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ABSTRACT

This study examines the influence of local mother tongues, such as Shimaoré and Kibushi, on the acquisition of mathematical skills in Mayotte, where French the official language of instruction is rarely spoken outside the school environment. A survey involving 167 students was conducted, employing a mixed-methods approach to explore the relationship between linguistic practices and the understanding of mathematical concepts. The findings indicate that while translating and converting instructions into local languages can facilitate comprehension for some students, this strategy often falls short in addressing the complexities of mathematical reasoning, which necessitates an understanding of semiotic representations and symbolic language. Statistical clustering analysis, combined with insights into actual didactical needs, identified six distinct student profiles. These profiles reveal that the use of local languages varies according to students' mathematical performance levels; however, this variation does not consistently lead to improved outcomes. The study underscores the importance of cultural contextualisation in teaching and proposes tailored didactic strategies. These include the judicious incorporation of local languages, the contextualisation of mathematical concepts through culturally relevant examples, and the integration of interactive visual aids. The aim is to equip educators with effective tools to design responsive teaching strategies in multilingual settings, enabling students to better grasp mathematical concepts while simultaneously enhancing their proficiency in the language of instruction.

Keywords: Multilingual education, Semiotic representations, Cultural contextualisation, Mathematical concepts, Linguistic diversity

1) INTRODUCTION

Teaching mathematics in multilingual contexts poses distinctive challenges, particularly in Mayotte, an overseas department of France where French, the official language of instruction, is spoken by only a minority of the population. The linguistic landscape is predominantly shaped by Shimaore and Kibushi. This complicates the implementation of curricula designed for monolingual French-speaking contexts. While these challenges echo those encountered in other overseas territories such as Réunion or Guadeloupe, they also present unique local specificities. In contrast, the mother tongues of most students, Shimaoré (71.3%) and Kibushi (22.5%), dominate daily communication (Priolet, 2021; Maturafi, 2021). This linguistic landscape creates significant barriers to learning, especially in mathematics, a subject that requires navigating the interplay between natural language and symbolic representations (Laborde, 1982; Duval, 1993). In (Adler, 2001) and (Meaney, 2020), in South African and Oceania classrooms, authors demonstrate that children's linguistic repertoires are crucial to how they engage with and make meaning in mathematics, an insight highly relevant to the context of Mayotte. Ndhlovu and Makalela (2021) provide a critical sociolinguistic perspective on the coloniality of language, emphasizing how dominant colonial languages marginalize indigenous languages and their speakers. This framework is highly relevant to mathematics education in Mayotte, where French is the official language of instruction, but many students are mother-tongue speakers of Shimaore or Kibushi. The work of (Ndhlovu & Makale, 2021) argues that western language hierarchies continue to devalue local languages, producing a "deficit view" of learners who do not speak the dominant language (in this case, French). National and international assessments, including PISA (2018), highlight persistent underachievement in mathematics among students in Mayotte. This phenomenon is often linked to two factors: difficulties understanding instructions in French and an incomplete grasp of mathematical representations. For example, in primary schools, problem-solving success rates in the first year (CP) were as low as 20% in 2021 and 25% in 2022 (Brun, 1990; Andreu, 2021). These challenges are compounded when students are expected to decode instructions in French while simultaneously engaging with abstract mathematical that exacerbates their linguistic and cognitive insecurities.

This study seeks to understand how students in Mayotte negotiate the use of their mother tongue alongside French to engage with mathematical concepts. Didactic research emphasizes that learning mathematics often involves transitioning from a problem expressed in natural language to one requiring mastery of symbolic and semiotic representations (Julo, 1995; Nguala, 2005; Hache, 2017). These transitions are influenced by the students' familiarity with the semantic context and their capacity to translate instructions into their dominant language. The reseach question of this study is: How do students in Mayotte leverage their mother tongues to overcome linguistic and cognitive barriers in mathematics, and what are the limitations of these strategies? In addressing this question, we aim to examine the personal techniques students develop to navigate these challenges and explore how these strategies can be recognized and enhanced within

a didactic framework that accounts for the cultural and linguistic specificities of Mayotte. This inquiry not only sheds light on the role of multilingualism in mathematics education but also contributes to the development of teaching practices that support equitable learning outcomes in linguistically diverse contexts.

2) PROPOSED CONCEPTUAL FRAMEWORK: LANGUAGE, LEARNING BARRIERS AND CONTEXTUALISATION IN MATHEMATICS EDUCATION

2.1. Language and semiotic representations

The process of learning mathematics is deeply rooted in the use of specific representational systems that interweave natural language and symbolic notation. This interplay, as theorised by Duval (1993), underscores the need for proficiency across multiple semiotic registers. Natural language serves as a medium for explanations and instructions, while symbolic language facilitates the articulation of mathematical reasoning through formal notations. The interconnectedness of these registers is critical for conceptual understanding. However, their concurrent mastery poses significant challenges, particularly for students whose first language diverges from the language of instruction.

Building on the foundational work of Laborde (1982), this framework highlights the linguistic practices and cognitive demands involved in transitioning between natural and symbolic languages. Laborde's insights into these transitions are pivotal, as they reveal the complexities that arise when mathematical concepts are expressed through diverse semiotic codes. A semiotic approach is therefore indispensable for our study, as it elucidates why a straightforward translation into a learner's first language may fail to address deeper conceptual barriers. The crux of the issue lies in the non-equivalence of symbolic and linguistic representations; the mathematical lexicon requires abstract conventions and syntactic structures that resist direct translation. This discrepancy can inadvertently lead to misunderstandings or fragmented conceptualisations.

Our study situates this theoretical lens within the unique multilingual context of Mayotte, where shimaoré and kibushi, the predominant local languages, coexist alongside French as the language of instruction. We aim to investigate the impact of these linguistic dynamics on students' mathematical comprehension, exploring how the use of their first language shapes, supports, or constrains their engagement with mathematical representations. By analysing the interplay between language, semiotics, and mathematics, this research seeks to provide insights into how culturally and linguistically responsive practices might mitigate these challenges and enhance students' mathematical learning outcomes.

2.2. Linguistic challenges and learning barriers

The second axis explores the linguistic barriers that impede students' comprehension of mathematical concepts and processes. Within the unique sociolinguistic landscape of Mayotte, where French serves as the medium of instruction, the daily use of this language is limited for the majority of learners (Millon-Fauré, 2020). For many students, French is an auxiliary language, predominantly encountered within formal educational settings,

creating significant challenges in grasping mathematical terminology and interpreting instructions. This disconnect between the language of instruction and students' everyday linguistic practices exacerbates the difficulty of acquiring and internalising mathematical knowledge.

Empirical studies have demonstrated that even when students possess the requisite mathematical understanding, their ability to follow instructions is often compromised due to linguistic obstacles (Mendonça Dias, 2020). This suggests that the issue extends beyond mere vocabulary acquisition to encompass deeper difficulties in bridging conceptual and linguistic domains.

This axis critically examines the specific linguistic challenges associated with learning in a multilingual context, focusing on how these barriers hinder both the assimilation of new knowledge and its subsequent application. In particular, the analysis identifies problematic practices in translation and conversion such as the simplistic substitution of words across languages that fail to accommodate the nuanced interplay between language and mathematical meaning. By addressing these deficiencies, this study seeks to propose pedagogical strategies that better integrate students' linguistic repertoires into a coherent and inclusive didactic framework, ultimately enhancing their engagement and success in mathematics

2.3. Contextualisation and cultural adaptation

The third axis of this theoretical framework focuses on cultural contextualisation as a powerful lever for addressing linguistic and semiotic barriers in mathematics learning (Julo, 1995; Delcroix et al., 2013). Cultural contextualisation refers to the deliberate incorporation of local, culturally relevant situations and examples into mathematics instruction to render abstract mathematical concepts more tangible, meaningful, and accessible to students. This approach moves beyond mere translation of content to actively engage with the cultural and social realities of learners.

