two opposite forces... **[G]** imagine a ball floating in space you tape your feet to. And you start spinning the ball around, you're gonna **[G]** feel like you're gonna be **[G]** thrown off. But if it's a small ball, then the attraction between you and that little small mass is negligible....	Gesture Shape, Motion, & Force indicat.	Analogy	Extreme C	Gedanken
72	S4: If you **[G]** increased air pressure **[G]** incredibly on all of us, like if you **[G]** go to a planet with a lot more air pressure, you'd just get **[G]** squished....	Gesture Motion, Force indicat.	Analogy	Extreme C	Gedanken
74	S4: … and so I think if you **[G]** removed all the air in here, we'd all be a little bit lighter.				
166	S4: You know that **[G]** machine at the carnival that **[G]** spins around and **[G]** turns on its side and you stay? **[G]** I think that spinning will generate a lot of force and **[G]** not always trying to **[G]** throw you away…. I think that **[G]** in this case it's somehow helping to hold.	Gesture Motion & Force indicat.	Analogy		

[a] The student has added rotation to the teacher's static presentation of the case, and in such a way that the effects could apparently be sensed. It is doubtful the student is speaking from experience; one does not normally experience the effect of the Earth's rotation in this way.

TABLE C-II(b). Gravity

Transcript Line #	**Episodes in which at least one non-formal reasoning process was observed**	**Gesture Codes**	**Reasoning Codes**	
182	S4 (off camera): OK, say that [rotation of the Earth] is throwing you. Then that still means that the top [North Pole] is still gonna be throwing you left, and at the side [at the equator] (garbled). So your weight's gonna be different.	Gesture Shape, Force indicat.		Gedanken
183	S5: Yeah, but that has nothing to do with gravity.			
184	S4: Why not? What if the **[G]** Earth is trying to throw you around at the Equator?			
186	S4: How could that not have anything to do with it? If the Earth is trying to throw you off, in effect, **[G]** at the equator, then it will kind of **[G]** counteract the **[G]** pull of the Earth on you. And at the **[G]** North Pole, it wasn't trying to throw you off, and the Earth had **[G]** more pull on you. Which means you'd weigh more.			Student refines his Gedanken
201	S6: [If Earth spun faster on its axis] I believe [ones weight] would decrease.	Gesture Force indicat.	Analogy	
203	S6: At the fair they often have this **[G]** horrible ride so you get thrown in a **[G]** circle…			
205	S6: …and you get **[G]** pulled up like this, by centrifugal force. And so I think at the equator you would feel the same **[G]** sort of (garbled).			
215	S13: We're talking about the **[G]** Earth spinning around on its axis, but the Earth is also moving **[G]** around the sun. So the only effect on gravity would be if all of a sudden the Earth moved around the Sun **[G]** twenty times faster…. I think that the fair question can be explained by saying that the centrifugal force is entirely separate from gravity.	Gesture Motion indicat.	Analogy	
217	S13: (I)f somebody puts me in a catapult and I go **[G]** hurling two hundred feet into the air, gravity is the same, there's just another force acting.	Gesture Force indicat.	Analogy	
229	S4: I have no idea if you **[G]** spin something around if there's no… centrifugal force in space.... If you have a **[G]** space ship that's **[G]** spinning around, someone could be standing on the outside and they're **[G]** not going to get thrown off? And I just find that kind of hard to believe, that the only reason we have centrifugal force is because of air or because of gravity.	Gesture Motion, Force indicat.	Analogy	Gedanken

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