Primary teachers implementing *TouchTimes*

Sandy Bakos

Simon Fraser University, Canada; sbakos@sfu.ca

After integrating TouchTimes *(hereafter, TT) into their teaching practice, four primary school teachers (K–5) in British Columbia, Canada share their experiences, both as learners of this relatively new technology, and as teachers utilising TT as a tool to guide and support student learning. Using the notion of double instrumental genesis, I examine how these teachers experienced this digital technology from 2018–2021, both as learners themselves, as well as their subsequent transitions to thinking about and adopting it as a didactical instrument for teaching mathematics. The aim of this research was to identify and highlight specific ways in which these teachers adopted technology-enhanced mathematical learning, managed obstacles they experienced during personal instrumental genesis and how instrumental distance affected their professional instrumental genesis.*

Keywords: Touchscreen technology, TouchTimes, instrumental distance, double instrumental genesis

There are a wide variety of resource options available for the teaching and learning of primary school mathematics. Physical (hands-on) objects have been used to support the development of mathematical understanding for many years and, with the emergence of touchscreen devices which are better suited to the as-yet developing fine motor skills of younger students, digital technology is becoming a more viable resource to primary school classrooms (e.g. Sinclair & Baccaglini-Frank, 2016). Integrating technology into their teaching repertoire and becoming adept at leveraging the opportunities that technology can offer for teaching and learning remains challenging for many teachers (Trigueros et al., 2014), and this is also the case when implementing TT in primary school classrooms (Sinclair et al., 2020). The notions of *instrumental distance* and *double instrumental genesis* (Haspekian, 2014) are useful for examining the impact of integrating digital technology on mathematics teachers' practice.

TouchTimes (Jackiw & Sinclair, 2019), a multi-touch iPad application, enables primary school children to experience relational and functional aspects of multiplication through engagement with two different microworlds, *Grasplify* and *Zaplify*. While using their fingertips to create and transform pictorial representations of multiplicative situations on an iPad screen, the children receive immediate visual, tactile and symbolic feedback from TT in response to their actions.[1]

The design of TT focuses on the two quantifying dimensions that comprise the multiplicative relationship; the first being the unit of measurement (the multiplicand), and the second involving the quantity of that unit (the multiplier). Multiplication from this perspective involves "a count of a [larger] unit for which a relationship to another, smaller unit, is already established" (Davydov, 1992, p. 12). The design of *Grasplify* is influenced by Davidov's (1992) double change-in-unit approach to multiplication that is grounded in measurement. The first unitising occurs when the multiplicand is established (in *Grasplify*, this is the creation of the pips) and the second occurs when determining the number of units to be used (the number of pods). Rather than repeated addition, both *Grasplify* and

1 For further information on *TouchTimes*, view this short video demonstration. https://youtu.be/JkznPdu8RkA

Zaplify focus on doubling, tripling, etc., a design choice influenced by the relational and functional aspects of Vergnaud's (1983) work on the conceptual field of multiplication.

Theoretical framing

The instrumental approach extends Vérillon and Rabardel's (1995) theory of instrumentation of human tool-use into the domain of mathematics education, utilising its focus on instrumental genesis for analysis of technology-mediated teaching/learning (Artigue, 2002). There is a two-way process during instrumental genesis, in which a physical object or tool, defined as an artefact, influences the user (*instrumentation*) whilst the user adjusts to the tool (*instrumentalisation*). It is during this process that the artefact develops into a functional instrument for the user. This progression is even more complex in the case of teachers, who must engage in what Haspekian (2014) terms *double instrumental genesis* when adopting unfamiliar technology for teaching. Initially, a personal instrumental genesis occurs when teachers first engage with an artefact as learners themselves. As the artefact becomes an instrument for mathematics, teachers then engage in a professional instrumental genesis as they appropriate and construct the technology into a didactical instrument for use with students. Haspekian declares, "The teacher's professional genesis with the tool is much more complicated as it includes the pupils' instrumental genesis" (p. 254).

In examining the sustained integration of technology into mathematics teaching, Haspekian also refers to the notion of *instrumental distance* between the digital technology and the mathematics. This relates to the gap between 'current school habits' and the didactical experiences offered by the technology, and can include the computer transposition (how the computer mediates the mathematical concepts in question, as per Balacheff, 1996), institutional, didactical or epistemological changes that occur when a tool is introduced into mathematics teaching. The gap must be large enough to make the benefits of adopting the technology apparent, but not so large as to discourage teachers from its integration.

