Paper Title A Nondeficit View for Studying Bilingual Learners Engaging in Mathematical Activities With Touch Screen Technology

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A non-deficit view for studying bilingual learners engaging in mathematical activities with touchscreen technology

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In this paper, I use a non-deficit view to examine how recent advances in touchscreen technology and gestures as a form of communication may serve as access for bilingual learners to engage in mathematical activities and communication meaningfully. The topic of high school calculus was chosen to highlight the potentials of this work to provide access for students from non-dominant communities to "important mathematics" and opportunities to participate in STEM disciplines. By analysing episodes of two bilingual students engaging in a mathematical exploration with touchscreen technology, I show that the use of technology was instrumental for facilitating meaningful discussion of mathematics and that a non-deficit model of learning is essential for identifying learners' competence in today's increasingly multilingual classrooms.

Introduction

In recent years, there has been increased attention on issues of linguistic diversity in mathematics education (Morgan, 2007). From an equity standpoint, the ever-increasing multilingual classroom context gives rise to an emerging tension between addressing learners' lack of proficiency in the language of instruction and emphasising communication as an essential process for mathematics learning: "They communicate to learn mathematics and they learn to communicate mathematically" (NCTM, 2000, p. 60). The value of communication is further emphasised by NCTM (2000) as a *process standard* for mathematics learning, pointing to the value of rich conversations about worthwhile mathematical tasks for students' learning. It is suggested that "support for students is vital" (p. 60) as they learn to participate in these conversations, and that teachers need to build a community in which the exchange of ideas can freely occur—a potentially challenging task in multilingual classrooms. This raises questions about equitable teaching practices in classrooms where students are encouraged to grapple with concepts by communicating in their own words, yet the ability to do so varies among students with different experiences and language proficiencies.

Currently, research focussing on linguistic diversity in mathematics education has provided tremendous insights into the complexities of teaching and learning mathematics in multilingual contexts (Adler, 2001; Clarkson, 2007; Setati, 2005), while those focussing on supporting bilingual learners' communication are limited. In this paper, I use a non-deficit lens to examine how recent advances in touchscreen technology and gestures as a form of communication may serve as access for bilingual learners to engage in mathematical activities and communication meaningfully. In terms of mathematical content, I have chosen to examine the learning of high school calculus to highlight the potentials of my work to provide access for students from non-dominant communities to "important mathematics" in the sense of opportunities to participate in STEM disciplines (AERA, 2006).

The sociocultural view of learning mathematics

Moschkovich (2007) describes three views of bilingual mathematics learners and examines how these views impact instruction. The first perspective emphasises acquiring *vocabulary*, while the second emphasises *multiple meaning*. She questions the efficacy of the first two perspectives for understanding bilingual mathematics learners because they focus on what learners *don't know* or *can't do*. In contrast, the third perspective, *the sociocultural view*, focuses on bilingual learners' competence and the resources they use in communication—a non-deficit view of studying bilinguals learning mathematics.

The sociocultural view sees learning as participating in *mathematical Discourse practices*. To begin, Moschkovich draws on Gee's notion of Discourse. By a *Discourse*, with a capital "D", Gee means a socially accepted association among ways of being, acting and using language at certain times and places, so as to assume particular "recognisable" identities. Thus, Gee argues for a view of learning as induction into Discourses (ways of being), not just discourses (ways of using words). Furthermore, *mathematical Discourse practices* are practices which are specific to particular mathematical ideas and mutually shared by the members (teacher and students) as norms of the community (classroom) in the case of a mathematics classroom community.

Moschkovich (2007) illustrates *mathematical Discourse practices* with examples of Spanish American students' communication during mathematical activities. She illustrates that Alicia, who was asked by her teacher to describe a pattern, used gestures and her native language to explain what she meant. Although Alicia did not have the vocabulary of *rectangle*, *length*, and *width*, her "non-language resources" revealed that she was appropriately describing patterns and making comparisons between the perimeter, length, and width of a rectangle. Her study highlights bilingual learners' mathematical competence even without using the right vocabulary: "even a student who is missing vocabulary may be proficient in using mathematical constructions or presenting clear arguments" (p. 207).

