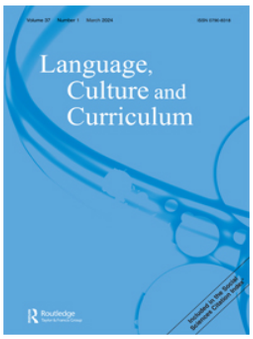


Language, Culture and Curriculum

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rlcc20

Mathematical benefits of a language-friendly pedagogical tool: a praxeological analysis of teachers' perceptions and practices

Alexandre Cavalcante, Antoinette Gagné & Emmanuelle Le Pichon-Vorstman

To cite this article: Alexandre Cavalcante, Antoinette Gagné & Emmanuelle Le Pichon-Vorstman (2024) Mathematical benefits of a language-friendly pedagogical tool: a praxeological analysis of teachers' perceptions and practices, Language, Culture and Curriculum, 37:1, 27-43, DOI: 10.1080/07908318.2023.2265407

To link to this article: https://doi.org/10.1080/07908318.2023.2265407

LANGUAGE, CULTURE AND CURRICULUM
2024, VOL. 37, NO. 1, 27–43
https://doi.org/10.1080/07908318.2023.2265407

Routledge
Taylor & Francis Group

Mathematical benefits of a language-friendly pedagogical tool: a praxeological analysis of teachers' perceptions and practices

Alexandre Cavalcante, Antoinette Gagné and Emmanuelle Le Pichon-Vorstman

Ontario Institute for Studies in Education, University of Toronto, Toronto, Canada

ABSTRACT

In this paper, we report on data from 40 middle and secondary school mathematics teachers and teacher candidates as they begin to articulate the intersection of language-friendly pedagogy, mathematics teaching, and a multilingual technological tool by way of a two-hour introductory workshop. We use an Anthropological Theory of the Didactic which recognises that mathematics instruction and language instruction are done differently under distinct institutional conditions (curriculum, culture, language, etc.) to analyse our data. Our findings suggest that teachers' beliefs and perspectives regarding their multilingual students guide their choices about how to use a powerful digital multilingual platform to either remediate what they perceive as deficits in their students or leverage the assets of multilingual learners.

ARTICLE HISTORY
Received 2 May 2023
Accepted 18 September 2023

KEYWORDS
Language-friendly pedagogy; mathematics teacher perceptions; learning platform; praxeology; multilingual learners; STEM

Introduction

The closure of schools across Canada during the COVID-19 pandemic highlighted significant gaps in educational provision, particularly with respect to the underutilisation of digital technologies for teaching in general, and in the context of this project, for STEM education. K-12 teachers struggled to find the necessary resources that matched the curricula they were mandated to teach. This made the transition to online teaching a major challenge for them, especially when teaching students not yet fluent in English and/or French, the languages of instruction in Canada. In fact, it is only recently that school stakeholders have become aware of the importance of languages and cultures in education as part of a dynamic and fluid learning process. Language-friendly pedagogies are based on the concept of interdependence (Cummins, 2021) which implies that the transition from one language to another allows for the positive transfer of skills and concepts and the strengthening of each language.

In this article, we aim to move beyond the benefits of a language-friendly pedagogy (Le Pichon & Kambel, 2022) to students' mathematics and science identities. We propose a discussion on whether a language-friendly pedagogy can also promote a deeper understanding of the content of mathematics for all students. Our assumption

CONTACT Alexandre Cavalcante alexandre.cavalcante@utoronto.ca

is that language-friendly pedagogy has the potential to uncover connections between mathematical concepts typically taken for granted in traditional mathematics curricula.

To this end, within the scope of the ESCAPE projects (*Enseigner les sciences aux élèves plurilingues, https://escapeprojects.ca*), we invited in-service and pre-service mathematics teachers to engage in language-friendly pedagogy using Binogi, an online platform that provides STEM instructional video content in several languages. At the time of the research, students could change the language of videos and quizzes to English, French, Arabic, Dari, Tigrinya, Spanish, German, and Somali switching the audio and/or adding subtitles (see Le Pichon et al., 2021; Le Pichon & Cummins, 2020). These were languages available in the Canadian version of Binogi. The Swedish (original) version contained other languages such as Swedish.

Access to the Binogi resource, therefore, represented an opportunity for teachers during the pandemic to engage in online mathematics education with a versatile multilingual programme aligned to the local curriculum which allowed students to experience learning in ways that would not have been possible without digital technologies. Our aim was to examine the feasibility and effectiveness of this tool to foster linguistically and culturally relevant and responsive teaching in Canadian classrooms. While 17 in-service teachers implemented the platform in their classes, more than 50 preservice teachers planned lessons to facilitate mathematics teaching and learning. In this paper, we report on data from 40 middle school (Grades 7 and 8) and secondary school (Grades 9–12) mathematics teachers and teacher candidates.

The journey to language-friendly pedagogy in mathematics

Around the world, most societies have become multilingual resulting in a large number of students learning mathematics via the medium of a language that differs from their home language(s). As such, an increasing number of scholars and policymakers have been calling for pedagogical approaches where multilingual learners' cultures, languages and experiences are understood as resources or assets for mathematics learning (Barwell, 2018; Beacco et al., 2016; Planas, 2018). In the last decade, the number of guides and articles for Math teachers has also increased (see for example, Baird et al., 2020: Chval et al., 2021; Kersaint et al., 2013; Mesta & Reber, 2019). In Ontario, various guides for teachers (see for example Ontario Ministry of Education, 2008) propose programme adaptations to meet the needs of multilingual learners. These adaptations range from accommodations (strategies that enable students to meet curriculum expectations) to modifications (changes to curriculum expectations).

In a guide for teachers, Mesta and Reber (2019) explain that numbers and symbols are not formed or interpreted the same way across languages and cultures. Consequently, the authors argue that multilingual learners need particular support in learning mathematics since they might encounter math problems with different approaches and cultural terms from their original country. Furthermore, Arizmendi et al. (2021) explain that the additional cognitive load of learning mathematics vocabulary and trying to make sense of complex sentences in word problems may create achievement gaps for English learners (e.g. Attar et al., 2022; Le Pichon-Vorstman et al., 2020; Moschkovich, 2015). For example, Alt et al. (2013) and Attar et al. (2022) report similar findings regarding mathematics test

performance of Spanish and Syrian-speaking students in the USA and the Netherlands: their performance was significantly better when the test was offered in their native language. These results suggest that these tests measure mathematics language rather than mathematics concepts and point to the important role that L1 and L2 language development can have on achievement in mathematics. It is therefore important to think about pedagogies that sustain and foster multilingual students.

