Please cite as: Flood, V. J. & Harrer, B. W. (2023) Kinetically-held questions: Representational gesture post-stroke holds in whole class interactions in STEM. *Linguistics and Education, 74*, 101164.

Kinetically-held questions: Representational gesture post-stroke holds in whole-class interactions in STEM

Teachers use "kinetically-held" questions by freezing representational gestures and holding them during Initiation-Response-Evaluation/Feedback (IRE/F) sequences in whole-class interactions. Drawing on Kendon's gesture studies and ethnomethodology and conversation analysis, we illustrate the role representational gesture post-stroke holds can play in (1) typical 3-part IRE/F sequences, (2) topically related sets of IRE/F sequences, and (3) expanded sets of reformulated IRE/F sequences. Our analysis demonstrates how held representational gestures in IRE/F sequences contribute to both (a) organizing multiparty participation and (b) providing durable, visuospatial support for the co-construction of classroom knowledge. This study contributes to a better understanding of the understudied phenomenon of how teachers use the timing and temporality of representational gestures in STEM classroom interactions.

Keywords: Classroom Interaction, Conversation analysis, Gesture, Embodied Teaching, IRE/F sequences, Whole-Class Discussion, STEM Education

1. Introduction

Teachers and students use a variety of embodied methods and resources to choreograph whole-classroom interactions, creating opportunities for learning and instruction (Fasel Lauzon & Berger, 2015; Kääntä, 2012; Sert, 2015). Although interest in these embodied instructional practices is increasing (Hall & Looney, 2019), there is still much to learn about how teachers use embodied resources to orchestrate productive whole-classroom discussions. In this article, we draw on ethnomethodology and conversation analysis (EMCA; Garfinkel, 2002; Mondada, 2012), as well as gesture studies (Kendon, 2004), to examine a previously undescribed embodied interactional resource used by teachers in whole-class interactions: We show how STEM teachers "freeze" representational gestures depicting STEM content during questioning sequences in the classroom. In everyday interaction, Adam Kendon called these "kinetically-held questions" (Cibulka, 2016).

We illustrate how *kinetically-held questions* are used in the context of Initiation-Response-Evaluation/Feedback (IRE/F) sequences (Mehan, 1979; Sinclair & Coulthard, 1975), where teachers suspend representational gestures during initiations, and, depending on how students respond, maintain or release in them in the third feedback turn. This article provides insight into two growing areas of investigation: (1) teachers' use of representational gestures in the context of STEM education, and (2) EMCA-based studies of the multimodal, embodied resources participants use to organize classroom interactions. Despite interest in the role of representational gestures in STEM instruction, their temporality has not been closely examined.

2. The embodied interactional achievement of participation and knowledge in classrooms

In EMCA investigations of classroom discourse, there has been increased interest in multimodal, embodied semiotic resources (Streeck et al., 2011) that are used in whole-class interaction to organize participation and the interactional production of knowledge, as evidenced by several recent volumes (Hall & Looney, 2019; Jacknick, 2021; Sert, 2015). A number of

studies have looked at how questioning sequences are carefully choreographed through teachers' and students' embodied conduct, especially in the case of Initiation-Response-Evaluation/Feedback (IRE/F) sequences (Macbeth, 2004; Mehan, 1979; Sinclair & Coulthard, 1975; Wells, 1993), where teachers ask a question (the Initiation), students answer (the Response), and teachers provide a follow-up (the Evaluation and/or Feedback). For example, students use hand raising (Sahlström, 2002), posture shifts and facial expressions (Petitjean & González-Martínez, 2015; Sert & Jacknick, 2015), gaze (Evnitskaya & Berger, 2017; Sert, 2015), or parallel activities such as rummaging through personal belongings (Koole, 2007), to display willingness and unwillingness to participate. Teachers' embodied conduct also plays a central role, and teachers deploy a variety of different embodied resources to organize turn-taking and participation (Duran & Jacknick, 2020; Fasel Lauzon & Berger, 2015; Waring & Carpenter, 2019), manage epistemic and interactional trouble (Ishino, 2021; Sert & Walsh, 2013; Tainio & Laine, 2015), prompt corrections and self-repair (Kääntä, 2014; Walper et al., 2021), provide hints (Flood, 2021; Sert, 2015), and mark and resolve behavioral breaches (Hazel & Mortensen, 2017; Jakonen & Evnitskaya, 2020; Looney & He, 2020).

As part of organizing classroom participation, teachers use a variety of multimodal, embodied resources to pursue responses (Stivers & Rossano, 2010) from students during questioning sequences. One of the most well-known resources is silence, which Rowe (1974) famously defined as "wait time." These periods of silence may occur between the teacher posing a question to students (wait time I), and when the teacher speaks again if there is no response (wait time II). In addition to using prolonged silences, teachers also pursue student responses with various forms of gaze shifts (Mortensen, 2008; Waring & Carpenter, 2019), prosody (Duran & Jacknick, 2020), and bodily actions (Kääntä, 2012, 2015; Mortensen, 2008). Holding or freezing the body in various ways is a common tactic (Kääntä, 2012, 2015). When at the front of the room, teachers will hold artifact-oriented pointing gestures to the board or freeze writing actions after soliciting student responses (Chazal, 2015). Teachers also hold deictic gestures pointed to relevant objects (aus der Wieschen & Sert, 2018) or pointed out towards participants as they seek willing participants to fill in a response (Walper et al., 2021). These same embodied resources are also used to preserve interactional space for students' responses and provide assessments of those responses (Kääntä, 2015; Sert, 2015; Waring & Carpenter, 2019).

In addition to organizing participation, teachers also use multimodal, embodied resources to contribute to the co-construction of knowledge in the classroom. In science and mathematics education, a number of studies have shown teachers frequently deploy *representational gestures* – hand movements that iconicly or metaphorically illustrate and animate entities and processes – to help convey semantic content to students (Alibali & Nathan, 2012; Roth, 2001; Singer, 2017). For example, a teacher may hold a forearm out at an angle to demonstrate the slope of a line for a mathematics class (Alibali & Nathan, 2012) or open and close a fist to illustrate a heart pumping blood for a biology class (Kress et al., 2001). Teachers will even increase their rates of gesturing when they perceive students are having difficulty with the content (Alibali et al., 2013). Representational gestures help teachers create instructional metaphors and analogies to bridge and ground abstract concepts in science and mathematics (Alibali & Nathan, 2012; Núñez, 2006; Weinberg et al., 2015). Representational gestures are also used by teachers to augment and animate processes in static diagrams and models to bring ideas to life for students like blood flow in the circulatory system (Kress et al., 2001; Pozzer-Ardenghi & Roth, 2005). During complicated explanations, teachers repeat particular representational gestures (catchments, McNeill, 2002) to help establish coherence within complex chains of logic (Flood, 2021; Nathan

& Alibali, 2011; Pozzer & Roth, 2020). They also use gesture to dynamically link different representations, such as a graph and its equation (Alibali et al., 2014). Teachers also use more elaborate representational gestures when students display difficulty answering questions (Flood, 2021) or understanding content (Nathan & Alibali, 2011). However, we know little about how teachers take advantage of the timing and ability to pause representational gestures during instruction.