Method

A study is conducted involving twelve participants who were bilingual learners enrolled in two sections of a calculus course in a culturally diverse high school in Western Canada. The goals of the study were to address bilingual learners' patterns of communication and mathematical competence in a touchscreen, dynamic calculus environment. The participants, aged 16 to 18, had recently moved to Canada from a non-English speaking home country from the age of 10 to 16. As part of the study, the students had become familiar with the Discourse of exploring and discussing calculus concepts through touchscreen dynamic geometry environments (DGEs) in pairs during a year-long calculus course. For this paper, I focus on analysing a mathematical discussion with the touchscreen DGEs between two bilingual learners, Huang and George, while exploring the area-accumulating function, a concept that was new to them, about four months into the school year.

The sociocultural view is used to focus on the participants' competence, i.e. the verbal and non-verbal resources that they used, in mathematical communication. In addition, as it is anticipated that the participants would make use of gestures and touchscreen-dragging during the exploration with touchscreen DGEs, I adopted a *synchronic* lens to analyse the interrelationships between verbal (language) and non-verbal modes (gestures and dragging) of communication, and a *diachronic* lens to investigate how this communication change over time. By performing these analyses, my goal is to highlight the use of touchscreen, dynamic technology for providing bilingual learners with access to calculus, opportunities to engage in mathematical communication, and possibilities to participate as members of the classroom community.

Episode

Huang and George had been exploring with the iPad-based DGE with very limited verbal communication for the first five minutes of their interaction. The utterances were mostly incomplete, and in fact, the longest sentence spoken thus far was only five-word long. Conversely, they communicated non-verbally through various gestures and dragging on the iPad by pointing at and enacting the movement of the green point. While dragging the point label '*x*' along the *x*-axis, they realized that the green point was also moving, but they had not realized that it was tracing the area under *f(t)* from '*a*' to '*x*' (Figure-1). Table-1 shows the transcript of a 30-second episode of Huang and George's discussion at the 5-minute mark.

The word "area" appeared for the first time in the students' exploration at 05:14. It was said by Huang and then immediately responded by George at Turn-58 and Turn-59. Moments before that, George had been dragging *'a'* continuously back and forth at Turn-53. Subsequently, with the iPad displaying a set of vertical green traces, George described the "vertical" movement of the green traces using the words "moving" and "shift" in his utterance at Turn-55. The use of active verbs accompanied by the word "vertical" shows that George was thinking about the behaviour of the green trace geometrically and dynamically. Then, at one point during George's dragging of *'a'*, the net area under *f(x)* became negative. At this very moment, Huang gestured with his right index finger towards the centre of the iPad and said, "Area's negative there" (Turn-58). Here, three modes of communication were simultaneously used by two students during this turn (Figure-2). Hence, Huang was able to talk and gesture about the sketch as it was being altered by George's dragging. The observation that George replied to Huang with the word "area" (Turn-59) and then again "the area here is…" (Turn-61) also suggests that both students had begun to develop their verbal communication around "area". Although they had yet to communicate verbally the functional dependency between *'x'* and *A(x)*, their verbal communication about "area" simultaneously with dragging implicitly suggest that they were attending to "area" as a function of dragging *'x'*.

Seventeen minutes later, Huang and George were attempting to solve a problem that was posed to them: using the whiteboard provided, sketch the area-accumulating function *A(x)* given the cosine function and *a=0*. Another 30-second episode was chosen and analysed below during the students' solving process. The transcript (Table-2) illustrates the change of Discourse in terms of Huang and George's use of speech, dragging and gesturing.