In multilingual and culturally diverse educational settings, the challenge lies in adapting mathematical content in ways that resonate with students lived experiences. When educators integrate familiar cultural elements, such as Mahoran traditions, local practices, or community references, these elements can foster not only comprehension but also motivation and a sense of belonging. This is achieved by leveraging local languages and cultural narratives as didactic tools, rather than viewing them merely as substitutes for standard mathematical terminologies.

The concept of cultural contextualisation intersects with multimodality and multipresentation, as defined by Nguala (2005). In multilingual contexts like Mayotte, multimodal resources (visual, symbolic, linguistic, gestural, etc.) are not ancillary but central to mathematical cognition (Duval, 2006). These approaches underscore the importance of using multiple representational modes to cater to varied learner profiles and address diverse learning needs. Multimodality enables mathematical concepts to be represented in ways that transcend traditional symbolic notation, incorporating images, physical representations, and cultural symbols familiar to students. This dynamic

approach ensures inclusivity and acknowledges the diverse ways in which students make sense of mathematical ideas.

Furthermore, cultural contextualisation extends into the training of educators. Teachers must be equipped with strategies to manage plurilingual classrooms effectively. Such strategies involve not only teaching mathematical concepts but also integrating students' linguistic and cultural backgrounds into their instructional practice. This requires teacher training programs to focus on culturally responsive teaching strategies and provide future educators with the tools to navigate and incorporate plurilingual and multicultural perspectives dynamically into their pedagogy. A culturally responsive framework (Ladson-Billings, 1995) offers an alternative to deficit discourses by recognizing the pedagogical value of students' linguistic and cultural backgrounds.

This enriched theoretical framework, which weaves together semiotic theories, linguistic challenges, and the dynamics of cultural contextualisation, offers a holistic lens for analysing the complex interplay between language, culture, and mathematics learning. By adopting this multi-faceted perspective, this study aims to identify and articulate pedagogical strategies that are responsive to students' unique linguistic and cultural contexts. These strategies are not solely about overcoming barriers but about leveraging students' cultural knowledge and lived experiences to enhance their mathematical reasoning, understanding, and engagement.

3) METHODOLOGY

3.1. Background and aims of the study

This study is part of a wider research project aimed at exploring the factors that influence the level of mathematics attainment of students in Mayotte, with a particular focus on the role of the mother tongue in learning. We want to understand how students use their mother tongue to overcome barriers to understanding mathematics and how this practice affects their performance. The main objective is to identify student profiles that can guide the adaptation of teaching practices in a multilingual context.

3.2. Population and data collection Tools

The study encompassed a sample of 167 students drawn from a variety of schools across Mayotte. The participants were carefully selected to ensure diversity in age groups, school levels, and socio-cultural backgrounds, thereby providing a representative cross-section of the local student population. This stratified sampling approach aimed to capture the range of experiences and educational contexts among the participants. Data collection was conducted using a comprehensive and structured questionnaire, meticulously designed to address the research objectives. The questionnaire was administered primarily in French, the official language of instruction. However, teachers and facilitators actively assisted students to ensure comprehension. They provided explanations and translations into Shimaore and other local languages where needed. Code-switching between French and local languages was thus encouraged during administration, recognizing the multilingual reality of the students and

allowing them to access the questionnaire content more fully. The questionnaire combined closed questions with predefined answer choices for quantitative consistency and open-ended questions to capture richer, more nuanced responses from students. Mixed-methods designs incorporating classroom observations or interviews could provide deeper insights. However, time and resource constraints necessitated focusing on quantitative data. The questionnaire was divided into distinct sections to gather multifaceted information on the students' mathematical learning experiences, linguistic backgrounds, and socio-contextual factors. The sections included: Mathematical Performance: Assessment of general achievement levels in mathematics, measured through the students' overall average in mathematics, graded on a scale of 0 to 10. Attitude and Motivation Towards Mathematics: Investigation of students' self-reported motivation levels and their perception of the difficulty of mathematics. This section aimed to capture attitudes that might influence mathematical engagement and performance. Types of Difficulties Encountered: Identification of specific learning obstacles such as challenges related to reading instructions, conceptual understanding, and familiarity with mathematical symbols and notation. Linguistic Practice: Analysis of students' primary language (mother tongue) and the frequency and type of its use during mathematical problem-solving activities. Special attention was paid to practices involving translation or conversion between the mother tongue and mathematical terminology. Contextual and Social Factors: Exploration of the students' linguistic environment at home, their academic background, and their aspirations for future educational or professional goals. This dimension provided insights into external influences that may affect mathematical learning and motivation.

This multi-dimensional approach to data collection allowed for a holistic understanding of the factors influencing mathematics education in Mayotte, incorporating cognitive, linguistic, and socio-cultural variables into the analysis. The structured questionnaire served as a reliable and systematic tool for gathering nuanced information directly from the students, aligning with both the study's goals and methodological standards in mathematics education research.

3.3. Data analysis

This study is part of a large research project called May'JeM on Mayotte island student's local cultural use in mathematical learning. In this paper, we focus on the influence of local mother tongues, such as Shimaoré and Kibushi, on the acquisition of mathematical skills in Mayotte, where French the official language of instruction is rarely spoken outside the school environment. The following Table show a partial view of the Database.

	Id <dbl>	Type_Difficulties <chr>	H_math_training <dbl>	Maths_level <dbl>
1	1	None	5.00	7.00
2	2	Training	2.00	5.00
3	3	None	2.00	7.00
4	4	None	2.00	8.00
5	5	Training	0.00	1.00
6	6	Training	0.20	4.00
7	7	Training	3.00	3.00
8	8	None	9.00	9.00
9	9	Training	5.00	5.00
10	10	Training	0.00	6.00

1–10 of 167 rows Previous 1 2 3 4 5 6 … 17 Next

Table 1: Representative Sample of Participant Data (n=10) Showing ID, Reported Difficulty, Training Hours, and Self-Assessed Mathematics Level.

3.3.1. Descriptive Data Analysis

Before delving into advanced statistical methods, an initial descriptive analysis of the collected data is conducted to establish a foundational understanding of students' mathematics performance, linguistic practices, and the nature of challenges encountered during mathematical tasks. Descriptive statistics, including means, standard deviations, and frequency distributions, provide an overview of these variables, allowing for the identification of general trends and initial patterns. This initial analysis is particularly focused on exploring correlations between students' mother tongues and their mathematics performance outcomes. Key descriptive statistics include: Central Tendency Metrics**:** Means and medians of mathematics performance scores. Dispersion Metrics**:** Standard deviations and range values to determine variability within the student cohort. Distribution Analysis**:** Examination of the spread of scores and linguistic diversity across the sample.

This stage allows researchers to discern broad relationships between linguistic backgrounds and mathematical success and to identify potential patterns and anomalies requiring deeper investigation.

3.3.2. Unsupervised Clustering Analysis

To explore the complexities of student profiles and their associated linguistic and cognitive variables, a clustering technique is applied namely the K-means clustering (Hans-Hermann Block, 2007). The K-means clustering algorithm is a widely used unsupervised learning method that partitions a dataset into K clusters (or groups), such that the elements within each cluster are more similar to each other than to those in other clusters. The goal is to minimize intra-cluster variance while maximizing inter-cluster variance. To account for dependencies between individuals, we employed the Mahalanobis distance (Brown, Paul O., et al. 2022), a statistical measure used to assess

the distribution of multivariate data, detect outliers, and consider the correlations between variables. This approach helps analyze the similarity between observations in multivariate datasets.