A continuum of pedagogies

There are several terms used in the literature to describe more inclusive pedagogical approaches for diverse students including culturally responsive/relevant pedagogy (CRP) (Gay, 2000; Ladson-Billings, 1995, 2006), culturally sustaining pedagogy (CSP) (Paris, 2012), culturally AND linguistically relevant pedagogy (LCRP) (Viesca et al., 2019), linguistically responsive pedagogy (LRP) (Avalos & Secada, 2019) and more recently, language-friendly pedagogy (LFP) (Le Pichon & Kambel, 2022). Although these pedagogical approaches have grown from fieldwork in either bicultural/bilingual or multicultural/multilingual school contexts, a focus on creating safe and more socially just learning spaces for diverse students underpin CRP, CSP, CLRP, LRP and LFP. It is useful to consider these on a continuum where either culture or language factors weigh more heavily in determining the teacher's pedagogical response (see Table 1). A brief overview of each pedagogical approach and how mathematics teachers and their multilingual learners might benefit from its implementation follows.

A focus on culture: CRP, CSP, LCRP

Building on Gay's (2000) work, Richards et al. (2007) build on Gay (2000) to provide a list of nine actions for teachers who want to be culturally responsive. These actions include affirming the cultural identity of students through classroom practices and teaching materials, helping students to learn about the many types of diversity that surround them, and building positive relationships with students, their families and the community.

Furthermore, Abdulrahim and Orosco (2020) explain that culturally responsive math teaching (CRMT) is grounded in sociocultural theory where the premise is that mathematical development and cognition are shaped by social interaction and mediated through the use of cultural practices (Vygotsky, 1978). In their synthesis, the authors contrasted their own study with six others where bilingual teachers used the first language of their bilingual students during mathematics instruction to facilitate their learning. They report that in

Table 1. Continuum of inclusive pedagogies.

A focus on CULTURE		A focus on CULTURE & Language	A focus on LANGUAGE & Culture	A focus on LANGUAGE (inclusive of culture)
CRP Culturally Responsive/ Relevant Pedagogy	CSP Culturally Sustaining Pedagogy	LCRP Culturally & Linguistically Relevant Pedagogy	LRT Linguistically Responsive Teaching	LFP Language Friendly Pedagogy

several studies in classrooms with mathematics teachers who were responsive to their students' cultures and languages, multilingual learners' mathematics knowledge improved. In order to create inclusive learning spaces, the authors argue that mathematics teachers need to embrace diversity and actively look for ways to build on multilingual learners' cultural and linguistic resources. Multilingual learners benefit from having a cultural frame of reference during mathematics instruction as a bridge between academic content and their home and community experiences (Ladson-Billings, 1995).

Building on the important contributions of culturally responsive pedagogy (Ladson-Billings, 1995) to the education of students who share the same home language, Paris (2012) proposes culturally sustaining pedagogy as an alternative approach for teachers who want to affirm their multilingual and multicultural students' racial, cultural, and ethnic identities. The author explains that culturally sustaining pedagogy 'seeks to perpetuate and foster—to sustain—linguistic, literate, and cultural pluralism as part of the democratic project of schooling' (p. 93). He suggests the word 'sustaining' to go beyond binaries such as English and Spanish because the term 'requires that [schools] support young people in sustaining the cultural and linguistic competence of their communities while simultaneously offering access to dominant cultural competence' (p. 95).

Viesca et al.'s (2019) culturally and linguistically relevant pedagogical framework for improving the teaching of mathematics to multilingual learners suggests that mathematics teachers should have math content knowledge, be aware of the language of math, know the stage of English or school language proficiency of their students, engage the families and community and adopt meaningful assessment practices. They suggest that by keeping these five elements in mind when teaching mathematics, multilingual students will achieve higher levels of learning regardless of their proficiency in English/school language or grade level. This is an example of a pedagogical framework that places aspects of culture and language at its core.

Moving to linguistically responsive and language-friendly pedagogy

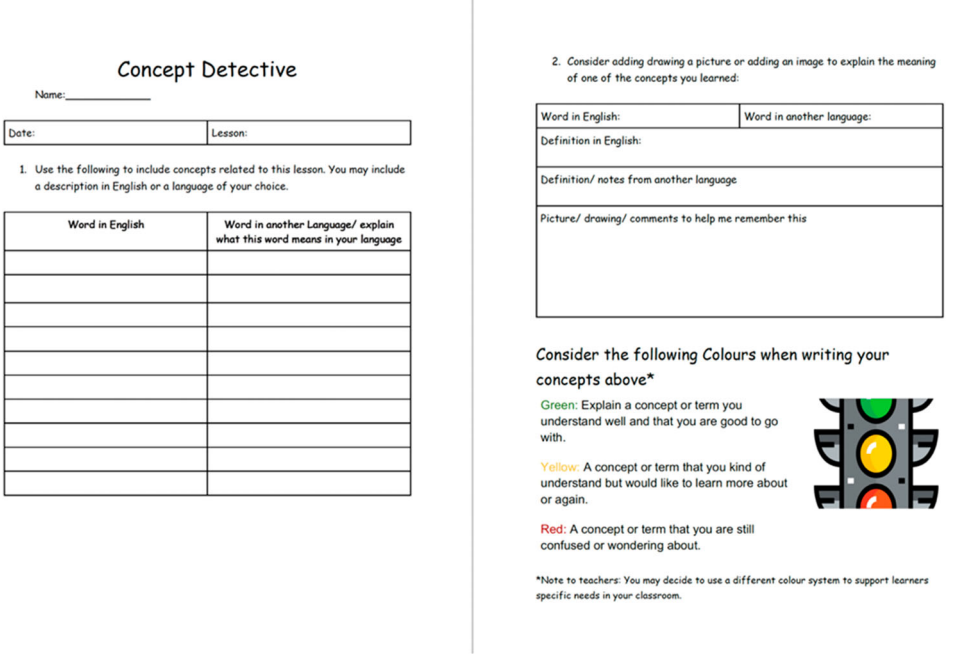
Increased mobility has led to greater linguistic diversity in schools around the world which, in turn, has inspired a movement toward linguistically responsive and language-friendly pedagogies. Several studies have highlighted the affordances incurred when teachers encourage multilingual students to draw on their full linguistic repertoire for learning mathematics (see for example, Barwell, 2018; Planas, 2018; Schüler-Meyer et al., 2019). Prediger and Uribe (2021), for example, observed instances where math teachers used linguistically responsive strategies that allowed students to understand new concepts better, and provided multiple perspectives on the concept introduced to support meaning-making.