Taken together, these studies demonstrate that multimodal, embodied resources are important ways teachers organize participation and the co-construction of classroom knowledge, and that representational gestures, in particular, are an important pedagogical resource in STEM classrooms. Our study extends current work by closely examining how teachers use the *temporality* of representational gestures in whole-class interactions.

3. Gesture holds

Representational gestures often consist of several distinct phases of action. These include (a) a preparation phase where the hands rise from rest, (b) one or more strokes that carry expressive information or content, and then (c) a retraction phase where the hands return to rest (Kendon, 2004) to a home position (Sacks & Schegloff, 2002). Sometimes, however, after a stroke is completed, the hands do not return to rest immediately but freeze in position, which is known as a *post-stroke hold* (Kita, 1993). Speakers may also use gesture holds to slow down and synchronize gesture and speech (McNeill, 1992). Sometimes, holds extend outside the boundaries of an individual's turn: Speakers' holds can overlap the turns of their listeners, and listeners' holds can overlap the turns of current speakers. As a result, holds can serve a variety of distinct purposes in interaction. However, these have not been as well studied as other aspects of gesture (Park-Doob, 2010).

Notably, holds both *carry* information about the content that speakers are trying to convey and *project* information about how participation can be organized (Cibulka, 2014; Park-Doob, 2010). To manage turn-taking, participants can hold gestures to project themselves as next speaker (Mondada, 2007), to transfer a turn at speaking to another speaker (Park-Doob, 2010), or to project that they intend to resume an interrupted turn (Mondada & Oloff, 2011; Park-Doob, 2010). Holds also play a number of different roles in marking and resolving unfinished or unresolved conversational projects. With holds, participants can display problems in understanding that are not yet remedied, such as issues with the interpretation of unclear or complicated turns (Sikveland & Ogden, 2012). Holds are also used by speakers while waiting for demonstrations of understanding from listeners, such as waiting to see if a listener recognizes a referent person or place (Sidnell, 2005), or whether they will follow a directive (Lilja & Piirainen-Marsh, 2019). Holds also can preserve a speakers' turn in the face of trouble, such as during pauses or disfluencies (Park-Doob, 2010). In the case of English as a Lingua Franca, speakers use gesture holds to display word searches and recruit help from listeners in the search (Matsumoto & Canagarajah, 2020).

Holds are also frequently used to pursue responses in question asking, both in spoken and signed conversation (Cibulka, 2016; Groeber & Pochon-Berger, 2014; Kendon, 1995; Park-Doob, 2010). In Southern Italy, Kendon observed that the "hand purse" or "finger purse" gesture, held after a question, signals that a speaker expects an answer (Kendon, 1995, 2004). According to Janet Bavelas, Kendon described this phenomenon as a *"kinetically-held question"* (Cibulka, 2016). Gestures held past turn boundaries mark that there is an unfinished project requiring

another's participation, and, in the case of questions, strongly indicate the relevance of a response. The hold illustrates the pending request for information that has yet to be completed, and is often released when the response is underway.

In general, the study of holds has received somewhat less attention than other forms of embodied conduct, both in ordinary interaction and institutional settings like classrooms. Although post-stroke holds have been shown to be an important feature of question-asking in everyday interaction (Cibulka, 2016; Groeber & Pochon-Berger, 2014; Kendon, 1995; Park-Doob, 2010), the role of post-stroke holds in teacher questioning sequences has not been systematically studied to date and deserves closer empirical attention. Our analysis focuses on the multifaceted functional nature of these holds in (a) organizing participation (including pursuing a response, managing the floor, and projecting continuation or close of the sequence) and (b) sustaining visual semantic information related to the content of the question.

4. Data and methods

4.1 Setting and participants

The video corpus for this study consisted of approximately 20 hours of video of a middle school science classroom in the United States, recorded daily over two weeks. Each class period was led by the same teacher and lasted approximately 60 minutes. Three different sections of Grade 8 students were recorded, ranging in ages from 13-14 years. Each section of students contained between 15-17 students. The recordings of classroom interactions were originally collected as part of a larger project to investigate the implementation of a project-based physical sciences curriculum. In the recorded unit, the class discussed the scientific concepts of forces, motion, and energy. As part of the unit, the classroom teacher regularly engaged students in teacher-led whole-class interactions and used questioning sequences to assess students' prior knowledge, review material, and introduce new material. All participants' names have been omitted, and participants' images have been digitally sketched to obscure their likeness.

4.2 Analysis

Our analysis of teachers' representational gesture post-stroke holds originally emerged from a broader, unmotivated analysis (Peräkylä, 2004) of multimodal interaction during whole-class interactions. During whole-class interaction, the teacher frequently "froze" representational gestures in Initiation-Response-Feedback (IRF) sequences, making this a 'perspicuous settings' (Garfinkel, 2002) for studying the role post-stroke holds can play in whole-classroom discussions. In the corpus, we identified 31 instances of the teacher using representational gesture post-stroke holds during IRF sequences.

In our analysis, we sought to understand how *post-stroke representational gesture holds* are deployed during IRF questioning sequences, and how they are coordinated with other multimodal resources. We use Kendon's gesture anatomy to identify and characterize in fine detail how post-stroke holds unfold in IRF sequences as one of the key multimodal resources teachers rely on. Our approach to the microanalysis of these sequences of embodied interaction (Goodwin, 2000; Streeck et al., 2011) comes from ethnomethodology and conversation analysis (EMCA; Garfinkel, 2002; Mondada, 2012), which focuses on unearthing how participants mobilize and coordinate diverse multimodal, semiotic resources in interaction (Goodwin, 2000).

We used the software ELAN (Lausberg & Sloetjes, 2009) to conduct our multimodal microanalysis, so we could carefully map out frame-by-frame how sequential and simultaneous interactional resources unfold over time, and when they co-occur. Our microanalysis highlights the temporality of each representational gesture, including its preparation, stroke(s), the duration of the holds, and the retraction. We also indicate how each hold is coordinated with other embodied semiotic resources and activities – both of the teacher and of other participants – and how the hold is situated in the broader interactional sequence. In this paper, we illustrate three representative cases of teachers' use of post-stroke holds occurring during IRF sequences in whole-class discussion to demonstrate how they illustrate questions and organize participation within (a) a single IRF sequence where an adequate response is supplied, (b) a topically-related set of IRF sequences, and (c) an expanded reformulated IRF sequence when inadequate responses are provided by students.

Our transcripts draw on conversation analysis conventions developed by Jefferson (2004) and conventions for annotating and illustrating embodied activity developed by Mondada (2014) and Goodwin (2018). We also enrich these conventions by including conventions from Kendon (2004) to annotate preparation, strokes, post-stroke holds, and retractions for the focal representational gestures. This added level of detail allowed us to more clearly demonstrate how each part of the gesture, including the hold, was coordinated with other embodied semiotic resources: Symbol sequences are shown below the speech, aligned with co-occurring syllables and other semiotic activity; preparation phases are marked with ~~~~, strokes are marked with ****, and held gestures are indicated with ****; the beginning and end of phases of gesture phrase boundaries are denoted with the | symbol. Each alternating gray box shows a set of vertically aligned co-occurring gesture phases, speech, gaze, and other semiotic resources. Within gray boxes, speech tracks are also aligned horizontally to show sequential turns. For focal gesture phases, left and right hands are marked independently in red and green (inspired by nautical conventions for lights on starboard and port sides of boats); all other gesture phases are marked in blue. Speech is marked in black, and other embodied activity is marked in gray. A complete list of all transcript conventions appears in the Appendix.

