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Gestures, systemic functional linguistics and mathematics education

Danyal Farsani ^{a,b}, Troels Lange^c, and Tamsin Meaney ^c

^aUniversidad Finis Terrae; ^bNorwegian University of Science and Technology; ^cWestern Norway University of Applied Sciences

ABSTRACT

Gestures have been shown to reflect speakers' embodied thinking about mathematical concepts and play a role in conveying understandings in teaching/learning interactions. However little research has been done to consider the similarities and differences in the functions that a particular gesture might have in mathematics classrooms in different parts of the world. In this paper, the occurrence of a metaphorical gesture to do with addition in a bilingual mathematics classroom in the UK and two Spanish-speaking classrooms in Chile is investigated. To do this, we elaborate on Systemic Functional Linguistics to consider how the gesture is integrated with other modes of communication to reflect the immediate context of situation as well as a wider mathematics education context of culture. An analysis of the interactions in three classrooms illustrates how the gesture seemed to convey extra meanings, sometimes complementary and sometimes contradictory, to what was expressed through other modes. Besides adding meaning to the mathematical ideas conveyed verbally, the gesture could potentially convey meanings to participants in the interactions about interpersonal relationships which were not as evident in the verbal communication.

Introduction

Unexpected things sometimes happen in the course of conducting research. In our case, the same gesture appeared in three lessons on different mathematical topics in different parts of the world. This made us ponder whether the gesture fulfilled the same function within the different interactions, and as such was part of a wider school mathematics culture, permeating classrooms worldwide. Although gestures in mathematics education have received considerable attention (Sfard, 2009), much of that work has focused on how gestures arise in communication events in specific classroom situations (Simpson & Cole, 2015) and not on how they might arise cross-culturally. Part of the reason for a lack of research on cross-cultural situations may be because of a lack of analytical tools for identifying the function of the gesture within both the immediate interaction and the wider social situation. In this article, we elaborate on Halliday's Systemic Functional Linguistics (SFL) to compare the functions that this gesture played in interactions in different contexts.

McNeill (1992) described gestures as primarily movements of the hands and arms which always accompany speech and that "speech and gesture are elements of a single integrated process of utterance formation in which there is a synthesis of opposite modes of thought" (p. 35). Although McNeill (2005) considered speech and gestures to be part of the same meaning-making process, neither should be seen as exact representations of a meaning. Rather, an interpreter of a gesture or speech interprets and responds

to what they see and hear based on their previous experiences and understanding. As meanings are produced as they are being conveyed, they will not exactly represent the producer's initial understandings, nor what the interpreter will take as meanings.

The role of gestures in mathematics education has been acknowledged for some time, with research focusing on different aspects of gestures, such as their contribution to students' visual engagement (Alibali & Nathan, 2007) and to learning specific mathematical meanings (see for example, Arzarello et al., 2009; Chen & Herbst, 2013). For example in a study in Chile, teachers' gestures increased students' visual engagement more in their mathematics lessons than in their English lessons (Farsani et al., 2021).

Alibali and Nathan (2007) observed that a teacher's use of spontaneous gestures, together with their speech, scaffolded students' gaining of understanding about mathematics. Gestures often seemed to provide additional spatial information to complement verbal information in mathematics classrooms (Williams & Ryan, 2019). By building on their multimodal resources students' mathematical terminology was increased (Arzarello et al., 2009). Such approaches are particularly useful when the instructional language is not the learners' main language (Krause & Farsani, 2021). Castellón (2007) showed how Hispanic students' gestures in mathematics classrooms in Los Angeles acted as aids to overcoming barriers to using English mathematical terms such as perpendicular. Castellón (2007) concluded that a "gesture served as a visual tool that enabled students to communicate their thought processes without being restricted to terminology such as vertical, horizontal, parallel or perpendicular" (p. 163). Thus, gestures can serve as visual resources, which help students resolve doubts about specific mathematical terms as they construct meaning (Alibali, 1999).

Nevertheless, the idea that gestures have to occur alongside verbal language has been challenged. For example, Roth (2010) described the unconscious gestures of a school child, Chris, that were incorporated into his meaning making as "immanent," or unavailable for reflection. For Roth (2010), Chris' repetition of a gesture showed a change from pre-intentional to intentional movement, which contributed to developing his understanding of a cube:

Chris's memory of the cube then is immanent to movements that experience and feel themselves and move by themselves. It is here that we have to seek/find an experience that only belongs to it, the movement. It is precisely then that we no longer have the distinction between mind and a material body – mind is the flesh itself, memory in the movement rather than in some bodily schema or representation that is used to bring the movement about. Mind does not act on the body or instructs it to do what it has to do. (p. 13)

Roth (2010) described how the unconscious movement of Chris' hands, which derived from previous handling of the cube, then contributed to the development of an understanding that was available for reflection. This is similar to how when describing an object or an event, a particular word is used unconsciously, but, once used, provides insights and new ways of understanding that object or event.

Gestures, as a mode for conveying meaning, are cultural artifacts in the same way that spoken language is a cultural artifact. In a study of three children playing with glass jars, Johansson et al. (2014) showed that, although the teacher appeared to focus on the spoken language, the children watched each other's gestures and incorporated some of them into their explanations, either by copying or adapting them. The children seemed to learn to not just interpret the meanings the gestures provided, but also adapt them to fulfill particular functions when conveying meaning to others. Although this example is from a small, local cultural context, it shows how gestures can be identified and then adapted within that culture.

Cultural contexts have an impact on the use of gestures with the frequency of gesturing and the meanings they typically convey varying across cultures (for a discussion of Arabic and Persian gestures, see, Barakat, 1973; Sparhawk, 1981), depending upon a range of factors (Núñez & Sweetser, 2006). For Radford (2008), learning involves becoming progressively conversant with the collectively and culturally constituted forms of reflection, which would include different modes of

communication, such as verbal language and gestures. Learning these forms of reflection embeds the individual within the historically-developed societal context. This happens in the entangled relationship between the individual, the collective and the forms of practice, mediated through artifacts.

In this paper, we consider how a specific gesture contributed to the production and interpretation of meaning in three different classroom interactions. To do this, we adapt Systemic Functional Linguistics (SFL; Halliday, 1978) to gain insights into whether this gesture fulfilled similar functions in the different interactions. SFL provides opportunities to consider how the local and the wider cultural context affect the potential meaning making within each interaction. The need for such an approach has been recognized earlier, with Williams (2009) arguing for “‘culture’ to be viewed as part of the learners’ embodied habitus” (p. 208) in mathematics classroom analysis.