Avalos and Secada (2019) explain that linguistically responsive mathematics teachers must understand the interconnection between language, culture, and identity as well as the sociopolitical aspects of language use and language education. They must also know that the language of the school is imbued with power and that the languages of their multilingual learners are often overlooked. Math teachers who are linguistically responsive create opportunities for multilingual students to draw on their full linguistic repertoire to translanguage (García & Kleyn, 2016; Maldonado et al., 2020) as one way to even the playing field and give them more agency in learning mathematics. The

authors also list linguistically responsive practices in terms of engaging multilingual students in a mathematics discourse community: 1) anticipate and plan for the language and content demands of new math tasks, 2) explain and use examples to ensure that students develop a deeper knowledge of math language and content, 3) promote translanguaging (García & Kleyn, 2016; Li, 2018) to ensure that MLs develop math knowledge, 4) talk about the context of the math problem as well as explore its meaning by focussing on the language embedded in the problem, and 5) build solid relationships with students and encouraging interaction in mathematics discussions in small or large groups.

In 2022, Le Pichon and Kambel proposed a language-friendly pedagogy that builds on the pedagogies described above but goes beyond them, as it involves a whole-school approach: all the languages of the community are valued and welcomed, and students, families, and various staff work together to infuse it at all levels, in the classroom, in the school, in the community. Figure 1 illustrates one of the tools used in classrooms, the concept detective. The team developed this resource within the ESCAPE projects, aiming to inspire teachers to incorporate language objectives into every lesson and empower students to expand their understanding while drawing upon their own and their families' knowledge.

Language-friendly pedagogy is a perspective that assumes that every individual needs to be included, as opposed to an integrative perspective that focuses on helping a particular student to catch up with the rest of the group. Language-friendly pedagogy embodies an asset-based orientation to every person in the school and calls for the languages and cultures of the school community to be visible both throughout the school and in the pedagogical approach adopted by subject area teachers. It is within this pedagogical perspective that we situate the project and findings described in this paper.



Concept Detective

Name:_____

Date:	Lesson:

1. Use the following to include concepts related to this lesson. You may include a description in English or a language of your choice.

Word in English	Word in another Language/ explain what this word means in your language

2. Consider adding drawing a picture or adding an image to explain the meaning of one of the concepts you learned:

Word in English:	Word in another language:
Definition in English:	
Definition/ notes from another language	
Picture/ drawing/ comments to help me remember this	

Consider the following Colours when writing your concepts above*

Green: Explain a concept or term you understand well and that you are good to go with.

Yellow: A concept or term that you kind of understand but would like to learn more about or again.

Red: A concept or term that you are still confused or wondering about.

*Note to teachers: You may decide to use a different colour system to support learners specific needs in your classroom.

Figure 1. The Concept Detective (source: https://escapeprojects.ca/teaching-resources).

Theoretical framework

To answer our research question (*What mathematical benefits do elementary and secondary teachers notice in a language-friendly pedagogical tool?*), we guided our analysis based on the Anthropological Theory of the Didactic, ATD (Chevallard et al., 2022). Using ATD to understand language-friendly mathematics education is particularly helpful for it acknowledges different ways of engaging with mathematics and language. Indeed, the approach defies the often-naturalized conception of disciplines as independent bodies of knowledge merely reproduced in schools. An Anthropological Theory of the Didactic perspective recognises that mathematics instruction and language instruction are done differently under distinct institutional conditions (curriculum, culture, language, etc.).

This framework's fundamental unit of analysis resides in the praxeological instance where praxeology is understood as any *intentional* human activity (Chevallard et al., 2022). A praxeological instance can be analysed as a set of four elements consisting of a type of task, a technique, a technology, and a theory. While the first two elements form the practice block of a praxeological instance (the material event), the latter two form the theoretical (the justifications for an event). In the following paragraphs, we explain these elements using one illustrative example.

Throughout the first year of the project, the Binogi platform was made available to teachers interested in Binogi and language-friendly pedagogy. The following passage is from one of the exchanges we had with a secondary mathematics teacher. After having used the platform for a while, this teacher wrote us the following message:

> I am finding most of the math videos and quizzes with Binogi helpful for my 9th graders but wanted to share that the equations series is not possible to use, as it goes about teaching balancing equations in a way we would not use in Canada (the index finger method). The series is missing balancing equations that require the distributive property and combining like terms, and equations involving fractions. Maybe you can pass that info on to your math team or ask the Canadian representative if other Canadian teachers have commented on the equation videos.

Figure 2 showcases brief 3 to 5-minute equation lessons in video format, offering language and subtitle customisation, quizzes for assessment, and video scripts in 13 languages, complete with key concepts and definitions.

The *type of task* subsumes the goal of the task and, in this paper, the following question captures its essence: 'What is the goal of using a digital platform?'. In the context of this example, the goal is to teach the concept of equation balance to students in a grade 9 class.

A *technique* subsumes the steps necessary to carry out the task, i.e. the methods chosen by an individual to carry out the task. In this paper, to understand a technique, we ask: 'How is a digital platform used or not?'. In this example, the teacher chose to teach the mathematical concept using a single method to solve equation balance (combining like terms) rather than, for example, allowing students to create their own methods that later could be compared and contrasted. As such the teacher chose not to use the digital platform because she viewed the content presented to solve equation balance in Binogi as irrelevant or inappropriate.