5. Findings

In our findings, we present three examples of post-stroke hold usage by the teacher during IRF sequences in whole-class discussion. Our analysis demonstrates that teachers' use of representational gesture holds serves multiple functions, allowing teachers (a) to organize and manage multi-party participation over the course of the sequence, including mobilizing a response, preserving the floor for responders, and marking the responses as sufficient or insufficient; and (b) to provide sustained visuospatial information related to the question that is preserved during the sequence, contributing to the co-construction of classroom knowledge.

Our first case illustrates post-stroke holds held across a first and second pair part in a single IRF sequence where an adequate response is given (Extract 1. "Pop!"). The second case we examine illustrates the use of post-stroke holds in an extended topically related set of IRF sequences (Extract 2. "Direct"). And our last example provides a case of a post-stroke hold held during an extended IRF sequence where inadequate responses are given and the questions are reformulated (Extract 3. "You"). In each case, we examine how the post-stroke hold(s) function (a) to organize multi-party participation in the sequence(s), and (b) to sustain imagery related to the question.

5.1 Extract 1. "Pop!" – Representational gesture post-stroke holds in an IRF sequence

Our first extract provides an example of how a teacher can use post-stroke holds during an IRF sequence to both manage participation and provide a durable illustration of the question. This extract contains an IRF sequence in which two extended post-stroke holds are used, each beginning during the teacher's initiation and persisting until just after students respond.

Prior to the beginning of Extract 1, the teacher is leading the class through an analysis of the ways in which energy is transferred and transformed in a cartoon image of a Rube Goldberg machine. Rube Goldberg machines are often comically complex, featuring a series of many interconnected, dynamic steps to carry out a simple task. In this case, the "machine" is an alarm clock, and the final steps of the sequence consist of water being poured into a bucket on a scale, which then tips the scale, and raises a dart into position so that it pops a balloon to wake a sleeping man. Together, the class is examining the cartoon and decomposing the complicated "machine" into its constituent parts and processes. At each point along the sequence of processes, the teacher guides the class in identifying what changes have taken place to help them recognize how energy is involved in each step. When the extract begins, the teacher is working to help the students describe the changes in the very last step of the "alarm clock:" when the dart is raised and pops the balloon.

```
01 tchgaze: >>looking at left side of room-->
02 TEACHER: So it GO::es from+ the  +MO:vement of
03 tchgaze:                --->+pivots+@center of room-->
04 tgestrh: |~~~~~~~~~~~~~~~~~~~~~~~~|************
                          rP1                rS1
05           the ↑dart (.....:0.3:.....) to: +what  +>do we see as a<
06 tchgaze:                                    --->+pivots+@right-->
07 tgestlh:              |~~~~~~~~~~~~~~~~~~~~~~|************************
                                    lP1                      lS1a
08 tgestrh: |************************************************************
                                  rH1-3.1
09           cha::nge or m+aybe hear a+s a change.
10 tchgaze:             --->+pivots left+@left-->
11 tgestlh: *********|************************|
                lS1a               lS1b
12 tgestrh: ***************************************
                          rH1-1.7
13           (...................+.:1.0:.+...................)
14 tchgaze:                  --->+pivots+@far left-->
15 tgestlh: |************************************************
                                  lH1-1.0
16 tgestrh: ************************************************
                                  rH1-1.0
17 STUDEN1: The ┌+balloon pops
18 STUDEN2:     └+Balloon  pop
19 tchgaze:   --->+pivots right-->
20 tgestlh: ******************
                  lH1-1.1
21 tgestrh: ******************
                  rH1-1.1
22             (.............:0.4:+.........)
23 tchgaze:                  --->+@right-->
24 tgestlh:   ******|~~~~~~~~~~~~~~~~~|
                  lH1-0.1        lP2
25 tgestrh:   ******|~~~~~~~~~~~~~~~~~|
                  rH1-0.1        rP2
26 TEACHER: POP (+.....................+:1.3:.....................) ka::y?
27 tchgaze:   --->+pivots left---------+pivots right-->
28 tgestlh:|***|*************************************************
           lS2                          lH2
29 tgestrh:|***|*************************************************
           rS2                          rH2
```

Extract 1. "Pop!"

Fig 1a. Right hand is held for a total duration of 7.0s.

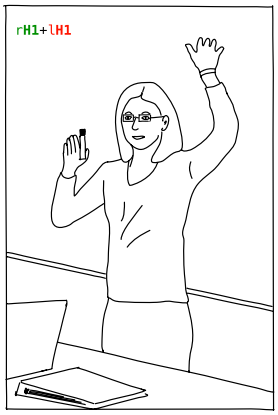

Fig 1b. Both hands are held together for a total duration of 2.2s.

The teacher asks, “So it goes from the movement of the dart to what do we see as a change or maybe hear as a change?” using a wh-interrogative (Hayano, 2012) to initiate the IRF sequence (E1.02-12). As she begins the question, she uses a representational gesture that evokes a dart being raised upwards. The stroke of this gesture consists of the teacher thrusting her arm and hand upwards at a 45-degree angle. Her hand is held flat, with her fingers rigid, depicting a sharp point (r**S1** in E1.04). As she says, “the dart” (E1.05), she freezes her raised right hand up in the air in the dart shape in a post-stroke hold (r**H1** in E1.08, as shown in **Fig. 1a**). As the teacher holds her right hand in the dart position (E1.08-25), she also involves her left hand in a second post-stroke hold during this sequence (E1.15-24): She waves her right hand in a circular motion in front of her eyes (l**S1a** in E1.07) as she says, “what do we see as a change” (E1.05, 1.09), and then waves her left hand in a circular motion around her ear (l**S1b** in E1.11), as she says, “or maybe hear as a change” (E1.09). These strokes can be seen as providing an abstract representation of a *physical indicator* – something hypothetical in the environment that a person could see or hear to detect the involvement of energy. As she finishes the question verbally, the teacher freezes her left hand in the air above her ear in a second post-stroke hold stretched above her head (l**H1** in E1.15, as shown in **Fig. 1b**). Both hands are held together, frozen (**Fig. 1b**). Throughout this initiation, the teacher uses a lighthouse gaze (Cekaite & Björk-Willén, 2018), and sweeps her gaze from the left side to the center of the room (E1.03), then to the right side of the room (E1.06), and eventually back to the left (E1.10), displaying that the question is addressed to all the students and projecting her search for a willing participant to answer (Kääntä, 2012; Mortensen, 2008).