Upon my question to explain what they had done, Huang communicated the "change" of "area" for the first time in their exploration (Turn-276). In fact, his utterance, "the rate of the area changes" suggests that he was actually talking about the rate at which area was changing under the cosine function as opposed to the change of area itself. Indeed, Huang's comment about the rate as "biggest" and then "decreasing" were both accurately stated mathematically, when matched to the area accumulation under cosine with $a=0$ and $a<x<\pi$. Although he did not use any gestures to accompany this part of his speech, he did gesture deictically at the beginning of his utterance by pointing towards $a=0$, which suggests that he was referring to the area accumulation under cosine with $a=0$. Similarly, in the rest of Turn-276, Huang stated the rate of change of area accurately with his speech complemented by a deictic gesture.

At Turn-279, Huang continued to communicate about the shape of the area-accumulating function. He said, "this point, the area, negative, so there become, became like, decreasing..." while he performed a gesture by forming a "C" shape with his thumb and index finger as if he was "measuring" the distance between $x=\boldsymbol{\pi}/2$ and $x=\boldsymbol{\pi}$ on the cosine graph (Figure-3). In mathematical terms, since the cosine graph was below the x-axis in the interval $(\boldsymbol{\pi}/2, \boldsymbol{\pi})$, the accumulated area begins to decrease and so does the graph of $A(x) = \int_a^x cost\ dt$. This seemed to be precisely what Huang was communicating in his utterance. His use of "so" suggests that he was disclosing a causal relationship. Although he did not communicate in full sentences verbally, his gesture helped him state the interval of $(\boldsymbol{\pi}/2, \boldsymbol{\pi})$ of which the function was "decreasing" according to him. In general, Huang did not speak in full sentences very much and used some self-repair speech in his communication, as can be seen in both Turn-276 and Turn-279. However, Huang was able to communicate the reason why the area-accumulating function ought to be decreasing with the present analysis. Furthermore, the analysis points out that Huang was engaging in a valued mathematical Discourse practice, that of reasoning mathematically.

Discussion and conclusion

As shown in the episode, Huang and George communicated significant mathematical ideas through the use of gestures and dragging with the iPad to negotiate the meaning of the green traces. Their mathematical Discourse practices, which included looking for patterns and reasoning, were uncovered through studying the interplay of the students' multimodal communication without evaluating their language *per se*. Hence, this study concurs with Moschkovich (2007) that the sociocultural view is beneficial for addressing the mathematical competence of students from non-dominant communities. In addition, it points to two positive effect of using touchscreen and dynamic technology for facilitating mathematical meaning-making and discussions. First, the touchscreen interface allowed the students to interact with mathematics with their own fingers, where the movement of the hands within the dragging action can be taken as a form of non-verbal communication (gestures). Secondly, the dynamic environment enabled the students to talk about temporal mathematical relations and functional dependency without relying on language alone, thus reducing the language demands for the bilingual learners.

Two dimensions reflecting research addressing equity, namely *access* and *identity*, were addressed in this study. According to Gutierrez (2009, 2012), *access* pertains to the tangible resources that students have available to them to participate in mathematics, and the *identity* dimension pays attention to whose perspectives and practices are valued, i.e., whether students have opportunities to draw upon their cultural and linguistic resources in mathematics learning. In this light, the touchscreen dynamic technology gave students access to important mathematical ideas and opportunities to STEM while drawing on their embodied resources (touch and gestures) in mathematics learning.

In conclusion, this paper highlights the significance of identifying bilingual learners' competence in mathematical activities using a non-deficit lens. This line of work is much needed in today's increasingly multilingual and culturally diverse classroom. It is essential to remind future research addressing equity to avoid the deficit models of learners and their communities. The potential for a "proficiency-based approach" in future research is promising, and it is also valuable for critiquing a normative paradigm in mathematics education.