The K-means algorithm, implemented using R software, differentiates among the groups by forming homogeneous subgroups based on shared linguistic behaviors and learning challenges. This classification is crucial for designing targeted intervention and teaching strategies. The optimal number of clusters, K, can be selected using methods such as the Elbow Method or by evaluating the Silhouette Score (Hans-Hermann, Block, 2007) or (Shahapure, K. R., 2020). However, in our study, we validated the choice of K=6 clusters based on pedagogical needs, drawing on educational experience and context within the region of Mayotte, instead of the use of the classical silhouette method Kute (2008).

This statistical approach serves to group students with similar linguistic patterns and mathematical performance into distinct subcategories or profiles. To ensure the robustness of the findings, triangulation of methods is employed. This multi-method approach combines K-means clustering, correlation analysis, and statistical testing (including Chi-square residuals tests) to identify the differences between groups in a better way by using these clustering methods.

3.3.3. Didactic and Linguistic Analysis of Profiles

Once clusters have been established, each student profile undergoes a comprehensive didactic and linguistic analysis to examine the implications of linguistic practices on mathematics learning. This in-depth analysis considers three main dimensions: The Relationship with the Mother Tongue: An investigation is conducted into how and why students engage with their mother tongue during mathematical activities. This includes its role in clarifying instructions, conceptual understanding, and problem-solving strategies. Linguistic and Cognitive Barriers: Analysis focuses on the primary difficulties encountered by each group, specifically concerning semiotic representations (Duval, 1993) and how these difficulties hinder mathematical reasoning and comprehension. Learning Strategies and Behaviours: An exploration of the strategy's students employ to reconcile their linguistic knowledge with the demands of mathematical language is carried out. This includes their adaptive behaviours and mechanisms for problem-solving in a multilingual setting. The integration of these three dimensions provides a nuanced understanding of how linguistic variables interact with mathematical cognition, offering insights into both the strengths and challenges faced by different student profiles.

This approach allows for cross-validation of observed relationships and patterns, ensuring that the results are reliable and not artifacts of a single analytical method. Triangulation confirms the observed associations between linguistic variables and mathematical performance, strengthening the interpretability and trustworthiness of the findings.

4) RESULTS

The findings of this study confirm that mathematics learning in Mayotte cannot be dissociated from the linguistic and cultural dimensions of education. Beyond translation challenges, it is the mastery of semiotic registers (Duval, 1993, 2006) and the cultural contextualization of knowledge that primarily determine students' success.

4.1. Impact of mother tongue on mathematics achievement

Statistical analyses show that students' mathematics performance varies according to their mother tongue, including Shimaoré, Kibushi, French, Malagasy, and other regional languages. Students often use conversion-translation into their mother tongue to better understand mathematical instructions and concepts. While this approach facilitates immediate comprehension, it has limitations when it comes to grasping abstract concepts in depth. Data mining revealed a correlation between mother tongue and mathematics achievement, with significant differences in understanding depending on the language used. For example, students whose mother tongue is French or Malagasy generally show higher mathematical performance (see Figure 1). Students whose first language is Shimaoré or Kibushi tend to rely on translation, which can facilitate comprehension but does not always ensure mastery of mathematical concepts, particularly those involving complex symbolic representations.

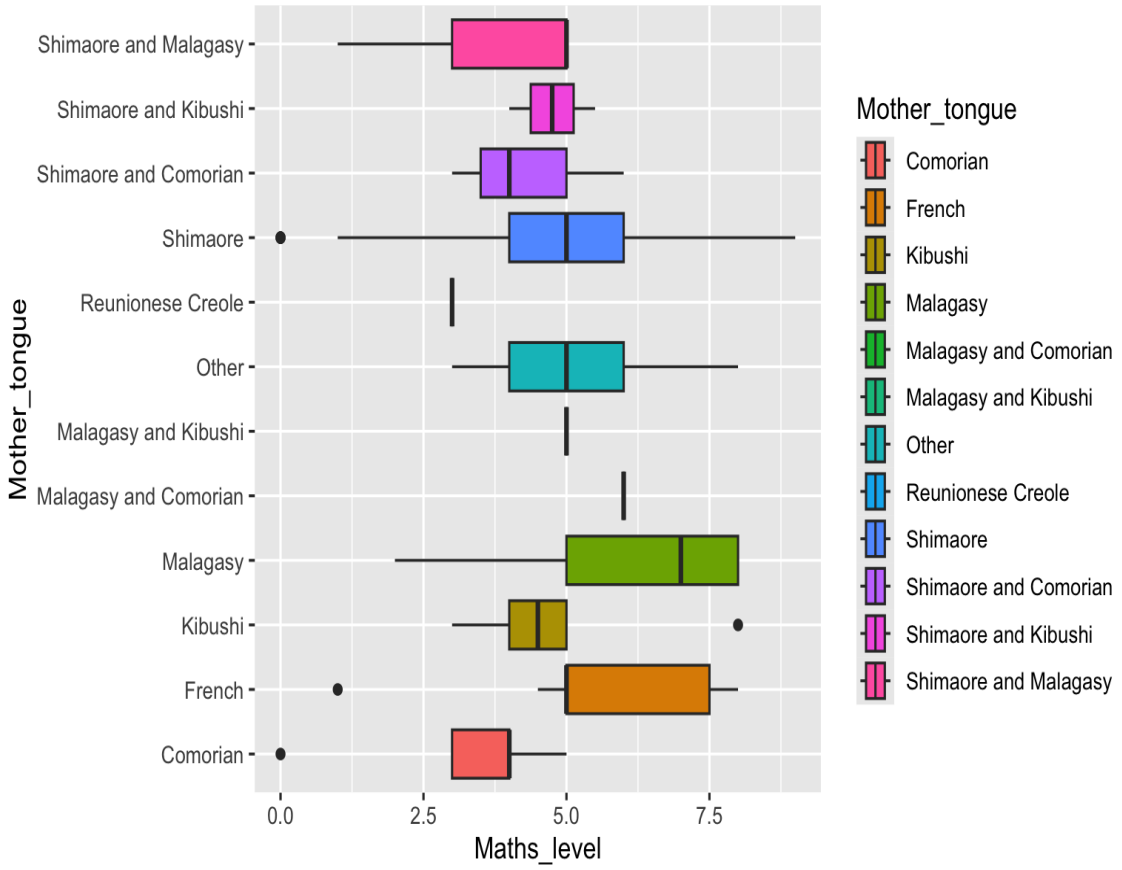

Figure 1: Boxplot of mathematics level according to recorded mother tongues

4.2. Conversion-translation variability in comprehension

Among students with above-average proficiency, approximately 70% use their mother tongue to perform occasional conversion-translations. These students report that this method clarifies certain concepts in algebra, analysis, or geometry, but is insufficient for solving problems that require a global and abstract understanding (see Figure 2). Conversion-translation thus serves as a partial cognitive tool, and students achieve better outcomes when other factors such as motivation and familiarity with specific mathematical vocabulary complement this strategy.

