GESTURES AND CODE-SWITCHING IN MATHEMATICS INSTRUCTION – AN EXPLORATORY CASE STUDY

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While gestures are considered an important resource in the mathematics classroom, gesture use in bilingual instruction has been largely neglected in research so far. This paper presents a case analysis of two teachers' bimodal bilingual instruction in the context of isosceles triangles to show how they coordinate meaning making of content and terminology through code-switching and gestures. Based on the analysis, we will introduce the concept of 'bimodal mnemonics' as means to support learning mathematical terminology together with the respective concept and conclude with a brief discussion of our preliminary findings and an outlook on future research.

INTRODUCTION

Mathematics teachers of English Language Learners (ELL) – and generally of students that learn in a second language – face additional challenges as they need to coordinate the students' varying levels of both mathematical proficiency and language proficiency (Moschkovich, 2013). However, language should not be seen as a barrier to learning that needs to be addressed first before it can be engaged with content. While learning mathematical terminology is important, "mathematics instruction should address more than vocabulary and support ELL participation in mathematical discussions as they learn English" (p. 50). For this, teachers are asked to acknowledge the students' home language as an important resource for meaning making rather than seeing it as a deficiency. For example, using two or more languages within a single communicative event – a phenomenon referred to as *code-switching* – can become a powerful tool for the teacher to support bilingual learners of mathematics by providing a scaffold for accessing mathematical content, and by facilitating links between verbal and visual representations of this content (Prediger et al., 2019). Furthermore, Moschkovich (2002, 2013) advocates for acknowledging the multiple resources beyond words in the mathematics classroom, like objects, drawings, and gestures. In fact, Church and colleagues (2004) showed that bilingual students benefit from gesture-rich instruction even more than their monolingual peers. It is hence surprising that in the steadily growing research on gestures in mathematics instruction (e.g. Alibali & Nathan, 2007; Arzarello et al., 2009), only very few scholars directed their attention to the bilingual classroom to understand better how teachers' gesture use can support these students' learning (e.g. Shein, 2012), and even less is known about how gestures interact with the practice of code-switching in bimodal bilingual mathematics instruction.

This paper presents an early exploration of teachers' gestures in relation to their use of two languages in bilingual mathematics classrooms, aiming at getting a better grasp of

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how gestures can contribute to instruction to support meaning in mathematics across languages. We will present two cases from Farsi-English bilingual classrooms in a complementary school in the UK, dealing with the context of isosceles triangles. The cases are analysed for how teachers use gestures coordinated with language to navigate the tension between concept and terminology. In particular, we focus on the questions:

(1) How do the teachers use gestures and the two languages Farsi and English in their bilingual mathematics instruction of language learners?

(2) How might bimodal bilingual instruction support learning mathematical content as well as the second language?

Our work is embedded within the larger body of research on bilingual mathematics education that adopts a situated-sociocultural perspective (Moschkovich, 2002), emphasizing on the social dimension in mathematics teaching and learning, especially on the role of mathematics communication in which meaning develops by drawing on social, linguistic, cultural, and material resources (ibid.). Learning mathematics can then be understood as increasing participation in mathematical discourse practices with the teacher facilitating the students' active engagement in these practices by acknowledging their resources for meaning making.

Gestures are considered those "idiosyncratic spontaneous movement[s] of the hands and arms accompanying speech" (McNeill, 1992, p. 37) that do not serve any practical or manipulative purpose. As semiotically different components of a single linguistic unit, speech and gesture are coordinated in thinking and expression as embodying "different sides of a single underlying mental process" (p.1), collaborating in forming an utterance as well as in its interpretation. With respect to the development of mathematical meaning, a special focus is set on representational gestures (Alibali & Nathan, 2007): the relationship between the content of the verbal utterance and the gestural reference is established through *pointing*, through perceived similarity to a physical object or action (*iconic*), or by representing an abstract idea mediated through concrete reference (*metaphoric*). The different categories are not mutually exclusive.