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Tables

Turn	Timespan	Who and what was said <what was done>
53	4:56.3 - 4:58.0	<George dragged *‘a’* continuously from Turn-53 to Turn-61>
54	4:58.0 - 5:01.5	<Huang made a ‘sss’ sound>
55	5:01.5 - 5:08.8	George: Moving *‘a’* only shift...vertical...
56	5:08.8 - 5:12.8	Huang: <Inaudible> <George continued dragging>
57	5:12.8 - 5:14.5	George: Hmm…
58	5:14.5 - 5:16.9	Huang: Area's negative there. <Huang pointed to the iPad (Figure-2)>
59	5:16.9 - 5:18.1	George: Area...
60	5:18.1 - 5:24.5	<Silence> <George continued dragging>
61	5:24.5 - 5:27.9	Huang: The area of here is… <Huang pointed to the iPad>

Table-1. Transcript of Huang and George’s exploration near the beginning of the task (Turn-53 to Turn 61).

Turn	Timespan	Who and what was said <what was done>
274	22:33.1 - 22:35.3	Researcher: Can you explain, can you explain, Huang?
275	22:35.3 - 22:36.9	George: <Inaudible>
276	22:36.9 - 22:57.1	Huang: Uh...like the...at first, like, <Huang gestured near the iPad> the...uh, the rate of the area changes...uh, is biggest and then it's decreasing...and so... <Huang gestured near the iPad> Uh...it's like concave down. And like, after the...
277	22:57.1 - 22:58.1	Researcher: After…
278	22:58.1 - 23:00.3	George: Oh, after the...inflection point...
279	23:00.1 - 23:06.6	Huang: This point the area, negative, so there become, became like, decreasing... <Huang gestured near the iPad (Figure-3)>

Table-2. Transcript of Huang and George’s exploration towards the end the task (Turn-274 to Turn 279).

Figures

(a)