When the question is finished, a 1.0 second silence elapses (E1.13), and the teacher keeps both hands frozen in place as she continues to scan the room (E1.14), displaying that she is still looking for a willing participant to respond, and that the floor is open to any participant to make a bid. This 1.0 second silence is recognizable as a wait time (Ingram & Elliott, 2015; Rowe, 1974), while the teacher conducts her search. Two students self-select, calling out candidate answers, overlapping each other (E1.17, 1.18). The teacher continues to hold her hands frozen in the same positions for the duration of the students’ response (E1.20, 1.21). After the students’ response, the teacher re-animates her frozen hands to provide a new, dynamic, visual illustration by rapidly opening them (l**S2** and r**S2** in E1.28, 1.29). With this gesture during her feedback turn, she evokes the image of an exploding balloon as she says “pop” (E1.26), loudly repeating the students’ word to provide a positive evaluation (Hellermann, 2003).

In total, the first post-stroke hold (r**H1**), depicting the dart with the right hand, is held for 7.0 seconds, starting during the teacher’s initiation, past the transition relevant place (TRP; Sacks et al., 1974), through the 1.0 second wait time, and through the students’ responses (E1.08-E1.25). The second post-stroke hold, which depicts energy indicators with the left hand (l**H1**), extends for 2.2 seconds, from the end of the initiation, through the wait time, and through the students’ responses (E1.15-24); thus, both hands are held together for a total of 2.2 seconds.

During this IRF sequence, the teacher’s post-stroke gesture holds have a variety of functions in the interaction. The initial *“dart”* post-stroke hold (r**H1**) supplies a durable visual reminder for the onlooking class of the premise of the question – the movement of the dart striking the balloon – and keeps this imagery available past the conclusion of the teachers’ initiation turn. It is not trivial to keep track of where they are in the complicated 12-step pictorial sequence of the Rube Goldberg machine that they are working through incrementally. By holding this visual imagery, the teacher does significant epistemic work in the interaction for onlooking students. Similarly, the second post-stroke hold (l**H1**) also does epistemic work: It

preserves the "image" that the *energy indicator* being sought is something that can be detected by the ears and "heard." As the sequence continues, the post-stroke holds – held together – represent a visual "backward oriented reference" (Cibulka, 2016) to the teachers' initiation of the sequence. This visual hint is not trivial, since sound can be challenging for learners to recognize as an indicator of energy transfers and transformations (Daane et al., 2015). When both strokes are subsequently held together, a durable visual reminder of this complicated two-part cause and effect question is presented to the students: Given the physical scenario (depicted and held with the right hand, r**H1**), what effect can they observe (depicted and held with the left hand, l**H1**) to know energy is present?

In addition to providing a visual backward oriented reference to support the co-construction of classroom knowledge, the holds also play a role in organizing multiparty participation in the IRF sequence. The temporal suspension of the gestures projects that a next course of action will be required for the resumption of movement, and it ongoingly embodies the unfinished nature of the sequence (Groeber & Pochon-Berger, 2014). In this case, the physical suspension of movement during the initiation results in a *kinetically-held question* that strongly projects the relevance of a response. Coupled with the teacher's lighthouse gaze to search for a willing participant, the hold past the transition relevant place serves to mobilize a response. The continued suspension of the gesture into the 1.0 second silence after the elicitation acts to preserve the interactional slot for students' responses, even when no bids are immediately forthcoming. The teacher's hands, suspended as they are, physically embody a wait time, making the silence hearable as an ongoing noticeable *absence of response*. When the students do respond, the hands remain frozen, signaling that the adequacy of the response is pending, and only when the hold is released into a new stroke is the adequacy of the response visibly evaluated as acceptable. Notably, the teacher does not explicitly positively evaluate the response in speech; instead, she positively evaluates it by releasing the hold to illustrate the answer given by the students, endorsing it by animating it for all in the onlooking class to see. The release, therefore, demonstrates that the unfinished project of the second-pair part has been accomplished, and the IRF sequence has been interactionally achieved and has successfully come to a close.

5.2 Extract 2. "Direct" – Representational gesture post-stroke holds in a topically related set of IRF sequences

IRF sequences often occur one after another in "topically related sets" (Mehan, 1979) that guide students step-by-step through complex, multipart lines of reasoning (Cazden, 2001; Lemke, 1990; Mehan, 1979; Wells, 1999). In our second extract, we provide an example of a representational post-stroke hold that is held through not just one but two IRF sequences in a topically related set.

The episode occurs during a whole-class discussion of Newton's Law of Universal Gravitation, which mathematically describes the gravitational interaction between two objects that have mass. The law states that the gravitational force between two objects is *directly proportional* to the product of their masses and *inversely proportional* to the square of the distance between the centers of mass of the two objects. The teacher is querying the class about what type of mathematical relationship is involved when two related quantities both increase. In this case, the larger the masses of the two objects are, the stronger the resulting force of gravity between them, which is considered a *direct* mathematical relationship.

```
01 tchgaze: >>looking at middle of room-->
02 TEACHER: A::s ma:+:ss        +goes ↑up
03 tchgaze:      -->+pivots left+@left side of room-->
04 tgestlh: |~~~|**********************|*
             lP              lS1
05 tgestrh: |~~~|************************
             rP           rH1-1.6
06          (...+...0.7+......)
07 tchgaze:  -->+pivots+
08 tgestlh: ********************
                  lH1-0.7
09 tgestrh: ********************
                  rH1-0.7
10 STUDEN1: Gra+:vity.
11 tchgaze:    +pivots right-->
12 tgestlh: **********
             lH1-0.6
13 tgestrh: **********
             rH1-0.6
14          (..0.2..)
15 tgestlh: *********
             lH1-0.2
16 tgestrh: ********|
             rH1-0.2
17 TEACHER:    +GRA:::vity   goes   up.
18 tchgaze: -->+@STUDEN1-->
19 tgestlh:    ************************
                     lH1-1.6
20 tgestrh:    |**************|********
                     rS2       rH2-0.3
21 TEACHER: So it's what type of relationship?
22 tgestlh: ***********************************
                        lH1-1.6
23 tgestrh: ***********************************
                        rH2-1.6
24            (+.....0.3...+...)
25 tchgaze: -->+pivots right+@right-->
26 tgestlh:   ********************
                     lH1-0.3
27 tgestrh:   ********************
                     rH2-0.3
28 STUDEN2: Dir┌ect
29 STUDEN3:    └DIR+ect
30 tchgaze:     -->+pivots left-->
31 tgestlh: ***********
             lH1-0.6
32 tgestrh: ***********
             rH2-0.6
33 TEACHER: A dir:+ECT. (.........1.9+........)
34 tchgaze:    -->+turns toward board+@board-->
35 tgestlh: *******|**********************|*****
            lH1-0.3          lS2             lH2
36 tgestrh: *******|**********************|*****
            rH2-0.3          lS3             rH3
37 TEACHER:    +As (..+..0.7...)+mass  +↑goes ↑up gravity goes up.
38 tchgaze: -->+pivots+@left-----+pivots+@board-->>
39 tgestlh: ******************************************************|
                                        lH2
40 tgestrh: ******************************************************|
                                        rH3
```

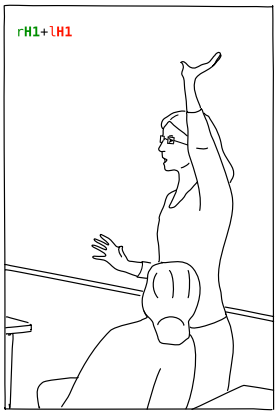

Fig 2a. Left hand is held up for a total duration of 5.9s.