METHODOLOGY

The data has been collected in the context of a study on multimodal communication in multilingual mathematics classrooms (Farsani, 2015), conducted in the UK in a bilingual British-Iranian complementary school. In this school, instruction was bilingual in Farsi and English and learners were encouraged to value both languages equally. What seemed to be at the heart of the school was creating multilingual spaces by using languages flexibly and integrating a full range of learners' linguistic repertoires. This bilingual school welcomed teaching strategies that supported learning both content and language simultaneously. The students in the recorded lessons were between 14 and 16 years old and of varying proficiency of the English language.

The selected excerpts are taken from longer episodes analysed for the relationship between gestures and code-switching in mathematics instruction. They present instances of teachers' use of gesture co-expressive to English and Farsi, in which they

provide an additional visual component that enriches meaning making. The audio-visual data was transcribed, transliterated, and translated for analysis, with transliteration and translation being carried out by the second author (a native speaker of Farsi) and kept as literal as possible while overall adopting the language structure of the goal language English. The transcripts as presented in this paper have been prepared to visualize the use of two different registers by using a different colour for the Farsi register in the original transcript and its translation in the English transcript. Simultaneity of performance of gesture (start and end of the main movement) and speech is indicated in the transcript using squared brackets. For spatial reasons only selected gestures discussed more in detail in the analysis can be represented in pictures.

A speech-based analysis focuses on the teachers' code-switching practices as they can be identified in the discourse, followed by an analysis of the gestures in context as related to speech and inscription. The former was carried out based on the transcripts, the latter by additionally reviewing the video.

CASE ANALYSES

The two excerpts are taken from different classrooms and display the gesture use of the two teachers Ebi – native speaker of Farsi, fluent L2-speaker of English – and Mamad – native speaker of Azeri and Kurdish, fluent L2-speaker of Farsi and English.

In both excerpts, Ebi and Mamad are dealing with the topic of isosceles triangles in the contexts of regular polygons. Isosceles triangles are characterized by having two sides of equal lengths. While English adopts the Greek terminology of 'isosceles', many other languages (such as German and Farsi) use a quite literal translation referring to variations of 'legs of equal length'. The Farsi translation for isosceles triangle is *motasaavi-al saaghain* – literally 'equal shins' – which will be used in both episodes.

Excerpt 1

In the first excerpt, the teacher (Ebi) explains to the students how to find an inner angle of a regular pentagon. For this, he divided the regular pentagon into five equal isosceles triangles, asking for the angle *x* located at the centre (see Figure 1a, in the transcript).

		Original Farsi-English dialogue	English version
1	Ebi	That's a regular pentagon obviously, and each side is four, ok.	That's a regular pentagon obviously, and each side is four, ok.
2	Ebi	Chon regular pentagon-e *(points at the centre)* centre-esh *(points briefly towards the diagram)* [age maa be behesh] *(traces lines, Fig. 1b)* vasl bekonim mitoonim hamash *(short pause)* [isosceles] (*points to his eyes, Fig. 1c)* triangles [peida bekonim, dorost bekonim, khob]? *(traces all five inner lines similar to the three lines in Fig. 1b)*	Because this is a regular pentagon *(points at the centre),* [if we connect] *(traces lines, Fig. 1b)* to the centre, *(points briefly towards the diagram)* [it will all become *(short pause)* [isosceles] (*points to his eyes, Fig. 1c)* triangles, okay?] *(traces all five inner lines similar to the three lines in Fig. 1b)*

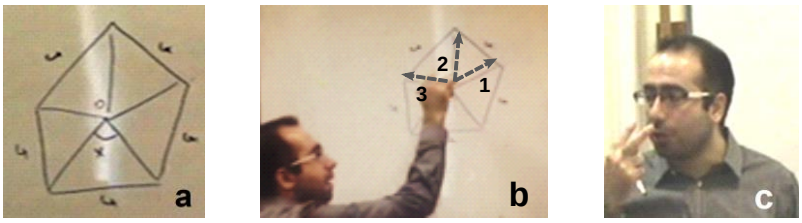

Figure 1: Ebi's inscription on the white board; (a), Ebi's gestures co-timed to "age maa be behesh" (b) and to "isosceles" (c)