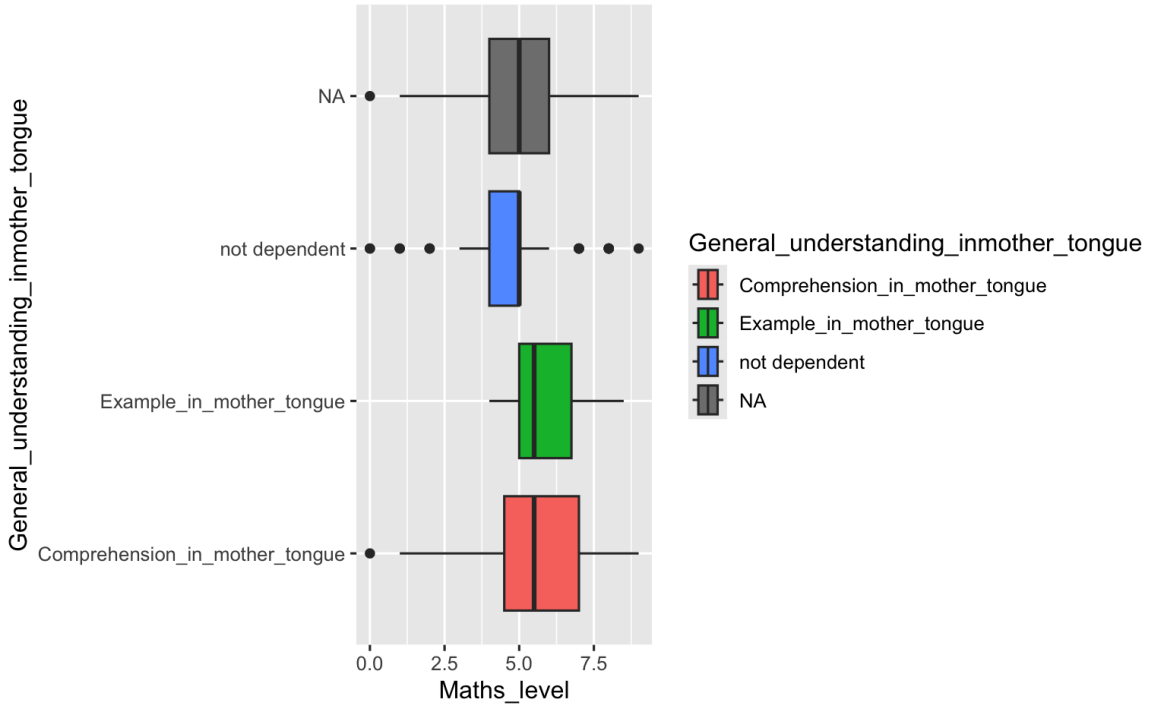

Figure 2: Boxplot of mathematics level based on mother tongue comprehension statements

4.2.1 Examples of student trajectories

Student 22, who regularly uses Shimaoré, illustrates this dynamic: despite difficulties with French, regular translations into Shimaoré help him understand mathematical content. Other students, such as student 29, create memorization strategies by developing stories in their mother tongue to internalize formulae. These cases highlight the value of regional languages as cognitive supports, even if translation alone does not ensure mastery of abstract concepts. Conversely, students with lower mathematics proficiency, such as students 39, 47, and 48, also translate into their mother tongue but show limited improvement. This underscores that mathematical language comprising symbolic and conceptual registers is not easily translatable into performance through simple lexical substitution.

4.2.2. Limitations of conversion-translation and the need for strong contextualization

Converting instructions into the mother tongue is insufficient for lasting understanding. As Barrier and Durand-Guerrier (2017) emphasize, mathematical language is a complex interplay of natural and symbolic systems, requiring deep comprehension of semiotic representations. Our results indicate that stronger contextualization is necessary for students to connect abstract concepts with their cultural reality, facilitating a more natural integration of mathematical knowledge.

4.2.3. Language, semiotics, and meaning-making

The data further indicate that students proficient in French are better able to coordinate the verbal, symbolic, and graphical registers necessary for mathematical conceptualization. In contrast, students who rely exclusively on their mother tongue remain confined to the linguistic register, without fully accessing symbolic abstraction. In this context, the mother tongue functions primarily as a cognitive support rather than a tool for conceptualization. These findings align with Adler (2001) and Meaney (2020), who highlight the limitations of spontaneous code-switching in multilingual classrooms. From a Vygotskian perspective, language mediates thought: students in high-performing clusters leverage bilingualism as a regulatory tool for reasoning, whereas less proficient students use it merely as a compensatory strategy without achieving genuine semiotic transformation.

2.2.4. Code-switching as a didactic strategy

Code-switching can support learning when integrated into a deliberate instructional strategy. Clusters 3 and 6 demonstrate that a flexible combination of French and the local language enhances understanding and learner autonomy. This resonates with Ndhlovu and Makalela (2021), who advocate moving beyond deficit oriented perspectives on African languages and recognizing their epistemic value in education. However, for the most vulnerable students, word-for-word translation does not promote conceptual understanding (Laborde, 1982).

4.2.5. Cultural contextualization and teaching implications

Contextualized teaching emerges as a powerful lever to overcome linguistic barriers. Anchoring mathematical situations in local references such as measurement practices, trade, or traditional architecture allows abstract concepts to connect with lived experiences. This approach, supported by Delcroix et al. (2013) and Ladson-Billings (1995), enhances motivation and legitimizes school knowledge. It also aligns with the principles of multipresentation (Nguala, 2005), which value diverse modes of thought and representation.

The results confirm that students would benefit from more contextualized teaching activities, adapted to their cultural and linguistic environment. By relying on familiar examples and analogies, teachers can help students build a frame of reference linking intuitive knowledge to formal mathematical concepts. This is in line with Duval (1993), who emphasizes the role of semiotic representations in mastering abstract concepts. Pragmatic controls (Houdement, 2006) could further support students in validating their

answers according to magnitude and contextual reasoning. For example, a lesson on proportions could incorporate elements from local daily life, allowing students to grasp the concept more intuitively.

4.2.6. Didactic implications

These findings call for a rethinking of teacher education around three axes. Integrate multilingualism as a didactic resource rather than a constraint (Axe 1). Design contextualized and multimodal learning situations to facilitate transitions between semiotic registers (Axe 2). Develop teachers' metalinguistic competencies to consciously guide the transition from familiar language to formal mathematical language (Axe 3).

Such an approach aligns with the decolonization movement in mathematics education (Ndhlovu & Makalela, 2021), recognizing linguistic plurality as a vector of cognitive justice. Ultimately, success in mathematics in Mayotte depends less on the choice of language than on the didactic management of linguistic interactions and the quality of semiotic mediation. Multilingualism, far from being an obstacle, can become a powerful learning resource when embedded within a contextualized, reflective, and culturally situated instructional approach.

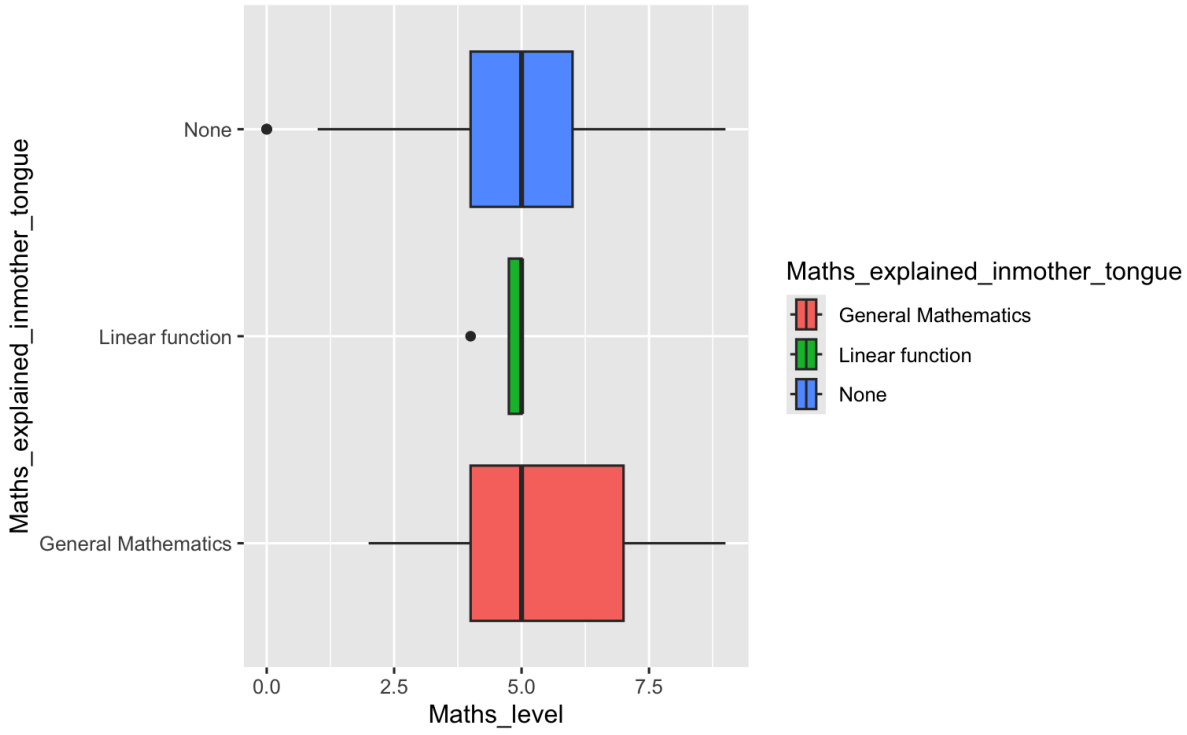

Figure 3: Boxplot of the level in mathematics according to the concepts explained