Gestures have often been investigated using semiotic frameworks, based on the work of Peirce (see for example, Arzarello et al., 2009), that focus on signs and sign making. These frameworks offer insights into how the mathematics was highlighted in the interactions through the gestures. SFL instead focuses on semantics or how meaning is produced. Although there are some commonalities between these approaches, by adapting SFL we consider that there are greater possibilities to gain insights into how the gesture contributed to meanings, produced and interpreted, in the lessons from different parts of the world.

Metaphorical gestures and mathematics teaching and learning

We consider the gesture that appeared in the different lessons to be a metaphorical gesture. Metaphorical gestures are expected to be interpreted as being the same thing as something else – in our case a mathematical idea – even though in reality they are not the same thing. McNeill (2005) described metaphoric gestures as “images of the abstract” (p. 39) that visualize some aspect of an abstract concept through movement of the hands and arms. A cupping of the hands, for example, can represent a particular idea being held for contemplation, with the idea being positioned as an object, even if in reality this cannot be. Farsani (2015) showed that the form of metaphorical gestures connected to the mathematical concept of “power” in a bilingual class differed according to the language being used. When communicating in English, both the teacher and learners pointed with their fingers toward the superscript position of the “power” notation in English. When communicating in Persian, a clenched fist gesture conveyed a meaning related to the “powerfulness” of an exponent, indicating a link between mathematical and physical power. However, for gestures to aid the interpretation of the mathematical meanings, students need to understand the metaphors they represent.

Lakoff and Núñez (2000) suggested, “a large number of the most basic, as well as the most sophisticated, mathematical ideas are metaphorical in nature” (p. 364). As a result of the abstract nature of mathematics, teachers employ metaphors to support the meanings they want to convey (Mildenhall & Sherriff, 2018). Lakoff and Núñez (2000) identified four grounding metaphors for addition, which were summarized by Kilhamn (2009),

- Construction of objects, combining, taking away (numbers as constructed objects)
- Construction of objects, combining, decomposing (numbers as constructed objects)
- Measuring lengths, comparing (numbers as length of segments)
- Motion along a path (numbers as points on a line) (p. 18)

The “object collection” metaphor treats an amount as a collection of objects and is connected to natural numbers, where “properties of object collections are mapped by the metaphor onto properties of natural numbers in general” (Lakoff & Núñez, 2000, p. 57). For example, three fingers held up can suggest the abstract quantity “three.” Lakoff and Núñez (2000) extended or, in their words, “stretched” this metaphor, beyond natural numbers. Similarly, Alibali and Nathan (2012) identified a middle school teacher using the object collection metaphorical gesture in an algebra lesson. The teacher used

a grasping hand to produce the idea of combining abstract amounts represented by the variable “s,” indicating that an addition operation was being enacted. Although Alibali and Nathan (2012) did not discuss the stretching of the metaphor to accommodate non-discrete amounts, the description is necessary for achieving closure with regard to the addition of algebraic terms and expressions, as “the requirements of closure say that the operations of arithmetic should give determinate results for any operation on numbers” (Lakoff & Núñez, 2000, p. 92). If it is possible to stretch any of the four grounding metaphors to achieve closure, then humans are likely to do this. However, Lakoff and Núñez warned that “sometimes it is impossible to stretch in a sensible way to fit the requirements of closure and consistency reflected in the notational system” (p. 94).

The object collection metaphorical gesture appeared in our research in three different classrooms, in countries different from where Alibali and Nathan (2012) conducted their research. Two of our examples involved the metaphor being stretched beyond natural numbers. We, therefore, wondered whether the gesture appeared because the mathematics education context dominated other aspects of the situations and whether cultural differences affected the function that the gesture had in each interaction.

Systemic functional grammar

SFL provided us with a way to investigate the communicative functions fulfilled by the gesture in the interactions. SFL was developed over several decades by Michael Halliday (1985) to analyze how written and spoken texts were produced within a specific context of situation, surrounded by a context of culture (Halliday & Hasan, 1985¹). In discussing the relationship between the context of situation and the context of culture, Halliday (in Halliday & Hasan, 1985) wrote:

For any ‘text’ in school—teacher talk in the classroom, pupil’s notes or essay, passage from a textbook—there is always a context of situation; the lesson with its concept of what is to be achieved; the relationship of teacher to pupil, or textbook writer to reader; the ‘mode’ of question-and-answer, expository writing, and so on. But these in turn are instances of, and derive their meaning from, the school as an institution in the culture; the concept of education, and of educational knowledge as distinct from common sense knowledge; the notion of curriculum and of school ‘subjects’; the complex role structures of teaching staff, school principals, consultants, inspectorate, department of education, and the like; and the unspoken assumptions about learning and the place of learning within it.

All these factors constitute the context of culture, and they determine, collectively, the way the text is interpreted in its context of situation. (p. 46-47)

A text is affected by three aspects, which Halliday labeled the “field” (what is happening), the “tenor” (who is taking part and the relationship between them), and the “mode” (the form of language that is used to convey the meaning). Each aspect affects the language choices, particularly the grammatical choices, that the communicator considers, usually unconsciously, as being appropriate for the context of situation, as part of the context of culture (see, Figure 1, from Meaney, 2005).

In Figure 1, the bubbles to the sides of the field, tenor, and mode aspects provide examples of the grammatical features that inform the meanings conveyed in the text. For example, meanings about the field are informed by what is named and how actions affect the participants, both human and non-human – known as transitivity. In mathematics, actions are often incorporated into nouns or noun phrases and provide information about what is happening, making them part of the field (Meaney, 2005). Halliday (2004) described this process as nominalization. Meaney (2005) gave examples of nominalizations, “‘derivative,’ ‘x squared’ and ‘three x’ belong to this category, in that there is a shift in meaning” (p. 121). Nominalizations are what Halliday described as ideational metaphors, because when an action becomes an object, there is a shift in meaning (Butt et al., 2000). Verbs such as “equals,” which Halliday called processes, describe relationships between objects rather than an action being done to those objects.