Given that TT was developed specifically for mathematics teaching, and that none of the teachers had any prior experience using it, double instrumental genesis provides a way to examine how these teachers experienced this digital technology as learners themselves, as well as their subsequent transition to thinking about it as a didactical tool for teaching mathematics and the effects of instrumental distance during the process of integrating TT. The research questions specifically relate to these ideas. (1) During their personal instrumental genesis of TT, were there specific problems or obstacles related to either the technology or the mathematics it represents, encountered by the primary school teachers interviewed? (2) How did the instrumental distance between prior ways of teaching multiplication and using TT affect the evolution of these teachers' professional instrumental genesis of TT? In order to respond to these questions, I draw on data gathered during interviews with these four teachers about their experiences implementing TT as a teaching tool in primary classrooms.

Method

Three of the teachers are primary school generalists, and one is a former secondary mathematics teacher, who is now a mentor teacher that works with K-12 teachers in her school district to improve mathematics teaching. Their teaching experience ranged from 9–24 years, each had a master's degree, and all were working in grade 3 or 3–4 classrooms in British Columbia, Canada when utilising TT. Each teacher had volunteered to provide feedback for a larger, multi-phase project, in which the

author is part of, involving the implementation of TT in primary school classrooms, and to contribute to the development of tasks and assessments to be used with it.

The teachers were initially introduced to TT during the first meeting of this larger project, which was videorecorded. With the exception of Leah's first reaction to TT (which is used as a comparison to her later thoughts about TT that emerged during the interviews), the data in this paper has been taken from 60–80–minute semi-structured interviews with each of the teachers individually (one for each teacher), which were conducted via Zoom in June through August of 2021. Having observed that teacher responses in the larger research group meetings would often build from the ideas shared with each other, it was hoped that this may also occur by interviewing pairs of teachers together. Therefore, two additional interviews were conducted where the four teachers were interviewed in pairs (one interview for each pair). In each interview, the teachers were asked about their initial experiences with TT as learners, their thoughts about how TT presents multiplication, how they used it as an instructional tool and their observations related either to TT or to its mathematical representations, as well as what they noticed about student learning during the implementation of this digital technology. Each interview was transcribed in its entirety and the resulting transcripts were then analysed for common themes that emerged based on the experiences shared by the four teachers.

Data analysis and results

With my research questions in mind, the data was analysed with two specific aims. The first was to identify instances of obstacles or challenges related to the personal instrumental genesis of TT shared by each teacher, while the second was to look for specific examples of instrumental distance that influenced the evolution of each teacher's professional instrumental genesis. I first categorised the experiences of instrumental genesis of TT as either personal or professional, while noting any obstacles or challenges shared prior to examining the examples of the latter more closely to determine if instrumental distance was apparent and, if so, whether the resulting gap was related to computer transposition, institutional, didactical or epistemological changes. I wanted to understand better the challenges these teachers experienced with TT as learners themselves, as well as what factors influenced the integration and use of TT into each teacher's mathematical teaching practice. I will now discuss five specific challenges in the teachers' double instrumental genesis.

(a) Leah: "*Grasplify* is backwards". A member of the research group, Leah's initial encounter with TT occurred during our first teacher–researcher team meeting. While using the app, she noticed the multiplicand × multiplier = product ordering displayed by TT and stated to the group that this was "backwards". Leah shared how she would refer to the textbook to guide her teaching. The textbooks that she referred to all showed 4 × 3 as four groups-of three, and were always in the multiplier × multiplicand = product ordering. *Grasplify* however, displays the equation in the opposite order, where 4 × 3 is four, three times (see Figure 1).

Figure 1: (a) Pips and pods; (b) *Grasplify* display of 4 × 3 = 12

Leah's reaction to this ordering occurred during her first exposure to *Grasplify*, and was immediate. Though she was still learning how TT functions, and in the very first stage of personal instrumental genesis, this obstacle intertwined with her professional instrumental genesis and how she could use *Grasplify* with her students. The instrumental distance between the computer transposition and the epistemological aspect of Leah's personal representation of multiplication and how she taught it was significant from her first use of the *Grasplify* world and continued to be problematic for her.