proportions could include elements of local daily life to help students grasp the concept more intuitively.

4.3. Detailed results of the classification of student profiles

The statistical analysis carried out by classification made it possible to identify six distinct profiles of students, each characterized by levels of performance, linguistic practices, and specific difficulties in mathematics. These profiles show how linguistic factors, learning habits and personal challenges influence the level of success in mathematics in Mayotte. We present here the Chi-square residuals that help to identify the differences in a better way using the above-mentioned clustering method. The chi-square residuals analysis (Figure 4) highlights significant associations between students' mother tongue and their mathematics achievement. Positive residuals indicate an overrepresentation of students achieving a given mathematics level relative to the expected distribution, whereas negative residuals show underrepresentation. For instance, students whose first language is French or Malagasy tend to achieve higher mathematics levels (positive residuals), whereas those speaking Shimaoré, Kibushi, or Comorian show mixed outcomes. Some clusters display overrepresentation at lower performance levels, confirming that translation into the mother tongue facilitates immediate comprehension but does not always ensure mastery of abstract concepts. This visual evidence reinforces the discussion on conversion-translation as a partial cognitive tool: while it provides initial scaffolding, higher-level conceptual understanding requires semiotic mediation and cultural contextualization.

	Maths_level														
Training and focus	0.0%	20.0%	0.0%	12.5%	11.1%	4.8%	21.4%	16.0%	0.0%	0.0%	0.0%	0.0%	12.5%	0.0%	25.0%
Training	75.0%	80.0%	100.0%	87.5%	88.9%	90.5%	50.0%	72.0%	0.0%	92.3%	46.7%	100.0%	50.0%	0.0%	25.0%
None	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	21.4%	8.0%	0.0%	0.0%	46.7%	0.0%	37.5%	100.0%	50.0%
Motivation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Math_Understanding	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lack of reading	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	6.7%	0.0%	0.0%	0.0%	0.0%
None	100.0%	100.0%	100.0%	75.0%	55.6%	52.4%	78.6%	66.0%	100.0%	76.9%	46.7%	0.0%	81.2%	100.0%	75.0%
Linear function	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
General Mathematics	0.0%	0.0%	0.0%	25.0%	44.4%	42.9%	21.4%	28.0%	0.0%	23.1%	53.3%	100.0%	18.8%	0.0%	25.0%
Shimaore and Malagasy	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Shimaore and Kibushi	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Shimaore and Comorian	0.0%	0.0%	0.0%	0.0%	11.1%	4.8%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Shimaore	75.0%	80.0%	100.0%	87.5%	44.4%	61.9%	71.4%	72.0%	0.0%	53.8%	93.3%	100.0%	43.8%	100.0%	100.0%
Reunionese Creole	0.0%	0.0%	0.0%	0.0%	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	0.0%	0.0%	0.0%	0.0%	11.1%	9.5%	0.0%	4.0%	0.0%	15.4%	0.0%	0.0%	12.5%	0.0%	0.0%
Malagasy and Kibushi	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Malagasy and Comorian	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Malagasy	0.0%	0.0%	0.0%	12.5%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	6.7%	0.0%	12.5%	0.0%	0.0%
Kibushi	0.0%	0.0%	0.0%	0.0%	11.1%	9.5%	14.3%	6.0%	0.0%	0.0%	0.0%	0.0%	6.2%	0.0%	0.0%
French	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	14.3%	10.0%	0.0%	15.4%	0.0%	0.0%	25.0%	0.0%	0.0%
Comorian	25.0%	0.0%	0.0%	0.0%	11.1%	9.5%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	1	1.58	2	3	4	4.5	5	5.5	6	7	7.5	8	8.5	9

Type_Difficulties

plained_inmothe

Mother_tongue

Figure 4: Chi-square residuals of mathematics level by mother tongue.

The clustering analysis identified distinct student profiles regarding language proficiency and mathematical performance. These groupings can be interpreted through Duval's (1993, 2006) cognitive framework, which emphasizes the importance of coordinating multiple semiotic representations (verbal, symbolic, graphical) in mathematics understanding. Students demonstrating greater oral fluency in French are better able to access and transform between these representations within assessment contexts, facilitating higher performance. Additionally, a socio-cultural influence (Vygotskian theory) helps explain how social interaction and language mediate learning; students more comfortable with French may more effectively engage with teacher explanations and classroom discourse, supporting their cognitive development in mathematics. Cross-referencing the clusters with the literature reveals that students with higher oral French fluency generally form a cluster with better mathematical performance, consistent with findings from Adler (South Africa) and Meaney (Aotearoa), who highlight language proficiency as a key factor in mathematics achievement in multilingual contexts. The six clusters identified in our study provide a nuanced understanding of how students' use of French and local mother tongues (primarily Shimaoré) interacts with their mathematical achievement in Mayotte. These findings resonate with existing literature on language-minoritized learners and mathematics education in multilingual contexts. The details of the six clusters are presented below.

- Clusters 1 and 6, which represent students with average to high mathematics performance, illustrate two effective linguistic strategies. Cluster 1 students, with sufficient French proficiency, rely minimally on their mother tongue, facilitating direct engagement with mathematical content in the language of instruction. This aligns with Ndhlovu and Makalela's (2021) critical sociolinguistic analysis of colonial languages, which argues that learners' academic success is strongly influenced by the linguistic alignment between their home language practices and educational assessments. Meanwhile, Cluster 6 students exhibit bilingual flexibility, effectively combining French and mother tongue use. This dual-language approach echoes the findings of Adler (2001), who emphasizes the cognitive and epistemological benefits of multilingualism in mathematics learning within African contexts.
- Cluster 3 underscores the role of mother tongue use as a cognitive scaffold. Students in this group, who achieve above-average mathematics scores, utilize their local language to support comprehension and concentration. This pattern supports a Vygotskian socio-cultural framework (Vygotsky, 1978), where language functions as a mediational tool within the zone of proximal development, enabling learners to internalize complex mathematical concepts before expressing them in French.
- Conversely, Cluster 5 demonstrates that while mother tongue use is a critical resource, it is insufficient alone to ensure mathematical success without adequate French proficiency. This reinforces Ndhlovu and Makalela's (2021) critique of the

coloniality of language, highlighting how the marginalization of indigenous languages in formal education contexts may limit learners' ability to fully access academic content and succeed in assessments.

- Clusters 2 and 4 reveal students with low to intermediate mathematics achievement who make little use of their mother tongue despite reported comprehension difficulties. This reliance solely on French, despite linguistic challenges, may reflect systemic pressures for linguistic assimilation without adequate pedagogical support. Such dynamics are characteristic of deficit perspectives critiqued in critical sociolinguistics and emphasize the urgent need for culturally responsive teaching practices (Benson, 2024; Ladson-Billings, 1995). Expanding multimodal instruction involving diagrams, oral discourse, and collaborative problem-solving could better support these learners (Duval, 1993; Meaney, 2020).