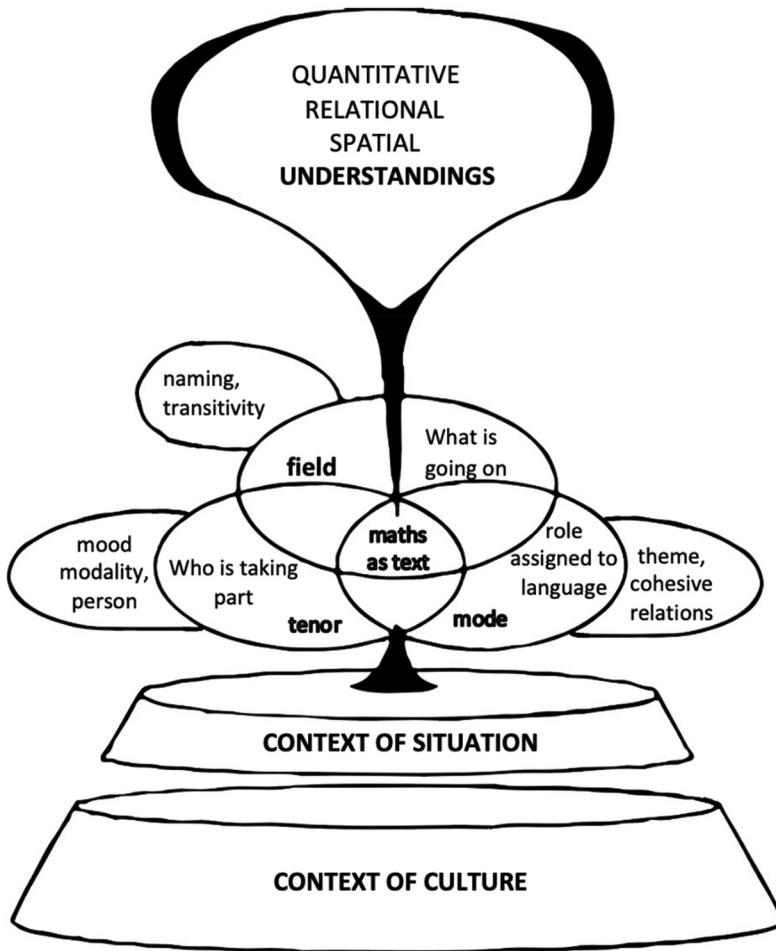


Figure 1. A model showing how language acts as a viaduct between culture and the development of mathematical understanding. (from Meaney, 2005).

Nevertheless, the context of culture does not just influence the context of situation, as the context of situation can also affect the context of culture. Gee (2005) described the relationship between language and situation as the “chicken and egg” question:

Language has a magical property: when we speak or write, we design what we have to say to fit the situation in which we are communicating. But, at the same time, how we speak or write creates that very situation. It seems, then, that we fit our language to a situation that our language, in turn, helps to create in the first place.

This is rather like the “chicken and egg” question: which comes first—the situation we’re in, e.g., a committee meeting, or the language we use, e.g., our committee ways of talking and interacting? Is this a “committee meeting” *because* we are speaking and acting this way, or are we speaking and acting this way *because* this is a committee meeting? After all, if we did not speak and act in certain ways, committees could not exist; but then, if institutions, committees, and committee meetings didn’t already exist, speaking and acting this way would be nonsense. (p. 10; italics in original.)

The context of situation of a particular mathematics lesson is supported by the ways that ideas are usually discussed within that classroom, which, in turn, are affected by wider societal expectations about what happens within mathematics lessons. At the same time, using these ways to discuss particular ideas reinforces the context of situation as being a mathematics lesson. For example, the

switch to virtual mathematics lessons in 2020 may have a long-term impact on how ideas are discussed in a mathematics lesson. Yet, the fact that these virtual lessons are mathematics lessons also contribute to what might be considered appropriate in the virtual interactions.

There is, therefore, a bidirectional relationship between gestures and culture – one that supports both the production and interpretation of mathematical meanings in classrooms and the production and interpretation of what is a mathematics lesson. A mathematics lesson, as a context of situation, is affected by the typical ways in which mathematics is described in spoken and written language and in gestures. At the same time, it is also affected by the typical context of culture, such as how teacher and students' relationships are enacted within formal school settings at a particular moment in time and in a particular society. Cultural contexts in which mathematics lessons take place are influenced by national curricula, making them, to some extent, country specific. Nevertheless, the global mathematics education culture means that there are many shared assumptions about what should occur in mathematics lessons even across different countries (see for example, Meaney, 2018). Consequently, mathematics education could be considered to have a culture of its own.

In SFL, a mode is the form of language that supports communication (Halliday, 1985). For example, a formal speech is a mode that is originally written, but with the intention of being spoken. The mode offers information about how the cohesion of a text is provided – for example, through the repetition of a name or the use of a pronoun to represent the name. Elaborating on the multimodality of texts, Kress and van Leeuwen (1996) discussed how color in magazine articles was a mode, in that it conveyed extra-linguistic information to readers, which contributed to the textual cohesion by focusing the reader's attention on the ideas being presented. Similarly, gestures are a mode:

Children use the full range of material and bodily resources available to them to make and express meaning Language is only one tool in a range of human semiosis, and . . . individuals' choices of semiotic modes are motivated by a complex web of interconnecting personal, institutional and social factors. (Flewitt, 2006, p. 46)

In the literature review of thousands of articles about mathematics classroom discourse, Herbel-Eisenmann et al. (2017) found no articles in which SFL has been used systematically to discuss gestures. Yet, SFL by showing how an interaction is affected both by the context of situation and the context of culture, has the possibility to compare whether a gesture fulfills the same function in classrooms, in different parts of the world.

In elaborating SFL, we are aware that Halliday, himself, would have been concerned about analyzing gestures. Halliday described symbolic mathematics as not being a mode, as it could not be analyzed linguistically. This was because equations, for example, could be verbalized in different ways, that while being “all equivalent mathematically, they are certainly not synonymous” (Halliday, 2003, p. 114). Nevertheless, O'Halloran (1998) adapted SFL to analyze symbolic mathematics which gave increased insights into how meaning could be conveyed through them. Similarly, in developing their understandings about multimodality, Kress and van Leeuwen (1996) adapted SFL to consider how other modes, such as color, could be analyzed for the meanings that they conveyed. Given these adaptations, we consider that SFL can be adapted so that it includes gestures.

Although gestures can be described verbally in many ways, to understand the context of situation and the context of culture of mathematics classrooms, there is a need for more than spoken and written words to be analyzed. As Williams (2009) stated, there is considerable evidence for “a sensuous, embodied and material view of the formation of mathematical objects, conceptions and imaginations” (p. 202). In this article, we use SFL to explore the roles that a specific gesture – alongside the roles of other modes such as speech and symbols – had in three different contexts of situation and their relationships to the contexts of culture. Focussing on what was occurring (field) and who was involved (tenor), we analyze how this gesture perhaps conveyed other meanings than those provided by spoken and written language.

An SFL analysis (Halliday, 1985) indicates how meaning can be expressed through metaphors in a variety of ways. Butt et al. (2000) described interpersonal grammatical metaphors as turning a direct demand – such as “Give me the book” – into a less direct, but usually considered more polite, request

for something, such as “Please may I have the book?.” In both cases, there is an expectation that the book will be handed over; but in the second case the interrogative form indicates a different relationship between participants, where the speaker may consider themselves less powerful than the listener. Lexical metaphors can be used to indicate that something is the same as something else, even if this is not possible. Butt et al. (2000) provided the example of the metaphor “the girl was a doll” being used to indicate that the girl was very small. As the girl cannot in reality be a doll, the literal meaning is incongruent with our understanding. Farsani’s (2015) example of a gesture connected to the Persian word for “power” can be considered a lexical metaphor in that it suggested that the power exponent was the same as being physically powerful, even though in reality it is not. From the perspective of SFL, the object collection metaphorical gesture can be classified as a lexical metaphor, in that the gesture suggests that addition is the same as the collecting together of objects. In reality this is not the case. Furthermore, because addition in spoken and symbolic mathematics can often be presented as a result of a process (rather than the process itself), the object collection metaphorical gesture can also take on aspects of ideational and grammatical metaphors.