When I interviewed her three years later, Leah mentioned again how she "couldn't get past the groups-of thing and it was so huge for me", but explained that, "if I really believe in […] how this [app] works and what multiplicative thinking means, it doesn't matter what happens next. It's what happens in their [her third grade students'] thinking." She went on to say, "I was so stuck on this groups-of thing and then I started thinking about, well, what does multiplication mean? So, it really changed my thinking about what it [multiplication] means." It was through discussion in the TT teacher–researcher group, and during Leah's use of *Grasplify* in her classroom, that the instrumental distance began to narrow. She explained that the commutative property makes the order of the factors irrelevant, so the product will be the same. Observing her own students using TT was what was most convincing for Leah, who noted that students, "didn't know any different, and so they were understanding it [the ordering] the way it was, and it didn't matter". The most significant growth in Leah's personal instrumental genesis occurred as a result of her professional instrumental genesis, rather than preceding it, as often occurs when implementing new digital technology in the classroom.

Another challenge that Leah described involved the impermanence of the pips and pods on the iPad screen. When first using *Grasplify* with her students, she was projecting it onto the wall for all to see. At that point, she only had access to one iPad with TT on it, and was engaging in teacher-led prediction tasks. For example, she would create pips and pods on the screen and asked the students to predict how she would double the product by only changing the pips (see Figure 2). Leah shared her frustration when, each time she removed her pip-making fingers, it would reset the screen. This left her 'stuck' at the front of the classroom and unable to view the predictions students were making on their mini-whiteboards. However, once multiple iPads were available for student use, she noted how the impermanent nature of the pips and pods forced her students to think more carefully about what they were doing, adding an element of concentration and a bit of planning that resulted in a more "metacognitive aspect to it. It's not just playing […], it's thoughtful play". This aspect of the technology and how it affected Leah's ability to use it and monitor student progress, created an obstacle for her professional instrumental genesis. It was not until she observed how this lack of permanence affected student engagement with the tasks, that the instrumental distance grew smaller.

Figure 2: Doubling task progression

(b) Rachel: It was not intuitive. When first using TT, Rachel did not find the app to be intuitive. She described it as hard to use and admitted to having difficulty thinking of ways to use it with her students. As was observed with Leah, Rachel's personal and professional instrumental geneses were

closely intertwined and the instrumental distance was initially large, making TT difficult for her to adopt and implement without assistance. It was through the shared experiences of other teachers within the teacher–researcher group, the teacher discussion about what they had difficulties with or found valuable when using TT with their students, as well as the provision of task ideas to be used with students, that helped Rachel overcome these initial obstacles and begin using *Grasplify* in her classroom. She explained that she needed teacher tasks that were already developed to support her initial implementation of TT and also suggested the creation of short videos to help other teachers better understand the app and the tasks that can be used with it. Rachel described the benefits of being part of a cohort of teachers who were talking more deeply about multiplicative thinking, their experiences teaching with TT and its accompanying tasks and how this influenced her thinking about the properties of multiplication and being more purposeful about this in her own teaching. The instrumental distance narrowed over time, and although TT was not initially intuitive to use as a teaching tool, its use began to change the way she thought about and taught multiplication.

(c) Amy & Rachel: Using *Grasplify* in the "opposite way". As these two teachers continued to use *Grasplify* with their students over the course of two school years, the ways they described using it were becoming more personalised, reflecting on-going professional instrumental genesis. When discussing *Grasplify* as a teaching tool, the differences between traditional methods of teaching multiplication and those afforded by TT were described as beneficial by both teachers. When interviewed together, the pair would often elaborate on and extend each other's ideas. They explicitly stated that TT is not the *only* model that they use with students when teaching multiplication, that it is simply *one* model. Going further, both described teaching multiplication using other models in comparison with how they used TT. Amy commonly begins by writing a multiplication equation on the board for all to see. After writing 3×2, for example, she would then proceed to use manipulatives or drawings to create three groups-of two, or the applicable array or area model or a number line drawing for skip counting. She was starting from the symbolic mathematics and then working to create either physical or visual representations that explained what the symbolic mathematics meant. Whereas when using *Grasplify*, Rachel described using it in the "opposite way". When asking her students to skip count to twenty, she was, "not necessarily looking to show a model for that equation, […] the equation is there, but you're trying to get at concepts that might be harder to get by just drawing something"[2].

Amy pointed out that *Grasplify* provided a visual representation of multiplication for students that is difficult to demonstrate using physical manipulatives or drawings and that, because *Grasplify* is constantly changing and moving, it encourages more open-ended thinking and discussion. For her, "the emphasis is on the exploration because the answer is already provided by TT and therefore that isn't where the focus is". She used other models when she wanted the focus to be on the answer. Rachel agreed and reiterated that she wanted her students to notice what happens when they add or remove fingers, how that relates to what is happening within the pods and then how this influences the numbers within the equation and the product itself. She was trying to enhance her students understanding of multiplication in a different way, through the growth of pips spreading across the pods. Rachel used these types of tactile experiences with immediate visual feedback, to "enhance

[2] For a more detailed description of Leah and Rachel's classroom implementation of Grasplify, see Bakos (in press).

students' comprehension of multiplication in ways that are different, you know harder, to get at through pencil and paper or even manipulatives".