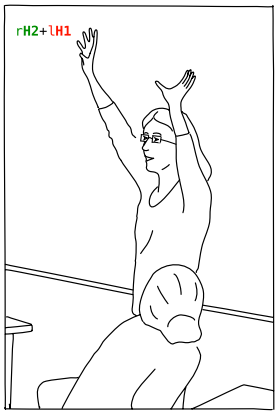

Fig 2b. Both hands are held up for a total duration of 3.1s.

Extract 2. “Direct”

The teacher initiates the first IRF sequence with a designedly incomplete utterance (Koshik, 2002; Walper et al., 2021): She says “as mass goes up” with rising intonation (E2.02) and starts to raise her left hand above her head, evoking an increasing quantity (l**S1** in E2.04), and freezes it in the air over her head (l**H1** as shown in **Fig. 2a**) as she says the word “up” (E2.02, 2.04). She also holds her right hand out at waist height (r**H1** in E2.05). She pivots her gaze from the middle of the room to the left side (E2.03), displaying an open framework for responding to the incomplete utterance. While the teacher’s right hand is still held at her waist

and her left hand is held suspended in the air over her head (l**H1** in E2.12 and r**H1** in E2.13, as shown in **Fig. 2a**), a student self-selects to provide a candidate response – "gravity" (E2.10). The teacher positively evaluates the student's response by repeating and elaborating it in speech ("gravity goes up," E2.17), emphasizing and elongating the first syllable (Hellermann, 2003). As she says this, she vertically lifts her right hand from waist height into the air parallel to her raised left hand (r**S2** in E2.20), evoking a second illustration of a quantity increasing (E2.17-20).

With both hands held frozen over her head (l**H1** in E2.22 and r**H2** in E2.23, as shown in **Fig. 2b**), the teacher then begins a topically related question with a wh-interrogative (E2.21) that is conditionally linked (Mehan, 1979) to the first IRF sequence (E2.02-20). Marking the next question's inferential connection to the first with "so" (Schiffrin, 1987), she asks "So it's what type of relationship?" (E2.21). She also uses indexical language (*it's* what type of relationship?) which ties (Sacks, 1992) this question backward to the first IRF sequence. Her suspended hands can be seen as continuing to depict two quantities that increased together.

She keeps her hands above her head through a brief period of wait time (0.3 seconds, E2.24) and pivots her gaze right across the room, displaying a second search for a willing participant (E2.24-27). A student answers, calling out "direct" (E2.28), and another student also calls out "direct," overlapping the first response (E2.29). As they answer, the teacher pivots her gaze left to look at them (E2.30), still holding her hands up frozen in the air (E2.31-32). The teacher positively evaluates the students' responses, repeating "a direct" (E2.33) with elongation, and then turns her body towards the board (E2.34; a form of body torque; Schegloff, 1998). She releases the hold to point with both hands to the equation of Newton's Law of Universal Gravitation that is written there (l**S2** in E2.35 and r**S3** in E2.36) and reiterates, "As mass goes up gravity goes up" (E2.37), continuing to point to the board (l**H2** in E2.39 and r**H3** in E2.40). The teacher's positive evaluation in speech, release of the representational gesture hold, and her body orientation towards the board (Chazal, 2015) all indicate that the topically related set is being closed down.

In Extract 2, we see that representational gesture post-stroke holds again do work to organize participation and illustrate semantic content. However, in this case, these functions are involved in coordinating not just one IRF sequence (as is the case in Extract 1), but two sequentially occurring IRF sequences that are topically linked and conditionally related. Notably, the left-handed post-stroke hold (l**H1**) is held during *six* different, consecutive turns at talk (E2.02, E2.10, E2.17-21, E2.28, E2.29, E2.33) from E2.04-35, and both hands are held together (l**H1** & r**H2**) for *four* consecutive turns (E2.17-21, E2.28, E2.29, E2.33) from E2.20-36. In total, the left-hand post-stroke hold is held raised in the air over the teacher's head for 5.9 seconds, starting during the first initiation and extending all the way into the second evaluation. Both hands are held *together* for a total of 3.1 seconds starting during the second initiation, extending through the response, and then being released during the evaluation.

The post-stroke holds in Extract 2 play a key role in illustrating the semantic content of and connection between the two IRF sequences for onlooking students. This topically-related set contains a somewhat complex line of reasoning in the form of a doubly conditional relationship: In the Newtonian Law of Universal Gravitation, if the product of the masses increases, the gravitation force increases, *and* if two quantities are related in this way, this should be called a direct relationship. The logic of this doubly conditional sequence is incrementally built through the teachers' use of held representational gestures. First, the teacher depicts how the quantities covary by showing what happens to one quantity (gravity) if another (mass) increases – by holding her left hand up, and then raising her right hand. In the second IRF sequence, the teacher

maintains both hands in the air, and uses the resulting Gestalt to illustrate what a direct relationship is. The imagery of the second scenario (the direct relationship) is dependent on the imagery of the first scenario (left and right increasing together). The teacher builds on the first hold to create the second hold, embodying the doubly conditional relationship since the second hold could not exist without the first. Maintaining the gesture holds signals to students that the imagery they depict remains relevant throughout both IRF sequences. The teacher's gestures provide a stable, spatial image for an abstract mathematical relationship. This case demonstrates how post-stroke holds can semantically build cohesion through a two-step logical explanation in a topically related set of IRF sequences.

The post-stroke holds in this Extract also help to organize participation in the two-part extended IRF sequence. They contribute to pursuing a response from students, holding open response slots for them, and signaling when the two conditionally related answers were adequately provided, and the class could move on to the next topic. The post-stroke holds play a key role in helping the teacher mobilize a response from students for both sets of the IRF sequences. The first post-stroke hold helps make the designedly incomplete utterance of the first initiation recognizable as unfinished and requiring action from students. It is treated as incomplete by the student who produces a candidate response. However, unlike in Extract 1, the teacher does not release the hold after the student's response to mark the sequence as complete, projecting there is more to come. The teacher continues to hold her left hand in the air and raises her right hand. Both hands held in the air together signal that the interactional sequence will not terminate after the third-turn evaluation, and that instead, there is remaining unfinished interactional work requiring continued participation from the students. In this respect, the hold plays an important role as part of the non-minimal post expansion (Schegloff, 2007) accomplished by the teacher as she asks the second, topically-related question in this extended sequence. The students orient to the unfinished project by supplying responses after the second initiation. Only during the teacher's evaluation in the second IRF sequence is the hold released, creating a sequence-closing third (Schegloff, 2007), and marking the boundary of this extended topically related set (Mehan, 1979).