Data

The data in this article originated from projects in the UK and Chile. In the different contexts of situations, the object collection metaphorical gesture, similar to that identified by Alibali and Nathan (2012), appeared, accompanied by a verbal expression to do with addition, or “joining.” There were multiple examples of this gesture in the data connected to verbal expressions about “adding,” and we focus on three to illustrate differences in how the contexts of situation were related to the contexts of culture.

One project was in a bilingual British-Iranian complementary school, where English and Persian were used (Farsani, 2015). In the UK, complementary schools run on weekends and support first- and second-generation bilingual students to learn the language associated with their heritage, in this case Persian. Complementary schools often teach subjects, such as mathematics and science, to support the work done in mainstream schools (Farsani, 2016). There were 12 students in the video-recorded lessons, with an average age of fourteen and a half. Sixteen lessons – about 12 hours’ worth of material – were recorded. One interaction from the data set is analyzed. Although there were two other instances where the teacher used the object collection gesture, the content of the lesson was different and the language of the lesson had shifted to English.

In Chile, audio-visual recordings were collected from eight state schools, with Spanish as the language of instruction. Spanish was registered as the mother tongue of all students. The video excerpts came from two schools: one from a second-grade class, with an average age of eight; and the other from a fourth-grade class, with an average age of ten. There were 34 and 32 students in each class respectively. Eight lessons were recorded at each school, lasting approximately 1 hour each.

Making decisions about what to focus on and what to include when transcribing is part of multimodal analysis. For each of the three transcribed interactions, the left-hand column provides a transcription of the spoken language while the middle column presents a snapshot from the video. The right-hand column provides additional information about the gesture.

In the examples, the motion and trajectory of the object collection gesture had two phases: an initial phase where both hands were wide open, and a second phase where both hands were brought close together in front of the speaker. Figure 2 illustrates this gesture based on the movement of the teacher in the first example.

All speech was translated into English. In the third transcript, the Chilean Spanish expression “po” has no equivalent in English. It is a colloquial deformation of the term “pues,” meaning “so” or, in a formal context, even “indeed.” In Chile, the use of “po” indicates that the speaker identifies themselves as coming from an urban environment.

The transcript conventions are the following:

T Teacher

S Student

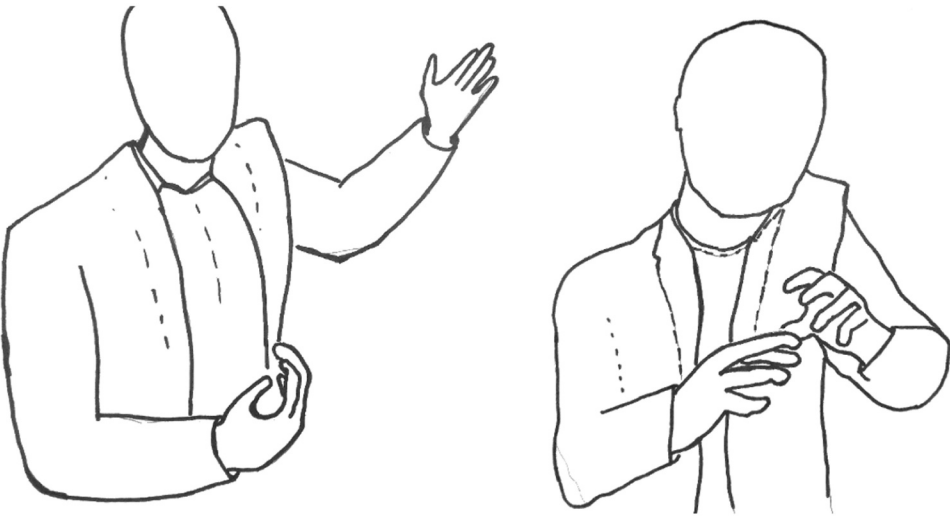


Figure 2. The object collection gesture.

[]Non-verbal communication

{Translation into English

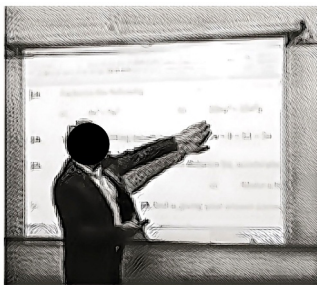
Italics Persian transliterated into Roman script

Transcript 1

The first transcription comes from a Persian-English mathematics lesson about the difference between two squares. After pointing to an example projected on the board, the classroom teacher (T1) wrote $a^2 - b^2 = (a - b)(a + b)$ and asked the students to pay attention to it.

In SFL, the field affects the language choices for expressing ideational meaning, about what is being discussed (Halliday & Hasan, 1985). In this interaction, the teacher's explicit goal was for the students to memorize how to factorize a quadratic equation. "Add up" referred to the action in the expression $(a + b)$, which in SFL is labeled a material process (Butt et al., 2000). Material processes can include information about: the actor (who is undertaking the action), the goal (what is affected by the action), the range (the limit of the action), and the beneficiary (who is affected by the action). It was not clear

T1: Alan S1, *iin dar morede in*, this one, *khob* S2, *in formula -royaddasht kardi?* {Now S1, this one, this one, OK, S2 did you make a note of this formula?}



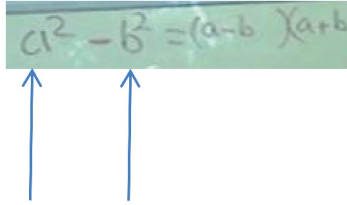
As T1 said the demonstrative pronoun *iin*, meaning "this one," he simultaneously pointed to the equation he had written on the whiteboard and tapped it twice with his left hand.

(Continued)

(Continued).

S2:*bale* {Yes}

T1:*harja do ta squares* {Wherever two squares}



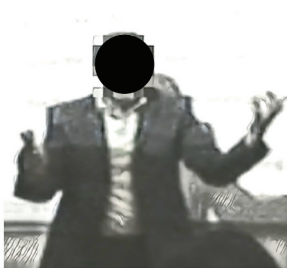
T1 used a pointing gesture with his left hand, first toward a^2 and then immediately toward b^2 , at the same time as he said "two squares." His gesture aligned with the prosody of his speech as he said "two squares."