Technology (i.e. the study of technique) subsumes the justification of each technique. Justifications exist in the form of explanations, reasoning, proofs, demonstrations, and

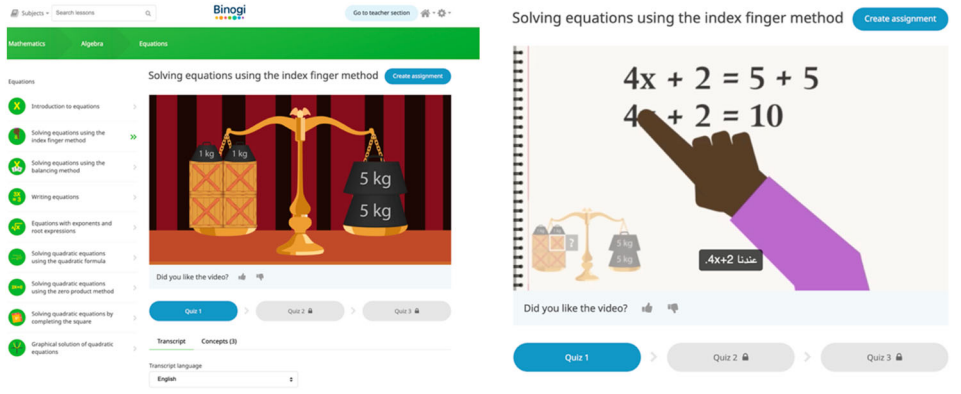


Figure 2. Binogi video on solving equations using the index finger method. Source: https://app.binogi.ca/l/solving-equations-using-the-index-finger-method.

other forms of discourse. In this paper, to understand technology we ask: 'Why is a digital platform used (or not)?'. Mathematics teachers can justify their teaching choices based on a variety of factors which include student content knowledge, access to materials and resources, beliefs about student learning, time constraints, etc. In this example, the teacher chose to disregard Binogi because it did not use the method described in the Canadian curriculum document that guided her practice. The curriculum is therefore the technology used by the teacher to validate her technique.

It is worth noting that such a justification is always a reflection of how a teacher reconciles various factors in decision making. This teacher's choice is based on her interpretation of the curriculum in question. She argued that the method presented in the platform was inconsistent with how the concept of equation balance is presented in Canada. Yet, the Ontario provincial curriculum states that linear equations should be solved 'using a variety of tools (e.g. computer algebra systems, paper and pencil) and strategies (e.g. the balance analogy, algebraic strategies)' (Ontario Ministry of Education, 2020, p. 40). Hence, the teacher likely relied on her interpretation of this curriculum based on her own experience and resources to evaluate the appropriateness of the content of the resource.

Finally, a *theory* subsumes the ensemble of technologies in a somewhat coherent ontology. While many theories are rooted in traditional academic disciplines, a social group can develop a coherent set of technologies to justify their everyday practices without them. In the case of mathematics teachers, their choices and justifications reveal their underlying philosophy of teaching mathematics. Hence, in this paper, to understand theory we ask: 'What is the nature of mathematics teaching reflected in the justifications for using a digital platform?'. In this context, the justification of using only what is consistent with her interpretation of the curriculum reveals that the teacher equates mathematics teaching with following curriculum expectations regardless of the demographics of the students in her classroom. Consequently, for this teacher, doing mathematics 'in a way we would not use in Canada' represents a challenge for mathematics teaching. Her justification implies that students should learn mathematics in the 'Canadian way'.

Table 2. Anthropological Theory of the Didactic in a multilingual mathematics class.

Anthropological Theory of the Didactic framework		Example from a teacher
Practice block	*Type of task* What is the goal of using a digital platform?	Teach equation balancing in a grade 9 math class
	Technique How is a digital platform used?	Use a single method (combining like terms) and disregard alternative methods (e.g. index finger)
Theoretical block	*Technology* Why is a digital platform used (or not)?	The teacher's interpretation of the curriculum defines the appropriateness of a digital platform and validates their choice.
	Theory What is the nature of mathematics teaching reflected in the justifications for using a digital platform?	Mathematics teaching is defined as the following of curriculum expectations.

It is important to emphasise that our analysis does not imply that the teacher deemed alternative methods as invalid. In fact, her decision to use Binogi in class reflects her willingness to provide opportunities for her multilingual students to learn mathematics. However, as the teacher in this example references the Canadian curriculum to justify her choices, she leaves little room for her students to learn mathematics through multiple lenses or to contribute with their own insights.

Table 2 summarises the main elements of ATD to analyse the praxeological instance of teaching equation balancing in the context of a multilingual mathematics classroom.

As we have pointed out, the perceptions of mathematics teachers with regards to a language-friendly pedagogical tool reveal their ideas of mathematics and language education. In this article, we report on the perceptions held by teachers in the context of a professional development workshop. In the next section, we describe the context of the project and the methods used for data collection and analysis.

Context and methods

Participants

This paper reports on the practices and perceptions held by mathematics teachers who participated in a professional development workshop on language-friendly pedagogy. A total of 40 teachers participated in the workshop and data collection. Twenty-eight of those were secondary teacher candidates enrolled in a graduate-level teacher education programme in Ontario, Canada. The workshop was their first time encountering the Binogi digital platform within the context of their mathematics teaching methods course.

We delivered the same workshop to 12 elementary school mathematics teachers during an onboarding session about Binogi. These teachers were interested in supporting their multilingual students by using the multilingual Binogi platform. After taking part in the onboarding workshop, they had the freedom to make their own pedagogical choices related to the use of Binogi in their classes.

Structure of the workshop

We developed a 2-hour workshop to introduce key ideas related to multilingual mathematics classrooms. The first part of the workshop was dedicated to exercises to raise

self-awareness. The structure chosen partially follows the framework proposed by Strong and colleagues (Strong et al., 2016). All participants were expected to have completed an initial exploration of the content and structure of the Binogi platform.

Then, we asked them to access the platform and watch at least one video in any language they were not familiar with. The rationale for such a preliminary exposure was to ensure that the workshop was focused on the pedagogical aspects of this tool instead of being a demonstration of technical features. Then, teachers were invited to reflect on their own experiences teaching language as well as their ideas about mathematics. To build awareness of language in mathematics, we used a checklist of teaching practices related to language in class including items such as ensuring understanding of vocabulary, providing students with opportunities to explain ideas in their preferred language, and promoting collaboration between students in multiple languages.