5.3 Extract 3. "You" – Representational gesture post-stroke holds in an expanded set of reformulated IRF sequences

Our third extract provides an example of a representational gesture post-stroke hold that is held through a series of IRF sequences where the initiations are reformulated after the student responses are treated as inadequate. The hold persists across several turns until an adequate response is given and positively evaluated. When the extract begins, the teacher is guiding the class through a discussion of indicators of energy and how a change in motion indicates the involvement of kinetic energy. To discuss this concept, she asks the students to recall a project they recently completed, where they built and experimented with wooden cars. The students had been tasked with designing "coaster cars" that coast as far and straight as possible.

```
01 tchgaze: >>looking at right side of room-->
02 TEACHER: We didn't have bra::kes, but what were the +brakes of  +
03 tchgaze:                                              -->+pivots left+
04 tgestrh:                        |~~~~~~~~~~~~~~~~~~~~~~~~~~|**********
                                                rP                rS1
05 TEACHER: +our coaster car til we +were ready ┌+for it to go.
06 tchgaze: +@middle of room--------+pivots left +@Student1-->
07 tgestrh: ******|**************************** | **************
             rS1                          rH1-1.6
08 STUDEN1:                                     └+Friction.
09          (...0.4...+..0.3..)
10 tchgaze:         -->+pivots right-->
11 tgestrh: ********************
                  rH1-0.7
12 TEACHER: Uh:+:::+ (.) ∞n-              ∞+(.....0.5.....)
13 tchgaze: -->+@rh+pivots left-----------+@Student1-->
14 tchnod:                ∞slight side-nod∞
15 tgestrh: ************************************************
                                rH1-1.4
16          ∞kin+da          ∞+so::rta       ∞(.....0.5.....)
17 tchgaze:  -->+pivots right+@Student2 @center-->
18 tchnod:  ∞slight side-nod∞slight side-nod∞
19 tgestlh:                        |~~~~~~~~~~~~|***|**********
                                      lP       lS    lH-0.4
20 tgestrh: ************************************************
                                rH1-1.6
21 TEACHER: >W:+:hat  +did we< do:: bef+or::e +(.....0.6.....) TCH
22 tchgaze: -->+pivots+@Student1--------+pivots+@rh-->
23 tgestlh: **********************************|-.-.-.-.-.-.-.-.-.-.-.-
                                lH-2.1                          lR
24 tgestrh: ************************************************|***|
                                      rH1-2.7                   rS1'
25          (.............1.6.............)
26 tgestlh: |-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
                              lR
27 tgestrh: |*********************************
                           rH1'-1.6
28 TEACHER:   ¤+Who were the br+a:kes    +of your coaster+car.
29 tchgaze: -->+pivots up/left-+@Student2+pivots left-----+@Student1-->
30 tchface:   ¤slight smile-->
31 tgestlh: .-.-.-.-.-.-.-.-.-|
                        lR
32 tgestrh: ************************************************
                                rH1'-1.6
33          (..0.2..)
34 tgestrh: ********
            rH1'-0.2
35 STUDEN1: ┌U::+s=          +
36 STUDEN2: └You+
37 tchgaze:     +pivots right+
38 tgestrh: ******************|
                 rH1'-0.4
39 TEACHER: +∞=You    ∞¤ (.........0.7.........) ka(h)y+(h)*? +.hhh¤
40 tchgaze: +@Student2-------------------------------+pivots+@right-->>
41 tchnod:   ∞down nod∞
42 tchface:          -->¤broad smile-------------------------------¤
43 tgestrh: |*********|*****************************************|
                rS2                        rH2
```

Extract 3. “You”

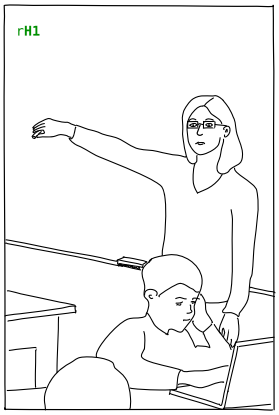

Fig 3a. Right hand is held with fingers pinched for a total duration of 8.0s.

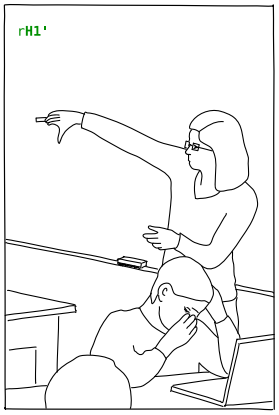

Fig 3b. Right hand is held with fingers stretched for a total duration of 3.8s.

At the start of Extract 3, the teacher reminds the students about the setup of an experiment they performed where the car was released from the top of a ramp. She asks, “We didn’t have brakes, but what were the brakes of our coaster car til we were ready for it to go?” (E3.02, 3.05) using a wh-interrogative. As the teacher says, “the brakes” (E3.02), she sweeps her hand backwards and upwards while holding her thumb and forefinger pinched together positioned apart about 2 cm, as if dragging an invisible coaster car up the invisible ramp (r**S1** in E3.04, 3.07). When she says, “coaster car” (E3.05), she begins a prolonged post-stroke hold: She keeps her arm raised and outstretched, holding her hand at head height. Her fingers remain

pinched, slightly spaced apart, as if she is grasping the coaster car perched at the top of the ramp (r**H1** in E3.07, as shown in **Fig. 3a**). During the initiation, she scans the room (E3.03, 3.06), displaying her search for a willing participant, and opening the participation framework.

Overlapping with the end of the teacher's question, a student calls out a candidate response, "friction" (E3.08). The teacher briefly looks toward the responding student (E3.06) and then looks back out at the room (E3.10) during a brief 0.7 second pause (E3.09), signaling trouble with the response (Park, 2015; Petitjean & González-Martínez, 2015). Then, she begins an ambiguous but somewhat negative evaluation: She uses "uh" (E3.12) to signal a delay, tilts her head to the side (E3.14), and takes a short pause (E3.12), projecting a forthcoming dispreferred action (Pomerantz, 1985). She provides an ambiguous assessment in speech with hedging language, "kinda, sorta" (E3.16), and briefly tilts her head to the side again (E3.18). Together, these displays, coupled with the continuously held gesture, treat the response of "friction" as inadequate.

During a brief pause, the teacher holds a point out to the class (Duran & Jacknick, 2020) with her left hand (l**S** and l**H** in E3.19-23). Still holding her right arm outstretched (r**H1** in E3.24), the teacher reformulates the original question, making it more explicit (Macbeth, 2004; Mehan, 1979): She asks, "what did we do before-" (E3.21), pivoting her gaze (E3.22), displaying an open participation framework for new candidate responses. Then, the teacher fills in the incomplete utterance with a change in the shape of her right hand, opening her fingers as if letting go of the imaginary car (r**S1'** in E3.24). As she does this, she makes a clicking noise (E3.21) and looks at her open hand (E3.22) while keeping her right arm held outstretched. In doing so, she uses an embodied completion (Mori & Hayashi, 2006; Sert, 2015) to finish a designedly incomplete utterance. Thus, the reformulated initiation is, "what did we do before [*we released the car*]." She keeps her right arm held outstretched, now with thumb and forefinger widened (r**H1'** in E3.27, as shown in **Fig. 3b**), through a 1.6 second pause (E3.25), but no student makes a bid to respond.