3	S1	motasaavi-al saaghain	Isosceles triangles
4	Ebi	motasaavi-al saaghain	Isosceles triangles
5	Ebi	khob, [iino *(points at "x" in the pentagon)* ke peida mikonim] angle of x is equal to angle of x equal to angle of x and so on.	Okay, [when we find this] *(points at "x" in the pentagon)* angle of x is equal to angle of x equal to angle of x and so on.

Ebi starts with establishing a common ground of reference by clarifying the figure drawn on the white board being a "regular pentagon" (1). While this first introduction into the situation is carried out in English, he switches back and forth between English and Farsi in his following utterance when explicating how isosceles triangles emerge through construction, using English exclusively for the technical terms – "regular pentagon", "centre", and "isosceles triangles" (2). He ends with 'okay?' inviting the students to ask for clarification. To this, one of the students reacts by repeating 'isosceles triangles' in Farsi – "motasaavi-al saaghain" (3) – potentially asking for reassurance that he can draw on his prior knowledge on a concept he already encountered in his mother tongue. After Ebi confirms by repeating the Farsi terminology (4), he returns to the actual task of finding the angle *x*, starting with Farsi but switching back to English to complete his statement about the central angles all being the same (5). His use of Farsi and English seems to emphasize mathematical terminology in the English language while using Farsi for the wider explanation that links the mathematical components. This reflects in praxis his approach to using English and Farsi in instruction as mentioned by him in an interview carried out prior to this study: There he stated that he emphasizes the use of English in instruction since "At the end of the day they go to an English school and they learn everything in English" but that he uses Farsi to support his students when he notices problems in understanding grounded in language use (see Krause & Farsani, *under review*).

The gestures Ebi uses during his explanation are reminiscent of gesture use of teachers described by Alibali and Nathan (2007) during monolingual instruction in an algebra lesson: There, they found gestures to ground instructional language by linking it to physical referents, including inscriptions, potentially making "the information conveyed in the verbal channel more accessible to students" (p. 350). In line 2, we see two forms of grounding through gestures: pointing and tracing. Remarkably, the pointing gestures are all co-timed to the English mathematical terminology, while the tracing re-enacting the drawing of the lines that result in isosceles triangles (e.g., Fig. 1b) are co-timed with Farsi. Moreover, the gestures accomplished co-expressively to

English and Farsi differ not only qualitatively, they also seem to offer different functions in grounding: The tracing gestures provide additional semantic information to clarify the incomplete/imprecise verbal expression; the pointing gestures can be considered semantically redundant to speech but grounding the terminology in the second language through providing a visual frame of reference. However, Ebi's gesture co-timed to "isosceles" remarkably appears to be different than the other two as it does not point to the diagram, but – seemingly unrelated – to his eyes (Fig. 1c). The pointing can be interpreted as a phonological rather than a semantic reference: emphasizing the "i" in "isosceles" by referencing the phonologically similar 'eye' by pointing to it, the gesture grounds the terminology and offers potential to provide a mnemonic device at service for the students with various degrees of English proficiencies to recall the technical term. In addition to the deictic reference, the concrete shaping of the gesture with two adjacent fingers of the same hand carries a reference to the semantic content of speech in the gesture's iconic dimension, reminding of the two sides with equal length an isosceles triangle itself. The gestures' deictic and iconic reference together offer a twofold semantic-phonemic link to both mathematical content and terminology.

Ebi's use of gestures coordinated with the two languages offers representational and phonemic support to potentially provide a scaffold for engaging in mathematical discourse about the respective topic through language and gesture, thereby helping the students learn and remember both the new mathematical concept and mathematical terminology. However, given that the gestural reference is rather implicit, further analyses of the classroom interaction would need to confirm this hypothesis.