T1:*az ham take away beshe*, {are taken away from each other,}



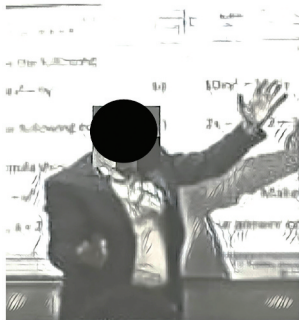
T1 put his hands close together in front of his chest and as he uttered "take-away," he moved them apart.

chimishe, {what will happen,} *Square-root*
-eshoon, {their square root,}



T1 put his hands on a and then b , which were the square roots of a^2 and b^2 , respectively.

take away, times-eshoon, {take away,
multiplied by each other}*ba ham jam*
mishe. {add up}

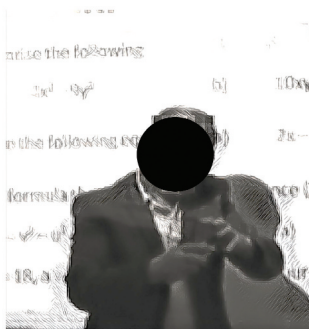


T1's hands were apart and then he moved them close together in front of his chest as he said "jam," meaning "add."

(Continued)

(Continued).

Inrobayadtooyezehnetbere {You should memorize this}



from the symbolic representation or the verbal utterances who was the actor doing the adding, although it could perhaps have been the teacher or the students. Of the other aspects of the material process, it is only possible to identify the goal of the action, which was about the role of addition in the equation.

“Add up,” along with other mathematical actions such as “take away,” were not verbalized by the teacher as actions, but as components in the algebraic expression $(a + b)(a - b)$, which was represented symbolically on the board. As such, $(a + b)$ can be considered an ideational metaphor in that there was a shift from action to object, leading to a shift in meaning (Butt et al., 2000). The symbolic representation of the equation indicated that “add up” was a component in a relational process, with the equals sign indicating the kind of relationship between the two sides of the equation. Such relational processes are common in mathematics (Meaney, 2005).

In the context of situation, the teacher’s goal, which was for the students to memorize the formula, was reflected in how the interpersonal meanings (the tenor) were expressed by the teacher through modal verbs such as “should”: “You should memorize this.” In this way, the teacher reinforced that he controlled the interaction, as students did not have the same possibilities open to them for telling the teacher what he should do. The context of situation reflected the context of culture, where in both the Persian and English classrooms, teachers were expected to determine what students did, which was reflected in the verbal language that the teacher used.

However, the gestures potentially conveyed other meanings. Many of the gestures, including the one connected to “add up,” focused on actions rather than relationships, suggesting that the gestures were acting as ideational metaphors. Although the “add up” gesture aligned with the spoken utterance, it could have provided an extra meaning by indicating, implicitly, that addition involved two variables, “a” and “b,” being put together. This gesture was related to the metaphorical gesture for subtraction, which, by including the same movements in reverse order, implicitly indicated that in $(a - b)$, “a” and “b” were being pulled apart. As part of the material process, the gesture could also have indicated that the actor was the teacher, as he was making the movement and so could be considered to be doing the addition. The gesture could have given information about the goal of the material process by implicitly showing how the items (in this case, variables) were to be brought together. The size of the movement could have indicated the range of the action, with the teacher’s hands starting far apart, before being brought together. This suggests that the magnitude of the amounts was immaterial to the operation. Although the gesture did not specifically indicate a beneficiary, the teacher, by looking straight at the students, seemed to suggest that understanding the addition process, as part of the equation, was beneficial for them.

The cohesion of the interaction provided by the “add” and “take away” gestures can be described in a number of ways. In SFL, lexical chains can be used to describe the cohesion of the text. We compare the lexical chains in this interaction with two alternative descriptions of gestural cohesion: McNeill et al.’s (2001) catchment and Arzarello et al.’s (2009) lexical bundles.

In SFL, a lexical chain contributes to the cohesion of a text, such as an interaction, by using the same or slightly altered versions of an original term to show how ideas are developed and connected (Butt et al., 2000). In the example, the teacher produced a lexical chain connected to the equation by referring to it both with pointing gestures and with words like “this formula” and “this” or “this one.” Another lexical chain was formed by reusing features of the “take away” gesture in the “add” gesture. Whereas, in their speech and symbolic representations, the algebraic expressions on both sides of the equal sign are objects, in their gestural forms the expressions $(a-b)$ and $(a + b)$ are represented as actions. The gestures contribute to the lexical chain, but can be viewed as adding extra information. The teacher explicitly requested at the end that the students memorize the equation. The combination of words, symbols, and gestures together suggests that the memorization had to include the different meanings in the formula.

McNeill et al. (2001) used the term *catchment* to describe the occurrence, “when two or more of gesture features recur in at least two (not necessarily consecutive) gestures” (p. 10). A catchment provides cohesive linkages in an interaction by visualizing the theme of the interaction. Given that the two features of the object collection gesture were combined in different ways to indicate adding and taking away, they can be considered a catchment. Yet, McNeill et al. (2001) suggested that gesture and speech develop from the same semantic intent. In the transcript, the gesture and speech are related, but, as shown in our SFL analysis, they do not convey the same meaning. The ways in which the gestures add meaning and provide cohesion are, therefore, more subtle than a catchment analysis shows.

Arzarello et al. (2009) described lexical bundles as combinations of different modes that provide coherent meanings both simultaneously and across time. In the transcript, the co-production of the spoken expression alongside the gestures indicate that they were related. A diachronic analysis shows how the individual movements connected to the “take away” gesture were transformed into the “add on” gesture. However, as was the case with a catchment, what is not captured in a lexical bundle analysis is how the gesture may have added meaning about the actor of the material process. This was different to the spoken and symbolic expressions which focused on the relationships between the parts of the equation.

In this transcript, the context of culture about how mathematics lessons should be conducted influenced the context of situation. This shaped how it was indicated to the students that the formula, written symbolically on the board and referred to by the teacher in a number of ways, needed to be memorized. The influence of the context of culture on the context of situation can be seen in the teacher’s verbal language choices, highlighting what was to be memorized. The use of the equals sign highlighted the relationship between the algebraic expressions which had been found in other mathematics lessons (Meaney, 2005). Yet, the function of the object collection gesture, stretched as was the case with Alibali and Nathan’s (2012) example to include algebraic terms, could have included other meanings, such as identifying the actor in the process.

Transcript 2

In the second example from Chile, a fourth-grade teacher (T2) placed paper stickers of different geometrical shapes on the board to form a tangram of a square (see, [Figure 3](#)). Tangrams are common in mathematics lessons around the world. In this lesson, T2 used different combinations of triangles so that the students could practice adding fractional parts. The triangles represented fractional parts of the original square which was the whole.