The teacher then reformulates the initiation again, asking a third version of the question: "Who were the brakes of your coaster car?" (E3.28). As she does this, she continues to hold her arm out with her fingers spaced apart (r**H1'** in E3.32) and shifts her gaze away from her fingers and out at the class (E3.29). Two students self-select, calling out "us" (E3.35) and "you" (E3.36) in overlapping turns. The teacher repeats the response "you" (E3.39) and releases the hold, flipping both her palms up and outwards (r**S2** in E3.43).

The right-handed post-stroke hold in Extract 3 plays a role in organizing participation in the extended sequence and also provides useful semantic information to help students answer this somewhat difficult question. In this case, we see how the hold functions in the case of two problematic responses by students (one inadequate, one non-response) and two resulting reformulations of initiations by the teacher to help resolve the trouble. Altogether, the teacher's right arm is held outstretched for a total of 11.8 seconds and through three separate initiations – the original question (E3.02/E3.05), and the two reformulated questions (E3.21, E3.28) – as well as through all three student response slots – one inadequate response (E3.08), one non-response silence (E3.25), and one pair of overlapping adequate responses (E3.35, 3.36). In total, the hold persists through eight turns (E3.02/E3.05, E3.08, E3.12, E3.21, E3.25, E3.28, E3.35, E3.36).

The teacher's held representational gesture pantomimes (Kendon, 2000) the act of holding the coaster car at the top of the ramp, and thus embodies the response the teacher is seeking: The "brakes" of the coaster car were provided by the person holding the car. This is a somewhat challenging question because the brakes of the car were not actually part of the car.

The experimental setup – including the coaster cars themselves – had a number of potentially relevant features that students could consider. Thus the gesture highlights (Goodwin, 1994) the salient aspect of the experimental environment (the person holding the car) and provides the information needed to answer the question. As the teacher continues to hold her arm through each subsequent reformulation of the question, she provides a consistent, durable reminder that helps to cohesively link together the consecutively rephrased questions throughout the extended sequence. This provides an opportunity for students to recognize that the teacher is still asking for the same information, although she changes her wording. In addition, by consistently holding her arm out, the teacher is also able to change her handshape (opening her pinched fingers as if releasing the car, and thus releasing "the brakes") to provide an upgraded, more explicit hint after the first inadequate response, to scaffold students' further responses.

Similar to Extracts 1 and 2, the hold in Extract 3 also does significant work to organize multiparty participation during this interaction. Like Extract 2, the hold is part of pursuing a number of responses in the extended sequence, preserving these slots to respond, and marking the sequence as incomplete, and later resolved. However, in the case of Extract 3, the sequence is extended not because of a topically related set but because the first student's candidate response is treated as problematic by the teacher. The teacher's hold plays a key role in rendering the response as problematic and shows that more interactional work is required to resolve the trouble. While the teacher's verbal evaluation of the first student's response is ambiguous, the teacher's continued hold of the gesture projects that the sequence will continue, and that more participation will be required from students to remedy the inadequate response. When the teacher reformulates the question, the hold is once again held past the TCU in the second reformulation, making another chance to respond relevant for students, and contributing to the teacher's mobilization of additional contributions from students. Through the silence that eventually becomes a nonresponse from the students, the hold preserves the floor for 1.6 seconds for students to make a bid, in a form of embodied wait time. After the second reformulation (the third initiation), the gesture of the outstretched arm – now with a slightly modified hand shape to provide a hint – is still held, again projecting the relevance of a response from students. When two students finally provide a set of overlapping candidate responses, the hold is released, illustrating the adequacy of the responses in the third try. By releasing the gesture, the teacher signals no more responses are needed and projects the close of the extended sequence on this topic.

6. Discussion

This study contributes to a deeper understanding of how teachers can use the temporality of representational gestures in STEM classroom discourse. We examined how teachers use representational gestures in IRF sequences in whole-class discussion by taking a closer look at what Kendon called "kinetically-held questions." Our analysis demonstrates how representational gesture post-stroke holds – where teachers suspend or freeze gestures in mid-air – are used to (a) organize participation in IRF questioning sequences and (b) provide sustained visuospatial semantic information to support the classroom's co-construction of knowledge. We presented three different examples showing the role of representational post stroke holds: Extract 1 demonstrates the case in an ordinary, single 3-turn IRF sequence, Extract 2 demonstrates the case of a conditionally linked, topically related set of IRF sequences, and Extract 3 demonstrates

the case of an expanded IRF sequence where initiations are reformulated after students' inadequate responses.

With regard to organizing classroom participation, Extract 1, 2, and 3 each show how, as part of managing multi-party student participation, teachers' post-stroke holds (i) make students' responses conditionally relevant, (ii) preserve the floor during student responses, and (iii) mark answers as adequate or inadequate, projecting whether more responses will be needed and if the sequence will continue. With respect to providing semantic information about the topic under consideration to support the co-construction of the classroom's knowledge, post-stroke holds (i) provide durable, visuospatial hints to support students' responses, and (ii) also provide helpful persistent linkages to cohere expanded questioning sequences (such as in the case of conditional follow-up questions that guide students through a chain of reasoning [as shown in Extract 2] or a series of reformulated questions needed to remedy missing or inadequate responses [as shown in Extract 3]). We also note the interesting effect that teachers' use of representational post-stroke holds is "Janus-faced" (Goodwin, 2018): Post-stroke gesture holds make reference backwards (Cibulka, 2016), while simultaneously projecting forward to organize action to come.

Our work contributes to a growing area of EMCA-based studies investigating the embodied instructional resources teachers use to orchestrate classroom discussions (Hall & Looney, 2019; Sert, 2015). We support and extend the findings of other studies that have shown how different embodied resources – such as silences (e.g., Rowe, 1974), pointing (e.g., Walper et al., 2021), interacting with artifacts (Chazal, 2015; Kääntä, 2012), prosody (Duran & Jacknick, 2020), and gaze (Mortensen, 2008) – can all be used as tools by teachers to pursue student responses, mark responses as adequate, and project if further participation is needed. An affordance of embodied resources like post-stroke holds as a pedagogical turn management tool, is that they can be silently sustained concurrently with other parties' talk and can provide ongoing information and assessment through different speakers' turns, projecting next actions. Notably, our analysis also shows that how teachers use representational gesture temporally is interactively and responsively shaped by students in these interactions. In particular, the duration of the representational gesture post-stroke hold is often ongoingly determined by how students respond (e.g., whether responses are treated as adequate, inadequate, or absent). Thus, we join others (e.g., Pozzer-Ardenghi & Roth, 2007) in arguing that teachers' use of representational gestures for instruction is an interactional achievement and never purely monologic.