The second excerpt will illustrate a variant of the "isosceles gesture" (Fig. 1c), contrasted with a gesture accompanying the teacher's explanation of the Farsi terminology. For reasons of space we will set the focus of our analysis of excerpt 2 on those gestures that are linked to the teacher's code-switching to English.

Excerpt 2

The second excerpt is taken from a lesson in which another teacher (Mamad) and some bilingual students are reviewing angles in the context of a regular octagon projected on the whiteboard. When they encounter isosceles triangles, Mamad (M) uses the occasion to discuss the terminology in both Farsi and English, using gestures as visual support.

		Original Farsi-English dialogue	English version
1	M.	aha, Farsi sho baladin bacheha? saagh yanni chi?	Aha/yeah. Do you know what's the Farsi for it guys? What does 'saagh' mean?
2	S1	paa	leg
3	S2	saagh yanni paaiinesh	saagh means the lower part
4	S1	chii bood dobare?	What was it again?
5	M.	motasaavi-al saaghain. [motasaavi yanni chi?] *(moves both extended index finger*	Isosceles. [What does 'motasaavi' mean?] *(moves both extended index finger together*

		together and apart, Fig. 2a) yanni equal. Motasaavi-al saaghain yanni do ta saghash chi-an, [do ta paahash chi-an?] *(points down his legs, Fig. 2b)*	*and apart, Fig. 2a)* It means equal. Hence 'Motasaavi-al saaghain' means both shins are what, [both legs are what?] *(points down his legs, Fig. 2b)*

Figure 2: Gestures co-timed to "motasaavi yanni chi?" (a) and "do ta paahash chi-an?" (b)

6	S-s	mosavi	Is equal
7	M.	mosavi. Englisi besh migan [isosceles] *(Fig. 3a)* yanni dota chesha shabihe haman, Irania [migan motasaavi-al saaghain.]	Is equal. In English they call it [isosceles], *(Fig. 3a)* meaning just like our two eyes. In Iranian [it is referred to as 'equal shins']

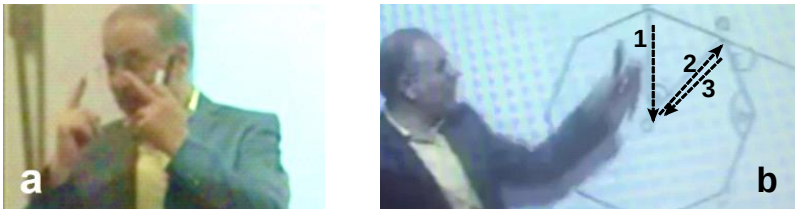

Figure 3: Gestures co-timed to "isosceles" (a),"migan motasaavi-al saaghain" (b)

Together with the students, Mamad recalls the Farsi term for the concept under investigation – motasaavi-al saaghain – and the meaning of its single components (1-6): First, they identify the reference to the shin (saagh) – the lower part of the leg (2, 3) – then Mamad asks 'What does motasaavi mean'. He does not wait for a response but provides it himself right away as "yanni equal" (5). His following prompt to put both together ('Hence (…) their legs are what?') is then responded by students with 'is equal'. Mamad then contrasts the terminologies in English and Farsi (which he mistakenly refers to as Iranian), explicating 'how they call it (in English)' and what the Farsi word refers to as just established, but now showing in the diagram (7, Fig. 3b).

Mamad switches to English twice in this short excerpt – first in line 5 ("equal") then in line 7 ("isosceles"). Similar to the use of English in excerpt 1, these switches to English concern mathematical terminology: While "equal" (5) is a rather general translation of the Farsi motasaavi, the teacher asks for its meaning in the context of the mathematical terminology motasaavi-al saaghain. Code-switching here serves the function of expressing meaning in the second language, using vocabulary supposedly known by the students. In the second instance (7), Mamad explicitly uses "isosceles" as naming the English terminology to refer to the same concept, establishing new mathematical vocabulary through code-switching.