Although this lesson occurred in another country and was about fractions, with different aged students, the gesture seemed to fulfill a similar function to the one used by T1 in the complementary school in the UK. Yet, there were some differences. The ideational meaning of the interaction was about determining the area of the fractional parts of the square, represented by the paper triangles. T2 began by discussing the area of the figure and how it could be calculated, thus highlighting the goal of the action. Furthermore, by using “we” to indicate who was adding, restated by the students, T2 made clear the actors were the teacher and the students. In this way, the teacher also highlighted that the

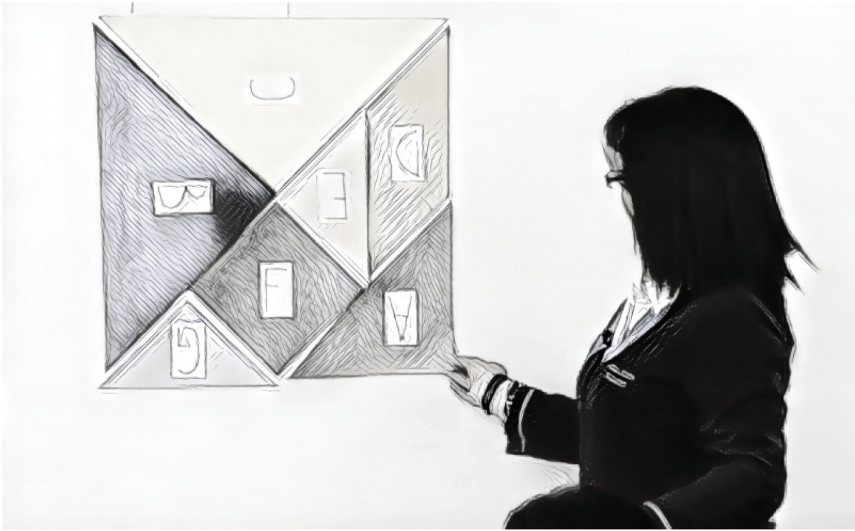
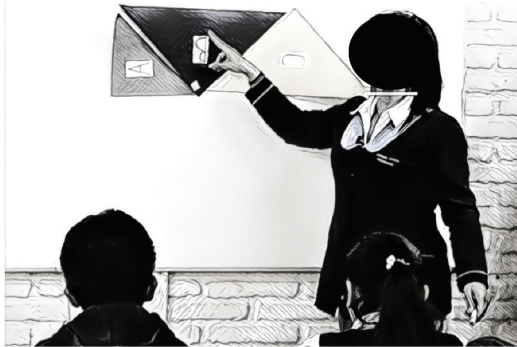


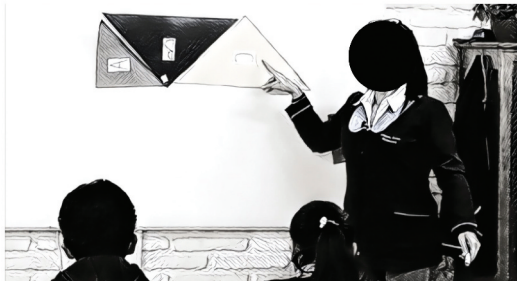
Figure 3. The tangram square.

T2:¿Qué parte del entero es este triángulo? {What part of the whole is this triangle?}
Ss:Un cuarto {One quarter}



T2 pointed to the middle triangle as she asked the question.

T2:¿Qué parte del entero es este triángulo? {What part of the whole is this triangle?}
Ss:Un cuarto {One quarter}

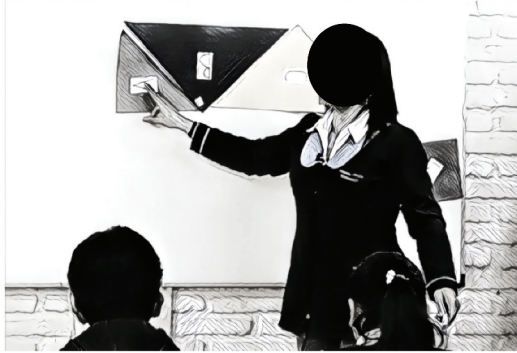


T2 pointed to the triangle on the right-hand side.

(Continued)

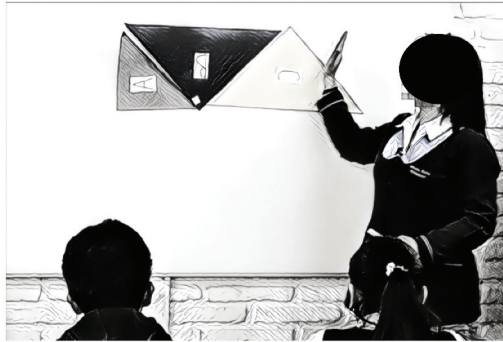
(Continued).

T2:¿Qué parte del entero es este triángulo? {What part of the whole is this triangle?}
Ss:Un octavo {One eighth}



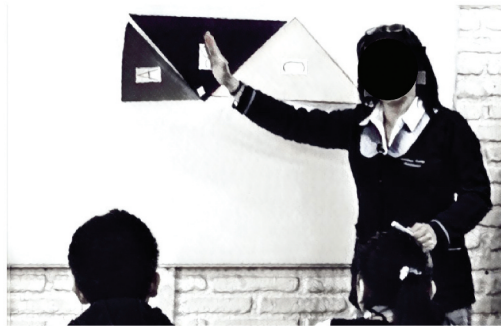
T2 pointed to the triangle on the left-hand side.

T2:Perfect {Perfect}, entonces como voy yo a saber qué parte del área de mi entero (S1) me conforma esta figura? {so S1, how do I know what part of my entire area is formed by these shapes?}



As the teacher asked the question, she moved her hand across the figure indicating that she was discussing the figure made up of these parts.

S2:Sumando {By adding}
T2:Sumando, qué vamos a sumar? {By adding, what are we going to add?}
Ss:Un octavo {One eighth}
T2:Un octavo, mas {One eighth, and}
Ss:Un cuarto {One quarter}
T2:Un cuarto {One quarter}
Ss:Un cuarto {One quarter}



(Continued)

(Continued).

T2: Más un cuarto, ya.
 ¿Podemos sumar? {And
 one quarter, so. Can we
 add them together?}
 Ss: Sí
 T2: Sí, podemos sumar.
 {Yes, we can add them up}



Both hands were held wide in front of the body for about one second before being brought together quickly.

students were the beneficiaries of the actions, as they now knew how to determine the area of the figure by adding the fractional parts. Also, in contrast to the previous example, the range of the action was clearly confined to the triangles on the board, even if these represented abstract fractional parts.