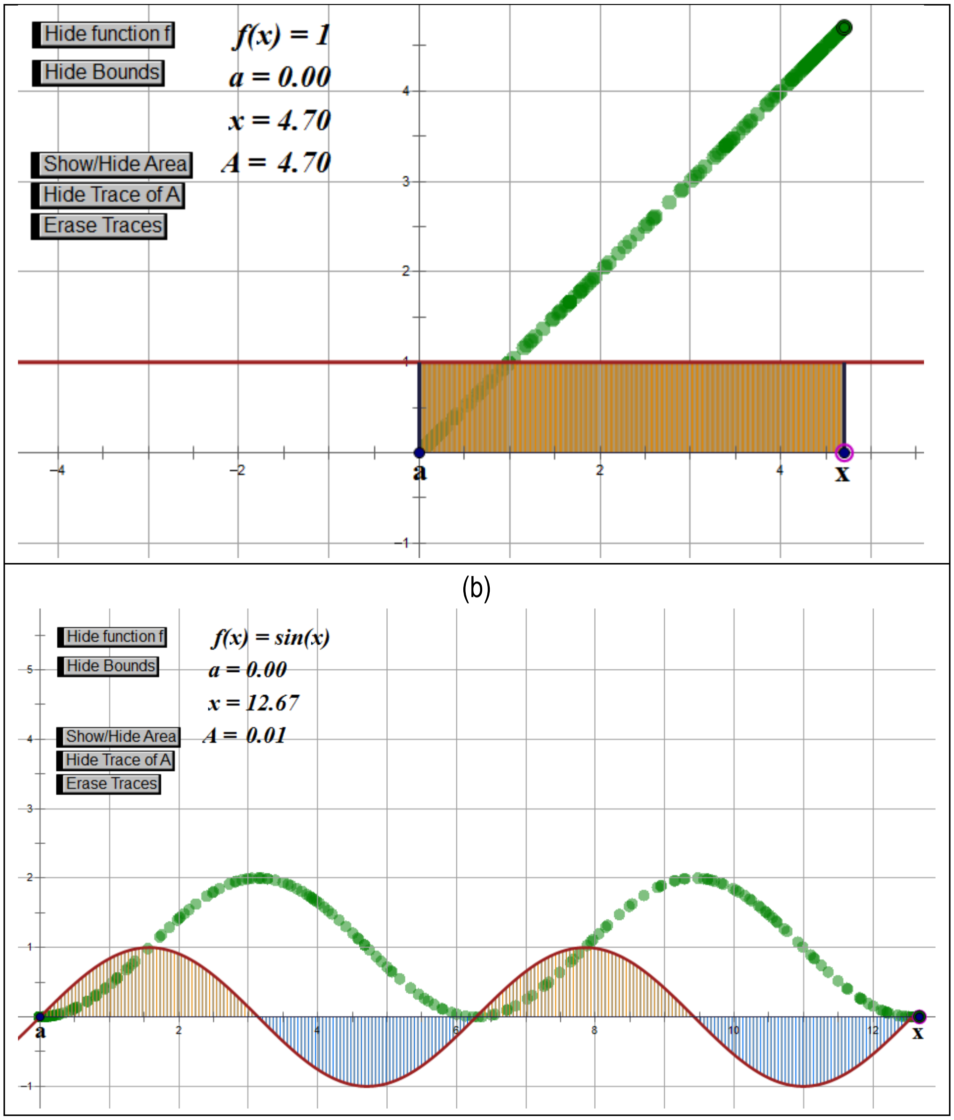

Figure-1. Sample screenshots of the DGE used in the study, showing the area under (a) a constant function and (b) a sine function with all buttons activated and 'x' dragged from zero to its current positions. The bounds 'a' and 'x' are draggable; the green traces represent the function, $A(x) = \int_a^x f(t)\, dt$.

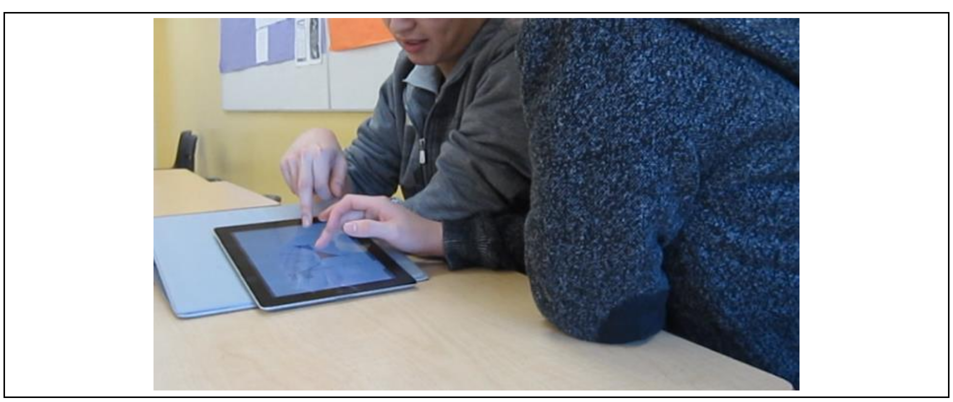

Figure-2. “Area’s negative there,” said Huang while he gestured and George dragged *‘a’* on the iPad (Turn-58)

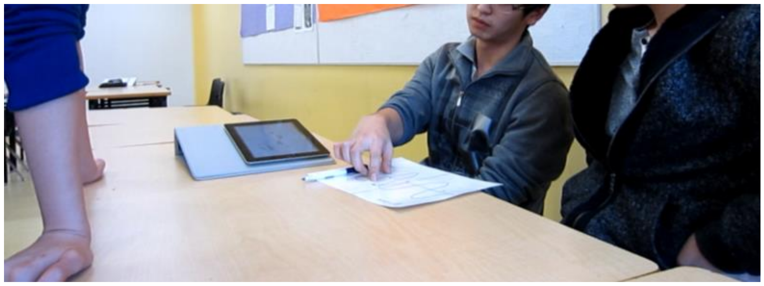

Figure-3. Huang gestured while uttering, “so there become, became like, decreasing...” (Turn-279)