We also extend knowledge of how STEM teachers use representational gestures in classroom discourse by contributing a close examination of how the timing and temporality of representational gestures can provide hints and cohere topics in questioning sequences. In this study, held representational gestures were used to illustrate complex, abstract topics like indicators of energy, mathematical relationships in equations, and experimental set-ups to make them more accessible to onlooking students. A particular strength of representational gestures is their ability to also provide visual semantic information and cohere longer sequences of turns together. In particular, we build on and draw parallels with previous instructional studies of representational gesture that have examined the important role of catchments (repeated gestures) in instructional dialogue for cohering complex STEM explanations (Nathan & Alibali, 2011). Like catchments, representational post-stroke holds are able to offer consistent visual linkages across topics and themes under consideration, however, instead of re-occurring, they are sustained through time. The holds we explored also challenge the view that representational gestures should be considered mostly short-lived and transient in interaction. While a number of scholars have emphasized the ephemeral role gestures play as interactional resources (e.g.,

Haviland, 2006; Roth, 2000), our study demonstrates that instructional representational gestures can be persistent and create stable images that are kinesthetically paused for pedagogical benefit.

We also add to the literature on gesture studies to illustrate how – at least in the institutional context of classroom discourse – representational gesture post-stroke holds are sometimes held across a much larger number of turns than has often been observed in the literature on ordinary talk-in-interaction. Many cases in the extant literature show holds that extend across TCUs into second or third turns until a pending action is completed (e.g., recognizing a referent, searching for a word; Matsumoto & Canagarajah, 2020; Sidnell, 2005). In our analysis, we found cases of holds being released in the third, evaluation turn during "ordinary" 3-turn IRF sequences. However, in this special institutional interactional context, we also found that representational gesture post-stroke holds were held for many more than three turns – sometimes up to *eight* turns – through extended IRF sequences. This occurred in cases of topically related sets of IRF sequences where a sequence of conditionally linked questions were asked. It also occurred in IRF sequences that were extended with repeated or reformulated questions when students demonstrated problems in understanding and initially provided inadequate or no response (e.g., Extract 3).

We also contribute *methodologically* to the EMCA literature by developing a novel transcription approach that combines embodied annotation strategies from Goodwin, Mondada, and Kendon, along with a color-coding system for focal gesture phases and handedness. The use of color-coding in Kendon's gesture phase annotation, coupled with the Mondadian and Goodwinian systems, provides a level of granularity that allows us to map the moment-by-moment sequential unfolding of the gesture phases, and how this co-occurs simultaneously with speech, gaze direction, different turns at talk, and other forms of embodied activity. We follow Goodwin's assertion that some of the most fundamental interactional practices occur simultaneously, not just sequentially (Goodwin, 2018). Primarily sequential analyses and transcriptions of pedagogical interactions can overlook some of the ways the body is deployed simultaneously as an ever-present locus of meaning in interaction (Goodwin, 2000).

In instruction, the skilful use of representational gesture post-stroke holds to orchestrate participation and knowledge construction in questioning sequences could be considered a form of teachers' *classroom interactional competence* (Walsh, 2013). In this study, the teacher skilfully uses post-stroke holds to shape the ongoing interaction to create opportunities for learning. While educators are frequently encouraged to engage students with multiple forms of representations (e.g., diagrams, videos, graphs, physical models) in STEM education (e.g., Ainsworth, 2006; Treagust, 2008), the use of gesture to shape interactions is rarely an explicit focus. Despite gesture's well-documented importance in STEM education (Alibali & Nathan, 2012; Roth, 2001), there is still very little emphasis in teacher education on how to use representational gesture effectively to achieve various pedagogical functions. Bringing more attention, awareness, and intentionality to how teachers use the timing of their representational gestures could become an important part of expanding teachers' repertoire of *embodied* classroom interactional competence.

One limitation of our current study is that we have only focused on representational gesture post-stroke holds in the context of whole-class interaction IRF sequences, and our analysis has not been exhaustive of the practice in other forms of classroom discourse. However, we suspect that teachers use post-stroke holds in a variety of interactional contexts for additional instructional purposes that we have not examined here. Future research could continue to examine forms and functions of post-stroke holds in instructional practice, as well as other

related temporal uses of representational gestures. Another limitation is that we cannot determine from this study if teachers' use of representational gesture post-stroke holds impacts how students learn over time. Future research could investigate whether classroom discourse with more instructional post-stroke holds has positive impacts on students' longitudinal learning outcomes. The use of representational gesture holds in instruction remains understudied, and we hope to inspire more investigation in this area.

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Appendix: Transcript Conventions

Symbol/Sample	Description
[So he was [Wait what	Bracket denotes overlapping talk
Does=	Equals indicates latching: one utterance follows the other unusually quickly
(...2.5...)	A number in parentheses, surrounded by periods, indicates a pause in speech, measured in seconds
. or ↓	Period or down arrow indicates falling pitch (punctuation *not* used grammatically)
? or ↑	Question mark or up arrow indicates rising pitch
,	Comma indicates slight falling pitch
if this-	Dash indicates cut off, abrupt stop, or unfinished words
<not yet>	A less-than and more-than symbol indicate slower or drawn-out speech
>hey you<	A more-than and less-than symbol indicate rushed or quickly spoken speech
°maybe°	Degree signs indicate quiet speech or whisper
TAKE IT BACK	Capitals denote loud speech, shouting
Take it now	Underline denotes emphasis (voiced stress)
So::o	Colons indicate elongated words or syllables
.hhh	Period and three h's indicate laughter
(h)	h in parentheses denotes laughter sounds within words
+pivots+	Plus signs denote teacher gaze actions and direction; synchronized with corresponding stretches of talk or pause time indications
¤smiles¤	Currency signs denote teacher facial actions; they are synchronized with corresponding stretches of talk or time indications
∞nods∞	Infinity signs denote teacher nodding; they are synchronized with corresponding stretches of talk or time indications
----	Multiple dashes indicate described embodied action continues
+--> --->+	The action described continues across subsequent lines until the same symbol is reached
>>	The action described begins before the extract's beginning
-->>	The action described continues after the extract's end
_gaze	Annotation of gaze action and direction for identified participant (identified by first initial, e.g., *tgaze* for teacher's gaze)
_face	Annotation of facial actions and expression for identified participant (identified by first initial, e.g., *tface* for teacher's face)
_nod	Annotation of nods for identified participant (identified by first initial, e.g., *tnod* for teacher's nodding)
tgestlh tgestrh	Annotation of teacher's left hand and right hand gestures, respectively
~~ lP	Gesture preparation phase is marked with tilde symbols l in label stands for left hand, P stands for Preparation
**** rS1	Gesture stroke phase is marked with asterisks r in label stands for right hand, S stands for Stroke, 1 denotes the first gesture stroke phase for the right hand in this extract
**** lH2	Gesture hold phase is marked with underlined asterisks l in label stands for left hand, H stands for Hold, 2 denotes the second gesture hold phase for the left hand in this extract
******* lH1-1.0	Gesture hold annotations in red denote focal gesture hold l denotes left hand, H1 denotes first gesture hold for left hand in extract, 1.0 indicates duration of hold on transcript line in seconds
******* rH1-0.8	Gesture hold annotations in green denote focal gesture hold r denotes right hand, H1 denotes first gesture hold for right hand in extract, 0.8 indicates duration of hold on transcript line in seconds
.-.- lR	Gesture retraction phase is marked with alternating period and dash
|***|	Vertical lines denote boundaries of gesture phases
'	Prime on stroke or hold annotation denotes a change in hand shape