Teaching with TT begins with students exploring the app, noticing the effects of their fingers on the pips and pods, then later, using intentional questioning, she directs student attention towards the mathematical symbols that are also visible on the screen. Student experience with the multiplicative models takes place first and then she builds her teaching on connecting such experience with symbolic mathematics. The more operational approach of starting with an equation and explaining it through a multiplicative model and using *Grasplify* to provide dynamic and relational experience with multiplication was a complete inversion of their approach to teaching multiplication and yet this was what Amy and Leah both welcomed about the digital technology. It was not seen to be detrimental: rather it was considered advantageous for student learning.

(d) Kate: Transitioning across multiplicative models. Of the four teachers I interviewed, Kate was the only one who had utilised both of the TT microworlds with her students. The use of the two different multiplicative models represented by *Grasplify* and *Zaplify* allows for examining what I term *intra-instrumental distance*, in that there are two related tools and a possible distance between them.

Kate was very purposeful in taking advantage of this *intra-instrumental distance*, wanting students to learn what multiplication is and for them to understand the different representations and how to go between them, while also recognising "that multiplication is the common theme" in the different multiplicative models embodied through *Grasplify* and *Zaplify*. She engaged students in activities that explicitly directed attention towards comparing and contrasting both worlds. For example, after sharing screenshots of the same multiplication sentence represented by *Grasplify* and *Zaplify* (see Figure 3), students were asked to describe how these were the same and how they were different. Kate would sometimes provide screenshots of a multiplication equation in one microworld and ask students to draw what that equation would look like in the other. Kate's goals were for students, "to make connections between the two different worlds, make connections between the symbols, the equations, the representations, because at the end of the day, I wanted them to know how to multiply and what multiplication was, so it kept coming back to that one idea". Kate's professional instrumental genesis involved her prioritisation of the symbolic mathematics and the instrumental distance between TT and her epistemological beliefs of what was important for students to learn mathematically she very intentionally kept narrow. The learning activities that she designed for students prioritised the symbolic and representational models of multiplication and how TT could be used as a vehicle to drive students towards those goals.

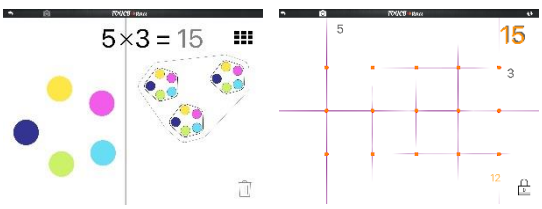

Figure 3: (a) *Grasplify* multiplicative model; (b) *Zaplify* multiplicative model

After engaging the children with various TT tasks for a few weeks, Kate described how she projected some examples of different representations of multiplication onto the board and found it "really powerful" when the students could easily identify *Zaplify* or *Grasplify* in the models, even though the

models projected were taken from another teacher resource. “Switching back and forth between the models connected to the different representations. So, when they see an array model, they’re connecting it to *Zaplify* or when they’re seeing the groups-of, they’re seeing it as pips and pods.” For Kate, this would be useful when transitioning into what she referred to as “the more formal symbolic type of math” that most teachers teach. She explained that this is beneficial to students because when they move on to another teacher, they can carry their TT experiences into other contexts and that multiplication would still make sense.

(e) Amy, Leah & Rachel: How *Grasplify* shaped their teaching. Both Amy and Rachel would sometimes have students create drawings to depict what they had learned after completing a task using *Grasplify*. Amy used these drawings as a formative assessment tool to “see what they noticed. Like did they notice the colours? What were they able to pick up on? What did they attend to?” Of importance to Rachel was determining what her students were seeing and what they understood from TT, so that she could use this information to plan what experiences she needed to provide during the next class. Her goal was not on students transferring this knowledge to an equation: rather, her goal was to know more about what her students, both individually and collectively, understood from that day’s task and to try to glimpse what it was that *they* were seeing.