Although the ideational meaning was different from that in the previous example, the interpersonal meanings were similar in that the teacher indicated – by asking questions when she already knew the answer – that she was in charge. The students were nominally involved in the solution process (they had to respond to the questions), but were funneled (Wood, 1998) into providing appropriate answers. The teacher praised the students' responses with "perfect," something that students were unlikely to say to the teacher. This reinforced her position as the person who evaluated the correctness of the responses.

Similar to the symbolic equation in the previous example, the paper stickers provided potential meanings by focussing the students' attention on what was being discussed. Moreover, T2's initial gestures of pointing to the different components of the figure were similar to T1's pointing to the components of the equation. Perhaps to support the students to recognize the goal of the action as being about finding the area of the three triangles, T2 changed from pointing to sweeping her hand across the entire figure. This gesture may have supported the students to respond correctly to the teacher's question about the area and to list what fractional parts were to be added together. The paper triangles represented the fractional parts as discrete amounts. However, by labeling them as fractions, the triangles came to metaphorically represent abstract fractional quantities, rather than the specific parts of a tangram square. The paper triangles had a similar function as abstract entities, to the algebraic expressions in the previous example.

The next gesture was the object collection metaphorical gesture, with the hands starting apart and then being brought together. This can be seen as a development of the previous movement, in that the hands remained flat. By changing the orientation of her body to face the students when making the new gesture, the teacher seemed to be emphasizing the action and the actors, rather than what was being added. Thus, in making this gesture, T2 seemed to convey both ideational meanings (about what was being discussed) and interpersonal meanings (about the roles of the people involved). The words and the gestures indicated that the fractional parts were to be collected together to form a specific amount, as something that could be done by all the actors, teacher and students.

Unlike in the previous example, here the expression and action were in alignment with the rest of the text. The two sets of gestures supported the lexical chain produced by the teacher's question and the students' answers concerning what was to be added. T2 seemed to use the object collection metaphorical gesture to reinforce what she was saying. As such, it could be considered a catchment (McNeill et al., 2001) in that the speech and the gestures indicate the same semantic intent by visualizing the same theme. The speech and gestures also formed a lexical bundle (Arzarello et al., 2009), in that they provided the same meaning, with the sweeping hand gesture morphing into the

object collection gesture. Yet, neither a catchment nor a lexical bundle provides insights into the relationship between the participants in the interaction as information from the SFL lexical chains does.

In this example, SFL provides similar analyses to those achieved by using other tools. This may be because the addition was the teacher's main focus, rather than one part of a wider aim. However, SFL also provides insights into the relationship between the teacher and the students, directly linked to the context of culture, that of being part of a classroom. This context of culture would have affected what the teacher might have unconsciously decided were the appropriate words and gestures for carrying meaning, which might have contributed to the object collection gesture appearing in this classroom in Chile.

Transcript 3

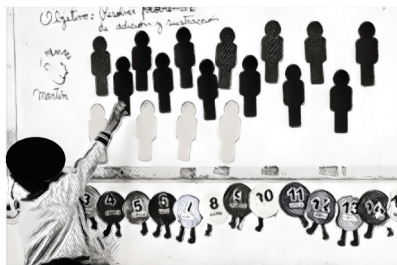
In the third transcript, a second-grade child described how he solved a problem. Consequently, the interpersonal meanings were different to those in the previous two examples. The task involved adding two-digit numbers with 1-digit numbers (e.g., $13 + 4$), and later adding two 2-digits numbers. The teacher used colored silhouettes to help the students visualize the problems. After S3 had used his fingers to solve a problem of adding 8 black silhouettes to 4 green silhouettes by counting, the teacher, T3, asked him to describe his solution process.

The ideational meanings being conveyed were about the amount of silhouettes, following from the

T3: Yo te vi contando. ¿Cómo lo hiciste? {I saw you counting. How did you do it?}
 S3: Lo hice así po {I did it like this}
 T3: ¿Ya, cómo lo hizo? {OK, how did you do it?}



S3: Lo primero que hice yo fue conté todos estos en mi mente {First I counted all of these in my mind}



He pointed to the black silhouettes as he talked.



(Continued).

en estos los puse al otro lado
de mi mente {these, I put
them on the other side of
my mind}



He indicated by touching the green silhouettes that he was talking about them.

Entonces los junté {then
I joined them}



The child's hands began in a relaxed position by his side. Then, both hands were extended with the palms facing each other, before being brought tightly together.

teacher's question about counting. In discussing his solution strategy for working out how many silhouettes there were, the child used the term "*junté*," which is derived from *juntar*, "to join" or "joining." Although the material process of joining was mentioned at the end of the text, the preceding utterances and the child's pointing suggested that the word "joined" and the joining gesture were about addition. Thus, the context of situation of being a classroom where addition problems were being solved could have reinforced for the teacher and the child's peers that joining was the same as addition.

Perhaps not surprisingly, the child situated himself as the actor, as the teacher had explicitly asked him about how he had used counting. In his explanation, the goal of the joining was linked to his solution strategy. The range of the action was restricted to the silhouettes on the board and by the child counting each one individually. As was the case in the first example, the beneficiary of the action was unclear. Implicitly, it could have been the child himself or his peers, who needed to be informed about possible solution strategies, or the teacher, who perhaps wanted to understand his thinking.

The paper silhouettes contributed to the object collection metaphor (Lakoff & Núñez, 2000) as it was the quantity of silhouettes, which was emphasized, with other characteristics being ignored. Color was important, but only as an identity marker for determining the two groups of objects to be collected together. In the previous examples, the gestures carried the metaphorical meaning of collecting objects together, but in both cases the object collection metaphor was stretched. In this text, S3 was more explicit about what was being collected together and about the link to addition.

The interpersonal meanings expressed through the tenor of the text were also different to those in the two previous examples. The child's use of "po" could have been an unconscious identity marker, which situated him as a Chilean Spanish speaker, from a city. Furthermore, although T3 could have guessed what the child would say about counting, she asked an open question and the child controlled how he answered. His explanation was very different from the choral responses in the second example. His fluency with explaining his thinking suggests that he was used to doing this, perhaps as part of the socio-mathematical norms of this classroom (Yackel & Cobb, 1996). He elaborated on what he had

done mentally, by using gestures to point and by enacting the object collection metaphorical gesture of moving his hands together quickly. The context of situation was that of giving a mathematical explanation for an addition problem. However by giving this explanation, the student reinforced that this was what was required in this situation, illustrating Gee's (2005) point about the relationship between the context and the specific communication requirements of that context.

The object collection gesture conveyed ideational meanings similar to those in the two previous examples, although the earlier gestures provided different input. In the first example, the lexical chain of gestures showed a relationship to subtraction and, in the second example, the lexical chain reinforced what was being added (the fractional parts). In these first two examples, the pointing gestures indicated globally what was being added. In this third example, the pointing gestures highlighted each silhouette as a discrete object. The joining gesture was the first indication that the silhouettes were to be considered as a group. This may have been because the child had already solved the problem and was retrospectively describing his solution strategy. His explanation had a different purpose from that of a teacher teaching learners and this may explain why the adaptations of the gestures in the lexical chain were different.