Both instances of using English can be linked to gesture use, even though the first one is carried out just before, co-timed to the Farsi equivalent of 'equal', carrying the same

semantic meaning: While asking 'What does 'motasaavi' mean?' (5), he moves his extended index fingers horizontally and symmetrically together and apart in front of his body (Fig. 3a), adding a visual dimension to his question that might be seen as a metaphoric reference to equality, but also as iconic indicator of two sides (represented by the index fingers) with equal length. Co-timed to the English "isosceles" (7), Mamad points to his eyes, similar to what we have seen in Ebi's gesture in excerpt 1, but – different to Ebi – verbally explicating the connection to 'our two eyes' right after. Again, the gesture grounds the accompanying language phonologically and anticipates the verbal reference in Farsi. In its performance, it however shows another difference to Ebi's gesture: Ebi points to his eyes with two fingers of one hand, Mamad's gesture is bimanual, pointing with the index fingers he used earlier in his reference to equality (line 5). This might indicate a *catchment* in the sense of McNeill (2005) – a recurrent discourse theme whose link can be identified in the recurrence of gesture features, here the use of the two index finger in the gestures for 'equal' and "isosceles". Even though this contextual link is made only implicitly, one can argue that gesture and speech are processed and interpreted as a unit such that the link carried in gesture can serve as potential additional resource for meaning making for both students and the teacher.

SUMMARIZING DISCUSSION AND OUTLOOK

The bimodal analyses of the two teachers' bilingual instruction provided some first insights on how bilingual teachers coordinate the use of both languages and gestures and how this might support meaning making in mathematical discourse. Similar to what has been observed in monolingual classrooms (Alibali & Nathan, 2007), the teachers grounded their instructional language in the physical world around them to support the students' understanding of the verbal explanation. However, the bilingual setting also directs our attention to some peculiarities in the teachers' gesture use.

A striking commonality in both cases is the teachers' use of gestures as linked to the English terminology "isosceles": Importantly, this does not only concern the phonemic support in the reference to the phonologically similar 'eye', but the concrete shaping of this reference that aligns with representational features of the concept. We see two variants – one-handed with two adjacent fingers (Ebi) and two-handed with the two index fingers (Mamad) – that both carry a reference to the two sides of equal length, a defining feature of isosceles triangles. We do not claim that the teachers established this link to the mathematics consciously – they certainly did not make it explicit. However, keeping in mind the multimodal nature of communication and speech and gesture being perceived as a unit in interpreting an utterance, the combination of gesture and speech can provide assistance for remembering the mathematical idea together with its English terminology – a combination we call *bimodal mnemonic*.

A difference in both cases concerns the focus of instruction, causing differences in the coordination of gestures with language. Ebi's explanation concerns the mathematics towards solving the problem with his gestures providing a referential frame to ground the English terminology by identifying the respective concepts in the diagram, and specifying the imprecise Farsi expression. The gestural reference to the English

mathematical terminology is integrated implicitly. Mamad foregrounds the terminology in both languages, reflected in his gestures as they are largely related to making meaning of this terminology. Here, the gestural reference to the mathematics with respect to isosceles triangles in a regular polygon is rather implicit. In both cases, the use of gestures and two languages played an integral role in helping the students being engaged with the ongoing flow of the lesson content.

The analyses presented here are only a first step in investigating the role of gestures for coordinating bilingual instruction with mathematical content to support language learners. They serve us as a starting point by pointing at different forms and functions of bimodal bilingual instruction along the three axes of code-switching, gesture, and focus of instruction. Our further research will concern the development of a methodological tool that integrates these three axes for systematic analysis. Furthermore, we plan a wider exploration of mathematical contexts, including also other language backgrounds in bilingual classrooms.

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