As her students used *Grasplify* to “play with” and learn about multiplication, Leah would watch what they were doing. She explained how, even if students were not always going in the direction she had hoped for, that she was better able to understand where they were coming from and that she could redirect with a different question to get them thinking about the relevant mathematical concept that was emerging from their explorations. Leah found that, “TT allowed me to actually see how kids were thinking about multiplication”, in comparison with her traditional teaching where she would show students what to do and expected them to mimic this.

Discussion and conclusion

Throughout the process of double instrumental genesis, all four teachers became increasingly responsive to the teaching opportunities that emerged from student experiences with TT. For Leah in particular, the reaction of her students to *Grasplify* significantly influenced how the instrumental gap continued to narrow. The mathematics learning that her students were engaged in influenced her comfort with using digital technology with which she was initially very uncomfortable. She explicitly shared that, “one thing that affected me is the conversations I had with the kids as a teacher”.

For Rachel, she was not focused on memorising facts or writing equations, and therefore TT meets her where she is concerned, which is about providing new meanings for multiplication. The use of *Grasplify* allowed her to provide learning experiences with visual representations of multiplication that were dynamic and with which students could interact in a relational way. The limits of static drawings and the difficulty for children to build multiplicative situations out of physical manipulatives without error was very visible for Rachel.

The process of double instrumental genesis was not straightforward for these teachers during their integration of TT. Although there was an initial experience of learning to use the digital technology personally, for these teachers, it was difficult to differentiate between their personal and professional instrumental geneses. Their reactions to TT and the manner in which it presents multiplication were clearly related to how they would use it as teachers to promote student learning. The instrumental gap

narrowed significantly as these teachers used TT with their students. When Leah's students were not having difficulty with the multiplicand × multiplier ordering, she began to re-evaluate her own thinking. When Kate's students were able to identify the multiplicative models experienced in TT to static drawings of multiplicative models, the *intra-instrumental distance* narrowed for her.

Although obstacles were encountered by these teachers during their personal instrumental genesis of TT, the instrumental distance between previously used ways of teaching multiplication and the relational experiences with multiplication offered by TT were either embraced as positive differences or narrowed as the teachers' professional instrumental genesis of TT advanced.

Acknowledgment

I would like to thank Dr. David Pimm and Dr. Nathalie Sinclair for their guidance and support.

References

Artigue, M. (2002). Learning mathematics in a CAS environment. *International Journal of Computers for Mathematics Learning*, *7*(3), 245–274.

Bakos, S. (in press). An *ensemble* approach to studying the teaching of multiplication using *TouchTimes*. In A. Clark-Wilson, O. Robutti & N. Sinclair (Eds.), *The mathematics teacher in the digital era* (2nd ed.) Springer.

Balacheff, N. (1996). Advanced educational technology: Knowledge revisited. In T. Liau (Ed.), *Advanced educational technology: Research issues and future potential* (pp. 1–20). Springer.

Davydov, V. (1992). The psychological analysis of multiplication procedures. *Focus on Learning Problems in Mathematics*, *14*(1), 3–67.

Haspekian, M. (2014). Teachers' instrumental geneses when integrating spreadsheet software. In A. Clark-Wilson, O. Robutti & N. Sinclair (Eds.), *The mathematics teacher in the digital era* (pp. 241–275). Springer.

Jackiw, N., & Sinclair, N. (2019). TouchTimes [iPad application software]. Tangible Mathematics Group, Simon Fraser University. (https://apps.apple.com/ca/app/touchtimes/id1469862750)

Sinclair, N., & Baccaglini-Frank, A. (2016). Digital technologies in the early primary school classroom. In L. English & D. Kirschner (Eds.), *Handbook of international research in mathematics education* (3rd ed.) Routledge. https://doi.org/10.4324/9780203448946

Sinclair, N., Chorney, S., Güneş, C., & Bakos, S. (2020). Disruptions in meanings: Teachers' experiences of multiplication in *TouchTimes*. *ZDM: Mathematics Education*, *52*(7), 1471–1482.

Trigueros, M., Lozano, M., & Sandoval, I. (2014). Integrating technology in the primary school mathematics classroom: The role of the teacher. In A. Clark-Wilson, O. Robutti, & N. Sinclair (Eds.), *The mathematics teacher in the digital era* (pp. 111–138). Springer.

Vergnaud, G. (1983). Multiplicative structures. In R. Lesh & M. Landau (Eds.), *Acquisitions of mathematics concepts and processes* (pp. 127–174). Academic Press.

Vérillon, P., & Rabardel, P. (1995). Cognition and artifacts: A contribution to the study of thought in relation to instrumented activity. *European Journal of Psychology of Education*, *10*(1), 77–101.