The object collection gesture in the present example was similar to those used in the previous two examples as well as the one noted by Alibali and Nathan (2012). Although the gesture carried a similar ideational meaning, the context of situation was different and this was reflected in the interpersonal meaning that the gesture conveyed. By explaining his solution strategy, the child identified more clearly the actor and the audience. This was reflected in the interpersonal meanings expressed by the gesture, which reinforced the child as the doer of the action. With the word "joining," the gesture shifted the focus of the interaction to the total amount of silhouettes. As the interaction was within a classroom setting, the context of culture indicated to the child that a clear explanation was required. He responded to this requirements by providing the gesture. Within the context of situation, the gesture affected the kinds of meanings that were conveyed in the text, such as making clear the shift from counting discrete objects to a focus on the total amount.

Discussion and conclusion

In this article, we consider the meanings that an object collection gesture carried in mathematics classrooms in two different countries and three different lessons. Our aim has been to investigate whether the meanings potentially conveyed by the gesture were the same and, if they differed, how those differences related to the context of culture and the context of situation. To do this, we elaborated SFL to consider how the gesture could have provided meanings related to the field, tenor and mode (Halliday, 1985).

Our analysis shows that SFL can provide information about the function that gestures had in the different interactions, especially with regard to the lexical chains that they formed with spoken language and other representations, such as symbolic equations, triangles and silhouettes. Although, as shown in the second transcript analysis, both catchments (McNeill et al., 2001) and lexical bundles (Arzarello et al., 2009) can provide similar information, the lexical chains, identified with SFL, showed that the gestures and speech did not always have the same semantic intent. The lexical chains potentially included information about the relationships between the participants, which appeared to not be in focus in the other kinds of analyses. Thus, it seems that SFL allows for a more nuanced analysis.

In the first two examples, the teachers seemed to use gestures to achieve the goals of their respective interactions, which were to remind the students to learn a formula and to understand that adding fractional parts determined the area of a figure. The interpersonal meaning conveyed by the gestures situated the teachers as the experts and the students as learners. The students had different possible ways of interpreting how the gestures indicated what was being added, as this was not explicitly identified. In the third example, however, the student was explicit about what was to be joined,

suggesting that he could not presume that the teacher would accept an explanation without this level of detail. Thus, the interpersonal meanings carried by the gesture reinforced the expected kinds of relationships in mathematics classrooms, which seem similar across the world.

All three transcripts included the metaphorical object collection gesture (Lakoff & Núñez, 2000), but in the first two examples it was stretched to accommodate the addition of abstract entities. As with the interpersonal meanings, the similar ideational meanings carried by this gesture suggests that there is some universality in how discussions about addition, whether implicit in the case of transcript 1 or explicit in transcripts 2 and 3, are developed. This suggests that interactions about addition may have enough in common across countries and languages of instruction to be considered a context of culture in and of itself. The goal of the interactions – the adding of abstract and discrete objects – was constructed as a process that did not need to draw on outside mathematics classroom knowledge. In Farsani (2016), the power gesture that accompanied an interaction on exponential numbers drew on the different natural languages being used, English and Persian. In our examples, the way that addition was described was similar, regardless of the language of instruction, perhaps providing the opportunity for the same, rather than different, gestures being used. This suggests that what counts as a lesson involving addition is restricted, as the gesture both conveyed information about the process, while at the same time reinforcing that the lesson was about addition.

In all three examples, the field of the interactions was about how items (abstract and discrete) could be added together, while the tenor indicated that the relationships were between teachers and students. Similarly, spoken language and the object collection metaphorical gesture were also used in all the examples. The differences appeared in the use of symbolic representations, paper triangles and silhouettes. Their use in the different examples reflected the topics being discussed and expectations about the components, which contributed to what constituted mathematical lessons in the particular classrooms. Students in the first example were no more likely to use silhouettes than the students in the second example were to use algebraic expressions. Therefore, even within the mathematics education context of culture, differences occur that reflect the specific contexts of situation.

The analysis, using SFL, suggests that the context of culture supported T1, T2 and S3 to include the gesture in conveying meaning in the different contexts of situation. Yet, differences between the contexts of situation contributed to the object collection metaphorical gesture not carrying the same potential meanings in each case. In the first example, the gesture provided meanings different from what was conveyed verbally, about the material process of adding – its actor, goal, and range. In the second example, the adding gesture developed from another gesture, which seemed to have the same function of indicating in a general way what was being added together. The object collection gesture reinforced that it was all the fractional parts, illustrated by the paper triangles forming the figure, that were being added. In the third example, the gesture indicated how the individual items, previously highlighted by a pointing gesture, were to be collected together and their total amount determined. The child seemed to use the gesture so that his teacher and peers had the best chance of understanding his explanation. In this case, the gesture and his speech conveyed the same meaning. As Gee (2005) highlighted with his “chicken and egg” analogy, the gesture was used in all three examples because the context of culture was about teaching and learning of some aspect of addition. However, by using the gesture, the participants reinforced that a text about the teaching and learning of addition should include this gesture.

Although the three examples came from data gathered in two different countries, it did not seem that the language of instruction or the context of culture related to, for example, national curricula affected the interactions. Nevertheless, the placement of the gestures with the spoken terms, alongside the orientation of the body, may have provided nuances related to the specific culture or language. For example, it may be that the Iranian teacher used the gesture to show a relationship between himself, as a doer of the action, and the students, which was more typical of what is found in everyday interactions, than in mathematics lessons. The gesture, therefore, may not only have carried ideational

meaning about the actor, but also reinforced how relationships between people are valued in Iranian culture. However, these ideas are speculative and further research would be needed to better understand whether this could be the case.

Cross-cultural descriptions of classroom episodes often presume difference (see for example Núñez & Sweetser, 2006). Yet, this analysis using an elaborated version of SFL has shown that, alongside some differences, there were in fact many similarities that seemed to be related to the mathematics education context of culture, which may have contributed to the inclusion of the same object collection metaphorical gesture in the three lessons. The differences in the function that the gesture had in each lesson seemed to be more to do with the specifics of the contexts of situation than with the specific contexts of culture linked to languages of instruction or national objectives for education. This indicates that assumptions about differences in cross-cultural studies may need to be reconsidered.

Notes

1. The book from which this quote comes has two authors, Michael Halliday and Ruqaiya Hasan. However, each author wrote a separate section of the book. The references come just from Halliday's section.

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ORCID

Danyal Farsani  <http://orcid.org/0000-0002-9412-3161>

Tamsin Meaney  <http://orcid.org/0000-0001-8371-9923>

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