To contextualise mathematical knowledge and place it in a cultural context, we invited participants to think about counting using their fingers. Our goal was to disrupt the notion that mathematical concepts, even the simplest ones, are universal. We illustrated how, in the duodecimal system (on a base of twelve), counting is done using the phalanges as opposed to counting in the decimal system (on a base of ten) which is typically done using the fingers (see Figure 3). There are several systems for counting using various parts of the hand in different countries.

The next part of the workshop was dedicated to a deeper exploration of these aspects of mathematics. We presented a series of word problems prepared by our Syrian research collaborator to help the participants get a sense of the experience of multilingual students in mathematics classes. Initially, the problems were presented in English with equations written in an unfamiliar format; then, the problems were presented in increasingly unfamiliar ways (mixing various languages and mathematical notations). We asked the participants to solve the problems and reflect on what difficulties they had faced. The final set of problems was presented in English, to help teachers consider the impact of culture on the understanding of the problem for students unfamiliar with local customs. Finally, to discuss the importance of focusing on the process rather than solely on the outcome (see also Strong et al., 2016), we shared feedback from multilingual learners regarding their experiences using the Binogi platform. (see Articles 2 and 3 in this special issue for more on this topic). Table 3 summarises the structure of our workshop sessions.

Figure 3. Counting using phalanges vs counting using fingers.

Table 3. Structure of the language-friendly mathematics workshop.

Time	Activity	Goal
Prior to the workshop	*Exploration of the Platform* Explore the Binogi platform & watch at least one Binogi video in another language	Ensure teachers have a sense of how the platform works in advance of the workshop
10–15 min	*Language Awareness* Discussion of personal experiences with language learning and the role of language in learning mathematics	Help teachers to become more aware of on their positionality, experiences in learning/using different languages and the role of language in learning mathematics
10–15 min	*Mathematics Awareness* Counting using different parts of the hand	Disrupt the notion that mathematical concepts are natural, intuitive, and universal
30 min	*Solving Math Problems* using different notation systems in a language not generally used at school	Help teachers grasp the experience of multilingual learners attempting to learn mathematics in a language they are also in the process of learning
30 min	*Solving Word Math Problems* with unfamiliar cultural referents in English	Help teachers grasp the experience of students from different cultural backgrounds faced with word problems with culture specific examples they are not familiar with
30 min	*Written feedback from students* who have been using the Binogi platform	Provide the perspective of students who have had the opportunity to learn with the Binogi platform
10–15 min	*Questions and comments* from the participants	Give teacher participants the opportunity to ask questions and share thoughts on the platform

Data collection and analysis

During and immediately after the workshops we invited workshop participants to respond in writing to open-ended questions related to their practices and perceptions of language-friendly pedagogy and the Binogi platform. Our questions included: *Tell us how you felt after watching a video in an unfamiliar language and then in English; What did you learn from this experience?; What are some ways you can use Binogi in and beyond the classroom?;* and *What suggestions or recommendations do you have for the resources shared in the workshop?*

Our data analysis focused on general patterns and themes across participants. Our goal was to identify how these teachers made sense of the Binogi platform and its mathematical benefits. Hence, we coded the responses according to the four elements of our theoretical framework – the goal of using Binogi, how Binogi might be used, why use Binogi, and the nature of mathematics teaching reflected in this rationale. In the next section, we present our findings based on these elements.

Findings

What is the goal of using a digital platform?

When prompted about their perceptions of the Binogi platform, all teachers had positive comments. The majority of the comments (20) recognised its usefulness in classrooms and the fact that it '*covers a variety of mathematical strands*'. Two other themes emerged in the responses which specifically mention participants' goals for using the platform.

Five teachers mentioned that Binogi's goal is to clarify mathematical vocabulary in the context of multilingual classrooms. These teachers recognise a diversity of syntaxes in mathematical notations, as well as the terms used in different languages. One teacher explained: '*We were talking about area; it is centimeter squared. My students are used to seeing me write 'cm' and exponent squared, versus the word squared*'. Because of the

notation in one of the Binogi instructional videos, this teacher said she would explain the different notations to make her students aware of these differences.

Seven teachers reported the goal of Binogi is to provide accommodations for multilingual students. For example, one teacher candidate mentioned that '*I learned that students with language barriers may experience the same thing in the classroom. We should provide these students with accommodations*'. The use of the term accommodations (see also Abedi et al., 2004) is noteworthy because it reflects the teacher candidate's awareness of the need to create equitable resources, i.e. that take into account the specific needs of students. The danger would be to consider multilingualism as a deviation or an obstacle to mathematics teaching. The gap between a deficit perspective and an equity perspective is narrow. In this case, it shows the empathy developed by these teacher candidates who have become aware of the specific needs of their students whose first language is not English. Another teacher provided similar feedback, writing that Binogi '*could also be introduced as extra support for students who speak another language*'.

How is a digital platform used?

Despite a few teachers suggesting the use of the Binogi platform in different ways throughout the school year, a majority of participants said that they would consider using the platform mainly to introduce new content and consolidate what they had taught. Seven teachers mentioned they would use Binogi to introduce particular math content they deemed difficult to teach to multilingual students. For example, one teacher explained that she would use Binogi '*as an introduction to integers when I am unable to communicate with them in English'*. Here, again, we notice the remedial use of Binogi. This participant sees it as a remediation tool that would be useful in case of a communication problem (the teacher fails to explain something to a student), as opposed to a resource that is part of a sustainable and inclusive pedagogy. These teacher participants also mentioned other concepts that they would introduce using Binogi including algebraic expressions, order of operations, prime numbers, and negative numbers.

Although the majority of respondents revealed a remedial view of Binogi, one teacher candidate proposed a distinct approach, to '*use Binogi as a minds-on activity to allow the students to guess and make inferences on the content'*. In fact, making inferences is a strategy suggested in the Ontario Math curriculum. Helping students anticipate what content will be taught helps them take ownership of the learning process. The same teacher goes on to explain that Binogi '*allow them* [math teachers] *to integrate different cultures in the lesson plans by providing them* [multilingual students] *with ways to express math in their own languages and to give them an opportunity to share with their peers.'* Here, we notice that the teacher candidate still recognises that students might be unfamiliar with the content being introduced. However, instead of using Binogi to compensate for the level of language proficiency of students, this approach takes advantage of the variety of experiences multilingual students have to contribute to the class. In this case, the teacher candidate considers the resource as a tool to implement a language-friendly pedagogy from a sustainable and inclusive perspective.