Cluster 1: Students with an average level of mathematics and little use of their mother tongue

This group of 17 students, mainly in the fifth and fourth grades, has an average of 6 out of 10 in mathematics. They are characterised by reading difficulties, although they need little recourse to their mother tongue to understand mathematics, most of them being comfortable with French and Shimaoré. Out-of-class study time is relatively low, with an average of 1.8 hours of mathematics and 2.8 hours of French per week. These students seem to benefit from having sufficient language skills in the language of instruction, which minimises their need for translation to understand mathematical concepts.

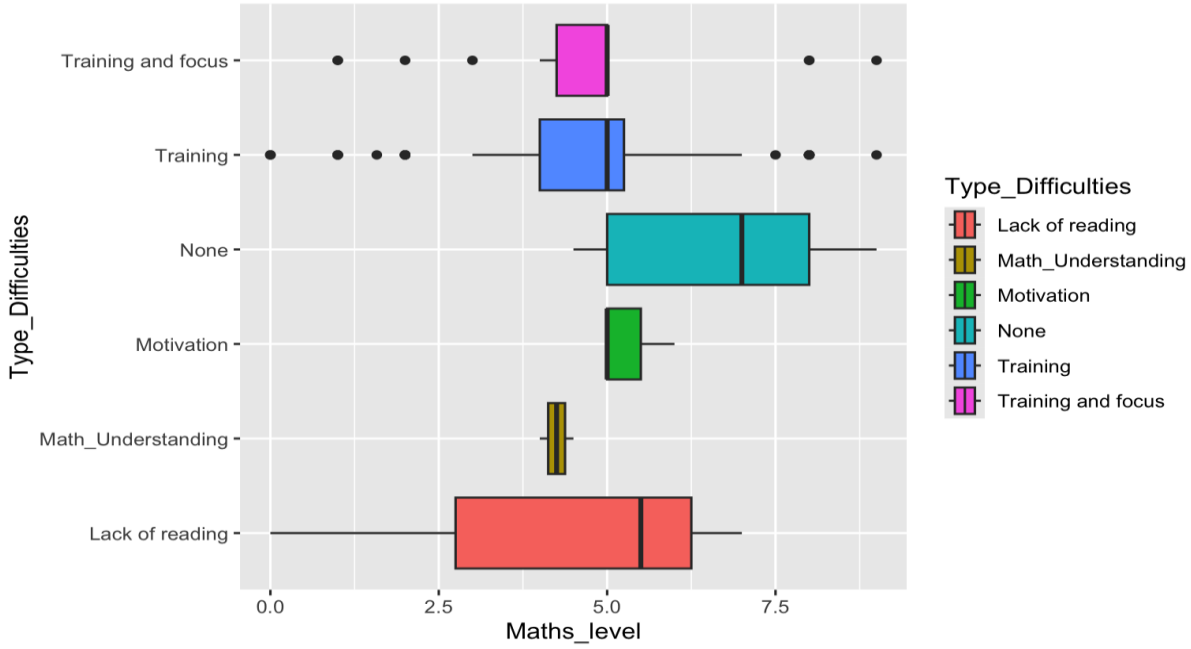

Figure 5: Boxplot of the level in mathematics according to the types of difficulty encountered

Cluster 2: Intermediate to low level students with focus on comprehension without translation

The second group of 17 students, mostly in their fourth year and one in their final year, has an average of 4.7 out of 10 in mathematics. Almost 50% of these students report problems with concentration and learning, while 24% report problems with understanding instructions. Despite their low level in mathematics, these students rarely use their mother tongue, suggesting that they try to rely on French to learn mathematical concepts. Study time is still limited to a maximum of 2 hours per week for mathematics and 3 hours for French.

Cluster 3: Advanced learners using mother tongue to support learning

The third profile includes 17 students with an above-average level in mathematics (above 6 out of 10). These students devote more time to their studies (up to 4 hours per week for mathematics and 10 hours for French) and mainly have difficulties in understanding instructions and concentrating. The majority of them use their mother tongue (mainly Shimaoré) as an aid in general mathematics, which seems to contribute to their academic success.

Cluster 4: Average students with challenging behaviour and little use of shimaoré

The fourth group, made up of 17 students (mainly in their second and final year), has an average of 4 out of 10 in mathematics, with 75% of the students above average. Discipline is a recurring difficulty and most of these students feel that they do not need to explain instructions in their mother tongue. This lack of recourse to Shimaoré suggests an attempt at linguistic autonomy, which could, however, be strengthened in order to improve understanding.

Cluster 5: Low achievers with high mother tongue dependency

This group of 24 students, including first year, second year, final year and BTS students, have an average level in mathematics of 3.7 out of 10. Most of these students use their mother tongue to understand mathematical instructions and believe that this facilitates their learning, although persistent difficulties suggest that the use of Shimaore, Comorian or Kibushi alone is not enough to overcome their challenges. The amount of time spent on mathematics is low, averaging about 1 hour.

Cluster 6: High level students combining French and mother tongue

The last group, consisting of 20 students, mostly in their first and second year, stands out with an average level of 6.75 in mathematics. These students spend an average of 4.7 hours per week on mathematics, and 65% of them report no particular difficulties. For the remaining 35%, the difficulties are related to learning and discipline problems. These students sometimes use their mother tongue to clarify certain concepts, but they also rely heavily on French to structure their understanding of mathematics.

The above results align with Duval's (1993, 2006) theory of cognitive functioning in mathematics, which stresses the importance of coordinating multiple registers of representation (verbal, symbolic, graphical) to develop mathematical understanding. Students with greater oral French proficiency (Clusters 1 and 6) show better capacity to navigate these representations, enhancing problem-solving. In contrast, learners heavily

dependent on their mother tongue but less proficient in French (Cluster 5) may struggle to access the French symbolic register critical for formal assessment success.

From a Vygotskian socio-cultural perspective (Vygotsky, 1978), the strategic use of mother tongue in Clusters 3 and 6 reflects how language mediates cognitive development within social interaction. The prevalent code-switching observed in classrooms acts as a scaffolding mechanism that supports internalization of mathematical concepts prior to their expression in French.

4.4. Interpretation of results

The results show that students with a good level in mathematics and a high degree of autonomy in the language of instruction use the mother tongue selectively, mainly to facilitate complex points of understanding. Conversely, students with a low level tend to rely heavily on the mother tongue to interpret instructions, without being able to fill the gaps in understanding abstract concepts. The different clusters show that the use of the mother tongue, although useful, needs to be accompanied by appropriate pedagogical support in order to have a real impact on results in mathematics. Students who require regular conversion-translation could benefit from more robust contextualisation techniques and continuous assessment systems to monitor their progress in the language of instruction.

5) DISCUSSION

The six clusters identified through our analysis reveal complex relationships between linguistic practices and mathematical achievement in Mayotte. These profiles cannot be interpreted through a simplistic binary logic (mother tongue vs. French) but require a nuanced reading through the lens of semiotic theories (Duval, 1993, 2006) and sociocultural frameworks (Vygotsky, 1978).

Clusters 1 and 6, which group students with medium to high performance, illustrate two effective yet distinct linguistic strategies. Cluster 1 is characterized by sufficient French proficiency and minimal recourse to the mother tongue. This aligns with Ndhlovu and Makalela's (2021) observations on linguistic alignment. They show how congruence between home language practices and school assessments influences academic success. These students benefit from linguistic capital enabling direct engagement with mathematical content in the language of instruction. Conversely, Cluster 6 demonstrates the effectiveness of strategic bilingual flexibility. These students, who judiciously alternate between French and their mother tongue, embody what Adler (2001) describes as the cognitive and epistemological benefits of multilingualism in mathematics learning within African contexts. This code-switching is not merely a compensatory mechanism but constitutes a cognitive resource providing simultaneous access to multiple semiotic registers.