As mentioned earlier a few participants proposed using Binogi at the end of a unit to consolidate the content taught. This suggestion positions Binogi as a formative assessment tool, in which students could, according to one teacher, '*access the different*

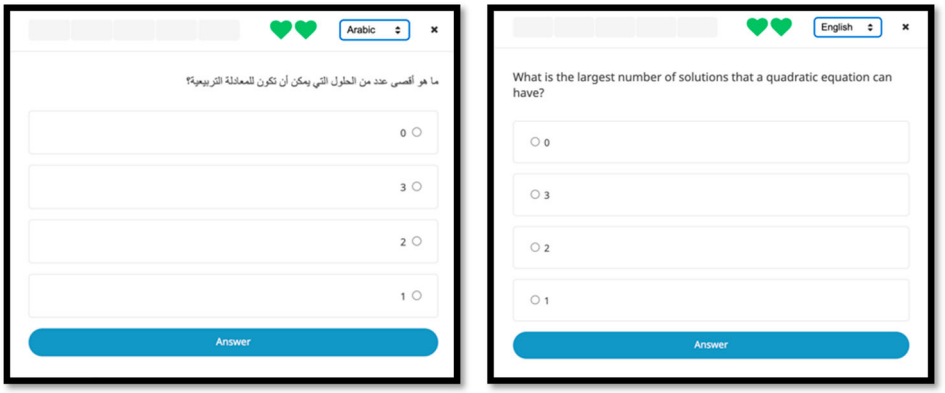


Figure 4. Binogi quiz in Arabic and English. Source: https://app.binogi.ca/l/graphical-solution-of-quadratic-equations.

quizzes attached to the video and interact with the videos to answer the questions in their own language and then again in English'. Using Binogi to support the consolidation of what multilingual students have learned provides them with the opportunity to express their mathematical understanding without being rewarded or penalised based on their language proficiency from an equity perspective.

The two screenshots in Figure 4 display two versions of the same quiz question, one in English and the other in Arabic. Regardless of the language chosen by the student, the teacher will have access to the student's answers to the quiz in the school language.

Why is a digital platform used?

The rationale for the teachers' use of Binogi was threefold. First, six teachers argued that it provided content aligned with the provincial mathematics curriculum. One teacher said that '*with fractions, everything is in Binogi. I'm just going through all those videos because all the important concepts are there.*' Another participant mentioned that '*coding is something I really wanted to watch* [on the Binogi platform] *to see if it will help me with the coding unit that I have left to teach.*' The Binogi platform could potentially support teachers in developing knowledge and understanding of the mathematics curriculum.

Second, seven participants explained that the Binogi videos helped them better understand the experiences of their multilingual students in mathematics. One teacher candidate, after watching videos in unfamiliar languages and then repeating them in English, mentioned that '*I understand the concept that is being talked about. I think now I can better understand students whose first language is not English*'. Such findings highlight the potential of this platform (along with the workshop we created) tools for teacher learning. It can be challenging for preservice and inservice teachers to understand the experience of learning mathematics in a new language. Binogi simulates such an experience through its multilingual features.

Third, two teachers recognised that using Binogi could benefit all students, not just those whose first language is not the dominant language used at school. In fact, these teachers justified the use of Binogi for its potential to elucidate mathematical concepts for all students. One teacher remarked that '*not only is it good for multilingual learners,*

but it also helps students visually see math concepts and the elusive 'Why is this like this?' or 'Why do we need this?' This perspective seems to recognise that mathematics is conceived, expressed, and communicated in different ways in different languages and across different cultures. If given the opportunity, multilingual students can learn new math content as well as much about mathematics *in* and *through* other languages. These participant responses allow us to see the potential of taking part in a workshop such as the one described here in understanding the Binogi platform as part of a language-friendly pedagogy rather than as a remediation tool with an integrative aim.

Discussion

Two main praxeological instances emerge from the responses of workshop participants as they relate to language-friendly pedagogy in mathematics. We have characterised one as remedial and the other as leveraging. Each of these instances reveals a distinct theory element within the Anthropological Theory of the Didactic framework.

The remedial praxeological instance

This praxeological instance is reflective of teachers who see Binogi as an instrument to cope with limitations in English language proficiency among students in the mathematics class. These teachers seem to operate from a logic of empathy and want their students to succeed within the education system. This intention is understandable as they have seen first-hand how challenging it can be for students to learn mathematics in an unfamiliar language and with little support. For these teachers, Binogi attempts to mitigate such problems by providing a curriculum-appropriate resource that students and teachers can use to complement the work of the teacher by clarifying vocabulary and providing accommodations. It can be used as a way to introduce students to new content while they transition to a class fully conducted in English. For the teachers espousing this praxeology, the Binogi platform is a remedial tool for their multilingual students to use until they attain a sufficient level of the dominant language of the school to be able to learn without the support of the Binogi platform.

The theory element of this praxeological instance of mathematics teaching is the same as the one described earlier in the paper, that is, despite being technically valid, diverse understandings of mathematics must be subjugated to the dominant group's representation of its concepts. In this instance, mathematics is understood as universal regardless of what language it is described or represented in. Consequently, taking the time and making the effort to work with mathematical content in various languages is not understood as the most efficient use of time and resources. From this perspective, there is no mathematical benefit in multilingual mathematics. In fact, this praxeological instance would support an integration rather than an inclusion approach (Auger & Le Pichon-Vorstman, 2021) in mathematics classrooms. Teachers who support the integration of multilingual learners expect them to adjust to the mainstream while inclusive teachers create conditions so that all students can participate fully in the mathematics classroom.

This remedial praxeology is at odds with the design and use of Binogi in Sweden and in some other parts of the world. The Binogi platform was developed as a resource for all

students with an element of equity for multilingual students. In other words, Binogi was created through the lens of leveraging praxeology.