Cluster 3 highlights the role of the mother tongue as a cognitive scaffolding tool. Students in this group, who achieve above-average results, actively use their local language to support comprehension and concentration. This observation corroborates the Vygotskian perspective (Vygotsky, 1978), according to which language functions as a mediational

tool within the zone of proximal development, enabling learners to internalize complex mathematical concepts before expressing them in French. However, Cluster 5 reveals the limitations of this strategy when not accompanied by sufficient French proficiency. These students, despite significant use of their mother tongue, present the lowest mathematical performances. This observation reinforces Ndhlovu and Makalela's (2021) critique of the coloniality of language: the marginalization of indigenous languages in formal educational contexts limits learners' access to academic content and success in assessments.

Clusters 2 and 4 reveal a paradoxical situation: students with low to intermediate performance who use their mother tongue sparingly despite evident comprehension difficulties. This exclusive reliance on French, despite linguistic obstacles, may reflect systemic pressures toward linguistic assimilation without adequate pedagogical support. These dynamics are characteristic of deficit perspectives critiqued in critical sociolinguistics and underscore the urgent need for culturally responsive teaching practices (Benson, 2024; Ladson-Billings, 1995).

Our results confirm that simple lexical translation of mathematical instructions into the mother tongue constitutes an insufficient strategy to guarantee deep conceptual understanding. As Barrier and Durand-Guerrier (2017) emphasize, mathematical language is a complex system articulating natural language and symbolic systems, requiring profound comprehension of semiotic representations. Students capable of effectively coordinating verbal, symbolic, and graphical registers predominantly those with strong French proficiency demonstrate better problem-solving performance. Conversely, those relying exclusively on their mother tongue often remain confined to the linguistic register, without fully accessing the symbolic abstraction necessary in mathematics. This analysis reveals a fundamental distinction: the mother tongue functions primarily as a cognitive support rather than as a genuine mathematical conceptualization tool. This distinction illuminates the contrasting results observed across our different clusters. Mother tongue use facilitates initial semantic anchoring and instruction comprehension but does not automatically guarantee mastery of the semiotic transformation processes necessary for advanced mathematical thinking.

The collected data demonstrate the crucial importance of cultural contextualization in mathematics teaching. Consistent with the work of Delcroix et al. (2013) and Ladson-Billings (1995), anchoring mathematical situations in local references measurement practices, traditional commerce, Mahoran architecture enables connecting abstract concepts to students' lived experiences. This approach serves a dual objective: reinforcing motivation by legitimizing school knowledge through connection to lived experience, and facilitating the construction of a reference framework enabling articulation between intuitive knowledge and formal concepts. Students in Clusters 3 and 6, who apparently benefit from such contextual approaches (directly or indirectly), present significantly superior performances. The concept of multipresentation developed by Nguala (2005) proves particularly relevant in the Mahoran context. Multimodal resources visual, symbolic, linguistic, gestural—do not constitute auxiliary supports but central elements of mathematical cognition in multilingual contexts (Duval, 2006). This dynamic

approach ensures inclusivity by recognizing diverse ways in which students construct meaning from mathematical ideas. It enables transcending traditional symbolic notation by incorporating images, physical representations, and cultural symbols familiar to students.

Our observations on Clusters 3 and 6 suggest that code-switching can support learning when integrated into a deliberate pedagogical strategy. This flexible code alternation between French and local language promotes understanding and learner autonomy. This conclusion resonates with Ndhlovu and Makalela (2021), who advocate moving beyond deficit perspectives on African languages and recognizing their epistemic value in education. However, for the most vulnerable students (Clusters 2, 4, and 5), word-for-word translation does not promote conceptual understanding (Laborde, 1982). Without explicit pedagogical guidance on how and when to use each language, code-switching can become a source of confusion rather than clarification.

The results of this study call for rethinking teacher education around three strategic axes. First, training teachers to perceive and exploit multilingualism not as a constraint but as a cognitive and cultural resource enriching mathematical learning. Second, developing teachers' competencies to create didactic situations anchored in local cultural context, facilitating transitions between semiotic registers through multiplication of representation modes. Third, equipping teachers with tools to consciously and explicitly guide the transition from familiar language to formal mathematical language, building on students' linguistic repertoires. This approach aligns with the movement for decolonization of mathematics education (Ndhlovu & Makalela, 2021), recognizing linguistic plurality as a vector of cognitive justice. It requires profound transformation of teacher representations regarding the place of local languages in formal learning.

This study presents several limitations that must be made explicit. First, the absence of classroom observations and ethnographic data limits our understanding of actual language practices in teaching-learning situations. The declarative data collected through questionnaires provide valuable information. However, they do not account for the complexity of real-time didactic interactions. Second, the privileged quantitative methodology though justified by time and human resource constraints does not provide access to the subtlety of cognitive processes and individual strategies deployed by students during mathematical problem-solving. Third, the choice of K=6 clusters, though validated by contextual pedagogical considerations, would merit confrontation with other statistical validation methods to evaluate its robustness.

These limitations open promising perspectives for complementary research. An in-depth ethnographic study combining classroom observations, semi-structured interviews with teachers and students, and analysis of problem-solving protocols would enable fine documentation of effective language practices and their effects on learning. The design of experimental frameworks presenting identical mathematical tasks according to different instructional modes (French only, mother tongue only, code-switching, multimodality) would enable rigorous evaluation of these variables' influence on resolution processes and performances. A longitudinal follow-up of students over several years would enable understanding how linguistic strategies and their effectiveness evolve

throughout cognitive development and schooling. The implementation and evaluation of training programs centered on didactic management of plurilingualism would constitute a major contribution to teacher professionalization in multilingual contexts.

Ultimately, this study demonstrates that mathematical success in Mayotte depends less on the choice of a single language than on the didactic management of linguistic interactions and the quality of semiotic mediation. Multilingualism, far from constituting an obstacle, can become a powerful learning resource when integrated into a contextualized, reflective, and culturally situated pedagogical approach. This perspective requires a paradigm shift: moving from a deficit vision where mother tongues are perceived as obstacles to overcome to a pedagogy of recognition valuing students' linguistic and cultural repertoires as legitimate foundations for mathematical knowledge construction. The challenge extends beyond the linguistic question: it involves building an inclusive and equitable Mahoran school capable of supporting all students toward mastery of mathematical concepts while respecting and valuing their linguistic and cultural identity. This ambition requires strong investment in continuous teacher training, production of contextualized didactic resources, and coherent educational policy recognizing linguistic diversity as wealth rather than problem.

6) CONCLUSION

This study examined the complex interplay between local mother tongues (Shimaoré and Kibushi) and mathematical achievement among 167 students in Mayotte. In this context, French serves as the official language of instruction but remains largely absent from students' daily linguistic environments. Through mixed-methods analysis employing K-means clustering and didactic interpretation, we identified six distinct student profiles revealing that the relationship between language use and mathematical success is neither linear nor uniform.

Three key findings emerge from this research. First, conversion-translation into the mother tongue facilitates immediate comprehension of instructions but proves insufficient for deep conceptual understanding, particularly when mathematical reasoning requires coordination across multiple semiotic registers (Duval, 1993, 2006). Second, strategic bilingual flexibility evidenced in high-performing clusters demonstrates that multilingualism can function as a cognitive resource rather than a barrier when deliberately integrated into pedagogical practice. Third, cultural contextualization emerges as a critical lever for connecting abstract mathematical concepts to students' lived experiences, thereby enhancing both motivation and conceptual anchoring. These findings challenge deficit-oriented perspectives on linguistic diversity in mathematics education. Rather than viewing mother tongues as obstacles to overcome, our results suggest they should be recognized as legitimate epistemic resources warranting explicit pedagogical integration. However, such integration requires moving beyond simplistic word-for-word translation toward sophisticated didactic approaches that leverage multiple representational modes and support transitions between familiar and formal mathematical language. The study's primary limitation lies in its reliance on questionnaire data without direct classroom

observation. Future research should employ ethnographic methods to document actual language practices in situ, explore experimental designs comparing different instructional language configurations, and develop longitudinal studies tracking the evolution of linguistic strategies across students' mathematical trajectories. Additionally, research-action projects focused on teacher education in plurilingual contexts would address the urgent need for professional development in culturally responsive mathematics pedagogy. For mathematics education in Mayotte and similar multilingual contexts, success depends less on choosing a single language of instruction than on the quality of didactic management of linguistic interactions and semiotic mediation. This requires systemic commitment to teacher training, development of contextualized curricular materials, and educational policies that reframe linguistic diversity as pedagogical wealth. Ultimately, equitable mathematics education in multilingual settings demands what Ladson-Billings (1995) termed "culturally relevant pedagogy" an approach that validates students' linguistic and cultural identities as foundations for mathematical learning rather than obstacles to be erased.

ANNEX DETAILS

Supporting Information: Data and codes

The original database and R codes for statistical analysis are available from the authors on reasonable request.

Table: Description of some of the variables used in the database is given below

Variable	Description
Type_difficulties	Type of difficulty encountered
Mother_tongue	The student's mother tongue
Maths_explained_inmother_tongue	Type of mathematical concepts explained in mother tongue
H_math_training H_french_training H_sciences_training	Learning time in mathematics Learning time in french Learning time in science courses
Maths_level	Average level in mathematics
General_understanding_inmother_tongue	*Mathematics understanding from mother tongue comprehension statements*

REFERENCES

Adler, J. (2001). Teaching Mathematics in Multilingual Classrooms. Dordrecht: Kluwer Academic Publishers.

Barrier, T., & Durand-Guerrier, V. (2017). La quantification au cœur des relations entre langage, raisonnement et apprentissages mathématiques. Dans *Actes du 22e colloque de la CORFEM*.

Benson, C. (2024). Culturally Responsive Teaching in Multilingual Contexts. Journal of Education and Language, 35(1), 23–45.

Brown, Paul O., et al. (2022) "Mahalanobis distance-based k-means clustering." *International Conference on Big Data Analytics and Knowledge Discovery*. Cham: Springer International Publishing.

Brun, J., & Conne, F. (1990). Analyses didactiques de protocoles d'observation du déroulement de situations. *Bildungsforschung und Bildungspraxis/Education et recherche*, 12(3), 261–286.

Campbell, A. E., Davis, G. E., & Adams, V. M. (2007). Cognitive demands and second-language learners: A framework for analyzing mathematics instructional contexts. *Mathematical Thinking and Learning*, 9(1), 3–30.

Duval, R. (1993). Registres sémiotiques et apprentissage des mathématiques. Educational Studies in Mathematics, 24(2), 175–197.

Delcroix, A., Forissier, T., & Anciaux, F. (2013). *Vers un cadre d'analyse des contextes : la didactique des langues-cultures et la créolisation*. In T. Forissier & A.-B. Stock (Eds.), *Contextualisations et médiations des savoirs* (pp. 47-70). Éditions des Archives Contemporaines.

Dias, C. M. (2020). Implications didactiques de l'appropriation du français sur une année scolaire, par les élèves allophones.

Duval, R. (1993). Registres de représentation sémiotique. *Annales de didactique et de sciences cognitives*, 5, 37–65.

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. Educational Studies in Mathematics, 61(1–2), 103–131.

Faure, K. M. (2020). *Analyse quantitative et qualitative des difficultés rencontrées par les élèves allophones dans leurs apprentissages mathématiques*.

Hache, C. (2019). *Questions langagières dans l'enseignement et l'apprentissage des mathématiques* (Thèse de doctorat, Université Paris Diderot).

Hans-Hermann, Block. (2007) "Clustering methods: a history of k-means algorithms." *Selected contributions in data analysis and classification* (2007): 161-172.

Houdement, C. (2006). *Contrôles pragmatiques dans la résolution de problèmes de géométrie*. Petit x, 71, 29-53.

Houdement, C. (2006). *Trouver ou ne pas trouver : Ce qui peut faire des différences entre élèves dans la résolution de problèmes arithmétiques ordinaires en deuxième partie d'école élémentaire* (N° 54). IREM de Paris.

Houdement, C. (2022). *Promenade sémiotique et mathématique*. Édition.

Jambu, M. (1977). Sur l'utilisation conjointe d'une classification hiérarchique et de l'analyse factorielle en composantes principales. *Revue de statistique appliquée*, 25(4), 5–35.

Julo, J. (1995). *Représentation des problèmes et réussite en mathématiques : Un apport de la psychologie cognitive à l'enseignement*. FeniXX.

Kute, T. B. (2008). K-means clustering. International Journal of Computer Science and Applications, 5(1), 25–30.

Ladson-Billings, G. (1995). Toward a Theory of Culturally Relevant Pedagogy. American Educational Research Journal, 32(3), 465–491.Laroussi, F. (2011). Le plurilinguisme en milieu scolaire à Mayotte. Paris : Karthala.

Laborde, C. (1982). Langue naturelle et écriture symbolique : Deux codes en interaction dans l'enseignement mathématique. *Université scientifique et médicale, Institut national polytechnique de Grenoble*.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, 32(3), 465–491.

Matturafi, L., & Dureysseis, F. (2021). *Rapport d'évaluation des dispositifs bilingues en maternelle 2014-2021 et proposition de plan d'action pour le plurilinguisme dans l'Académie de Mayotte* (Thèse de doctorat). Rectorat de Mayotte ; Centre universitaire de formation et de recherche de Mayotte.

Meaney, T. (2020). Multilingualism and Mathematics Education in Oceania. International Journal of Multilingualism, 17(4), 384–399.

Ndhlovu, F., & Makalela, L. (2021). Decolonising Multilingualism in Africa: Recentering Africa's Multilingual Practices. Multilingual Matters.

Nguala, J.-B. (2005). La multireprésentation, un dispositif d'aide à la résolution de problèmes. *Grand N, Revue de mathématiques, de sciences et technologie pour les maîtres de l'enseignement primaire*.

Nguala, J. (2009). *Multiprésentation de problèmes comme dispositif de ré-apprentissage au cycle 3 de l'école primaire : Mise en place, portée et limites* (Thèse de doctorat, Paris 7).

Priolet, M. (2021). *L'école à Mayotte : Approches plurielles*. L'École à Mayotte, 1–268.

Salone, J. J. (2022). Contexte et contextualisation à Mayotte, une approche systémique. *Contextes et didactiques : Revue semestrielle en sciences de l'éducation*, 20.

Shaftel, J., Belton-Kocher, E., Glasnapp, D., & Poggio, J. (2006). The impact of language characteristics in mathematics test items on the performance of English language learners and students with disabilities. *Educational Assessment*, 11(2), 105–126.

Shahapure, K. R., & Nicholas, C. (2020, October). Cluster quality analysis using silhouette score. In *2020 IEEE 7th international conference on data science and advanced analytics (DSAA)* (pp. 747-748). IEEE.

Sandra Andreu et al. (2021). *Évaluations 2021-point d'étape CP : premiers résultats*. Ministère de l'Éducation nationale, de la jeunesse et des sports.

Vygotsky, L. S. (1978). Mind in Society: The Development of Higher Psychological Processes. Harvard University Press.