The leveraging praxeological instance

Glimpses of this praxeological instance emerged in our findings whenever teachers discussed the potential benefits for all students to share and learn from one another when using the Binogi platform. Within the logic of this praxeology, teachers identify that opportunities to learn mathematics through the medium of various languages can be a source of learning in the classroom. These opportunities include learning alternative 1) terminologies that emphasise unique aspects of math concepts, 2) mathematical methods to solve problems, and c) notations of the same concept. For teachers who espouse this praxeology, Binogi can be used in open-ended, inquiry-based explorations when introducing new topics. The potential for higher engagement and ownership of learning is valued by these teachers. Most importantly, they perceive this process as benefiting all students and not only those whose first language isn't the dominant language used in school.

The theory element of this praxeological instance of mathematics teaching diverges from the one originally described in the paper, that is, teaching mathematics goes beyond representations of each concept in the dominant language of the school or in the country's approved curriculum; the languages available in the classroom become important resources and provide the necessary validation for the choices of a teacher. In fact, this praxeological instance would support an inclusion rather than an integration approach (Auger & Le Pichon-Vorstman, 2021) in mathematics classrooms with all students participating and contributing in equitable ways.

In summary, these teachers see Binogi as an instrument to learn mathematics *in* and *through* multiple languages. Table 4 provides a summary of the main elements of these contrasting praxeological instances which can be understood as existing at opposite ends of a continuum on which mathematics teachers might situate themselves in terms of their use of a multilingual digital platform such as Binogi.

Furthermore, the transition between praxeological instances is not always coherent. Teachers can have practices and perceptions that are inconsistent with each other. This aspect is particularly evident in the relationship between the importance of the curriculum versus broadening the mathematical horizons of all students. At different moments in the workshops, teachers transitioned between grounding their ideas to

Table 4. Praxeologies of multilingual mathematics teaching.

language-friendly pedagogical tool	Remedial praxeology	Leveraging praxeology
What is the goal?	Clarify vocabulary Provide accommodations	Learn different terminologies, methods, notations
How is it used?	Introduce new content Consolidate content taught	Open-ended, inquiry-based explorations
Why is it used?	Provide curriculum-related content Understand the experiences of multilingual learners	Benefits everyone
What is the nature of mathematics teaching?	Master one representation of math (e.g. via the English language as represented in Canadian mathematics curricula)	Learn math in and through multiple languages and through different perspectives

provincial curriculum expectations and reimagining their classrooms with the contributions of mathematics from multiple languages.

Although the Binogi platform was developed as a tool to facilitate student learning and inclusion, the way teachers encourage its use in and beyond the classroom can transform it into a tool which promotes culturally and/or linguistically responsive, relevant, sustaining and/or language-friendly pedagogies or not. Teachers' beliefs and perspectives regarding their multilingual students ultimately guide their choices about how to use a powerful digital multilingual platform such as Binogi to either remediate what they perceive as deficits in their students or leverage the assets of multilingual learners.

Conclusion

Teachers' reactions to the introductory workshop revealed their emerging awareness of the challenges that may be faced by multilingual students in learning mathematics and the need to adopt a more language-friendly approach. Some teachers viewed their students' needs through a deficit lens and understood the Binogi platform as a remedial tool to address their multilingual students' shortcomings. In contrast, other teachers adopted an inclusive perspective and perceived the knowledge and skills of their multilingual students as assets. These teachers understood that using a multilingual learning platform could enrich the learning of all their students by providing access to new concepts and topics via various languages and cultural lenses. Although the introductory workshop lasted only 2 h, it led to the emergence of awareness of the need for a more language-friendly pedagogy. However, we do not know the influence of our workshop on the implementation of language-friendly pedagogy in the participants' classrooms.

Our findings suggest an urgent need to support mathematics teachers in learning and using language-friendly pedagogies. The workshop that is the focus of this article is a first step on a longer learning journey. Additional workshops to help teachers compare the content and strategies introduced on the multilingual learning platform to the resources they traditionally use, would be an important next step in ensuring their comfort as they consider new ways to enrich their teaching while continuing to work towards the objectives of their local curricula. We need to support teachers in developing an understanding of the need for language friendly pedagogy and multilingual learning platforms that can enhance learning mathematics for all students.

Acknowledgements

We want to acknowledge the contributions of Dania Wattar, a member of the ESCAPE Projects research team, in the co-creation and delivery of the workshop described in this article.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was financed by the Social Sciences and Humanities Research Council of Canada.

ORCID

Alexandre Cavalcante http://orcid.org/0000-0003-0329-4713
Antoinette Gagné http://orcid.org/0000-0002-6179-177X
Emmanuelle Le Pichon-Vorstman http://orcid.org/0000-0001-6677-5317

References

Abdulrahim, N. A., & Orosco, M. J. (2020). Culturally responsive mathematics teaching: A research synthesis. *Urban Review*, *52*, 1–25. https://doi.org/10.1007/s11256-019-00509-2

Abedi, J., Hofstetter, C. H., & Lord, C. (2004). Assessment accommodations for English language learners: Implications for policy-based empirical research. *Review of Educational Research*, *74*(1), 1–28. https://doi.org/10.3102/00346543074001001

Alt, M., Arizmendi, G. D., Beal, C. R., & Hurtado, J. (2013). The effect of test translation on the performance of second grade English learners on the KeyMath-3. *Psychology in the Schools*, *50*(1), 27–36. https://doi.org/10.1002/pits.21656

Arizmendi, G. D., Li, J., Van Horn, M. L., Petcu, S. D., & Swanson, H. L. (2021). Language-focused interventions on math performance for English learners: A selective meta-analysis of the literature. *Learning Disabilities Research and Practice*, *36*(1), 56–75. https://doi.org/10.1111/ldrp.12239

Attar, Z., Blom, E., & Le Pichon, E. (2022). Towards more multilingual practices in the mathematics assessment of young refugee students: Effects of testing language and validity of parental assessment. *International Journal of Bilingual Education and Bilingualism*, *25*(4), 1546–1561. https://doi.org/10.1080/13670050.2020.1779648

Auger, N., & Le Pichon-Vorstman, E. (2021). *Défis et richesses des classes multilingues : construire des ponts entre les cultures*. ESF sciences sociales.

Avalos, M., & Secada, W. (2019). Linguistically responsive teaching to foster ELL engagement, reasoning, and participation in a mathematics discourse community. In L. C. de Oliveira, K. M. Obenchain, R. H. Kenney, & A. W. Oliveira (Eds.), *Teaching the content areas to English language learners in secondary schools English language arts, mathematics, science, and social studies* (pp. 165–179). Springer International Publishing.

Baird, A., Garrett, R., & August, D. (2020). Math and English language development: MELDing content and academic language for English learners. *NABE Journal of Research and Practice*, *10*(1), 1–12. https://doi.org/10.1080/26390043.2019.1653051

Barwell, R. (2018). From language as a resource to sources of meaning in multilingual mathematics classrooms. *Journal of Mathematical Behavior*, *50*, 155–168. https://doi.org/10.1016/j.jmathb.2018.02.007

Beacco, J.-C., Fleming, M., Goullier, F., Thürmann, E., & Vollmer, H. (2016). *The language dimension in all subjects – A handbook for curriculum development and teacher training*. Council of Europe.

Chevallard, Y., Barquero, B., Bosch, M., Florensa, I., Gascón, J., Nicolás, P., & Ruiz-Munzón, N. (Eds.). (2022). *Advances in the anthropological theory of the didactic*. Birkhauser.

Chval, K., Smith, E., Trigos-Carrillo, L., & Pinnow, R. (2021). *Teaching math to multilingual students, grades K-8 - Positioning English learners for success*. Corwin.

Cummins, J. (2021). *Rethinking the education of multilingual learners: A critical analysis of theoretical concepts (Vol. 19)*. Multilingual Matters.

García, O., & Kleyn, T. (Eds.). (2016). *Translanguaging with multilingual students: Learning from classroom moments*. Routledge.

Gay, G. (2000). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press.

Kersaint, G., Petkova, M., Thompson, D. R., & Thompson, D. R. (2013). *Teaching mathematics to English language learners*. Routledge.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*, 465–491. https://doi.org/10.3102/00028312032003465

Ladson-Billings, G. (2006). Yes, but how do we do it? Practicing cultural relevant pedagogy. *ESED 5234 - Master List*. 37. https://digitalcommons.georgiasouthern.edu/esed5234-master/37

Le Pichon, E., & Cummins, J. (2020). Case Study 1: Multilingual Programme Studi/Binogi. In *The future of language education in Europe: Case-studies of innovative practices* (pp. 44–52). Luxembourg: Publications Office of the European Union.

Le Pichon, E., Cummins, J., & Vorstman, J. (2021). Using a web-based multilingual platform to support elementary refugee students in mathematics. *Journal of Multilingual and Multicultural Development*, 1–17. http://dx.doi.org/10.1080/01434632.2021.1916022

Le Pichon, E., & Kambel, E.-R. (2022). The language-friendly school: An inclusive and equitable pedagogy. *Childhood Education*, *98*(1), 42–49. https://doi.org/10.1080/00094056.2022.2020538

Le Pichon-Vorstman, E., Siarova, H., & Szőnyi, E. (2020). The future of language education in Europe: case studies of innovative practices. *NESET report*. Luxembourg: Publications Office of the European Union.

Li, W. (2018). Translanguaging as a practical theory of language. *Applied Linguistics*, *39*, 9–30. https://doi.org/10.1093/applin/amx039

Maldonado, L., Krause, G., & Adams-Corrales, M. (2020). Flowing with the translanguaging corriente: Juntos engaging with and making sense of mathematics. *Teaching for Excellence and Equity in Mathematics*, *11*, 17–25.

Mesta, P., & Reber, O. (2019). *The classroom teacher's guide to supporting English language learners*. Routledge.

Moschkovich, J. (2015). Academic literacy in mathematics for English learners. *The Journal of Mathematical Behavior*, *40A*, 43–62. https://doi.org/10.1016/j.jmathb.2015.01.005

Ontario Ministry of Education. (2020). Secondary curriculum - Mathematics grade 9. Retrieved from: https://www.dcp.edu.gov.on.ca/en/curriculum/secondary-mathematics/courses/mth1w.

Ontario Ministry of Education. (2008). *Supporting English language learners A practical guide for Ontario educators*. Queen's Printer of Ontario.

Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher*, *41*(3), 93–97. https://doi.org/10.3102/0013189X12441244

Planas, N. (2018). Language as resource: A key notion for understanding the complexity of mathematics learning. *Educational Studies in Mathematics*, *98*(3), 215–229. https://doi.org/10.1007/s10649-018-9810-y

Prediger, S., & Uribe, Á. (2021). Exploiting the epistemic role of multilingual resources in superdiverse mathematics classrooms: Design principles and insights into students' learning processes. In A. Fritz, E. Gürsoy, & M. Herzog (Eds.), *Diversity dimensions in mathematics and language learning: Perspectives on culture, education and multilingualism* (pp. 80–97). De Gruyter.

Richards, H., Brown, A., & Forde, T. (2007). Addressing diversity in schools: Culturally responsive pedagogy. *Teaching Exceptional Children*, *39*(3), 64–68. https://doi.org/10.1177/004005990703900310

Schüler-Meyer, A., Prediger, S., Kuzu, T., Wessel, L., & Redder, A. (2019). Is formal language proficiency in the home language required to profit from a bilingual teaching intervention in mathematics? A mixed methods study on fostering multilingual students' conceptual understanding. *International Journal of Science and Mathematics Education*, *17*, 317–339.

Strong, L., Adams, J. D., Bellino, M. E., Pieroni, P., Stoops, J., & Das, A. (2016). Against neoliberal enclosure: Using a critical transdisciplinary approach in science teaching and learning. *Mind, Culture and Activity*, *23*(3), 225–236. https://doi.org/10.1080/10749039.2016.1202982

Viesca, K. M., Joseph, N., & Commins, N. (2019). A framework for improving the teaching of mathematics to bi/multilingual learners. In L. C. de Oliveira, K. M. Obenchain, R. H. Kenney, & A. W. Oliveira (Eds.), *Teaching the content areas to English language learners in secondary school English language arts, mathematics, science, and social studies* (pp. 135–150). Springer International Publishing.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.