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► **To cite this version:**

Susanne Prediger, Ángela Uribe, Taha Kuzu. Disentangling students' personal repertoires for meaning-making: The case of newly arrived emergent multilingual students. Eleventh Congress of the European Society for Research in Mathematics Education, Utrecht University, Feb 2019, Utrecht, Netherlands. hal-02435364

HAL Id: hal-02435364

<https://hal.science/hal-02435364>

Submitted on 10 Jan 2020

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Disentangling students' personal repertoires for meaning-making: The case of newly arrived emergent multilingual students

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Empowering multilingual students for mathematics learning requires building on their multilingual repertoires. Although this claim has often been repeated, the students' repertoires and the interplay of their components have so far only been partly understood. The repertoire comprises different state languages but also different registers and representations serving as multimodal sources for meaning-making. This paper contributes to unpacking students' personal repertoires for meaning-making of mathematical concepts (comparing fractions). A qualitative study of three newly arrived Syrian immigrants' learning processes identifies (re)sources that the study subjects have that are different from those of native residents that had been found in former studies. These results show that teaching-learning arrangements should connect the registers and representations in more flexible trajectories.

Keywords: Multilingual repertoires, language, qualitative case study, newly arrived multilinguals.

Background: Disentangling personal multilingual repertoires as a research gap

Theoretical background: Multilingual repertoire as a resource for mathematics learning

Academic and pedagogical discourses on multilingual mathematics classrooms have undergone several shifts, not only from language-as-problem and language-as-right to language-as-resource (Planas & Setati-Phakeng, 2014), but also from focusing on students' resources in different national languages from quite static perspectives to more dynamic conceptualizations carried by the construct of a person's *language repertoire* (Barwell, 2018; Planas, 2018). Blackledge, Creese, and Kaur Takhi (2014) define a person's communicative repertoire as "the collection of ways individuals use language and ... other means of communication to function in the multiple communities in which they participate" (p. 487) and emphasize its dynamic character. Disentangling these personal repertoires is crucial for teaching approaches that build upon these resources. In order to do this, we need to focus on the *communicative* role of personal repertoires but also on their *epistemic* role in the interactive construction of meanings for mathematical concepts (Prediger & Wessel, 2013). When personal repertoires are conceptualized as sources for meaning-making (Barwell, 2018), it is even more crucial that they contain different national languages as well as overlapping registers (i.e., the functional varieties of language use) tied to social practices (Halliday, 1978) and social languages (Planas, 2018). Besides these language registers, other multimodal sources such as graphical or symbolic representations, gestures, and prosody must also be taken into account as sources for meaning-making (Prediger, Clarkson, & Bose, 2016). This paper contributes to disentangling relevant sources of meanings in the personal repertoires of multilingual students with diverse immigrant backgrounds.

Relating registers and representations as a teaching approach for building upon students' personal repertoires

Dynamic, multimodal conceptualizations of multilingual repertoires resonate with teaching approaches that outline the didactical potentials of relating registers and representations for meaning making (see Figure 1 from Prediger, Clarkson, & Bose, 2016; similarly, Moschkovich, 2013). In many teaching approaches, teaching-learning arrangements start by activating students' informal experiences in concrete and graphical representations or familiar contexts and mobilizing their everyday languages, all of which are later systematically related to the target formal registers and representations. For multilingual students, this approach is extended to home languages (Moschkovich, 2013; Planas & Setati-Phakeng, 2014): Informal experiences and everyday language resources in home languages can be activated in multilingual mathematical discourses. Still, "meaning-making is relational" (Barwell, 2018), that is, it takes place by relating languages, registers, and representations to each other across all languages of the learners.

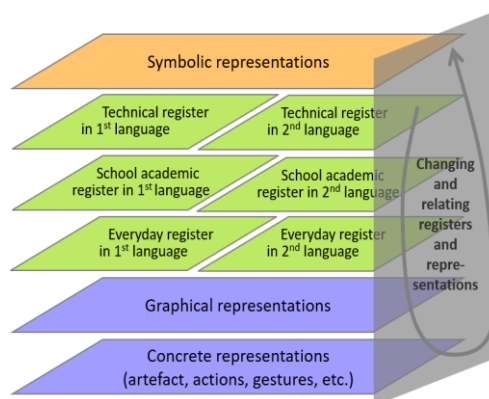


Figure 1: Relating registers and representations

Previously, based on this teaching approach, a bilingual German/Turkish teaching intervention on conceptual understanding of fractions was designed for multilingual seventh graders (native residents whose parents or grandparents born in Turkey). The study of this intervention provided quantitative evidence for the efficacy of the intervention despite the students' limited experience with the technical register in Turkish and qualitative insights into the functioning of relating languages, registers, and representations along the sketched learning trajectory from informal resources to formal learning content (Schüler-Meyer, Prediger, Kuzu, Wessel, & Redder, 2019).

In the current step of this research, the qualitative study has been extended to newly arrived immigrants from Syria. The analysis of Syrian textbooks and interviews with Syrian teachers gave indications that Syrian math classrooms prioritize the formal register and symbolic representation over the meaning-related register and the contextual and graphical representations. Thus, empirical research is required to investigate whether these different mathematical practices might influence the students' use of their multimodal repertoires.

Research gap: Disentangling the repertoires for newly arrived students from Syria

In order to adapt the main ideas of the teaching approach of relating registers and representations to multilingual repertoires of newly arrived students, it is therefore crucial to identify these personal repertoires and their activation empirically. Therefore, the learning-process study in this paper pursues the following research question: *Which personal repertoires do newly arrived students activate for meaning-making in the subject of comparing fractions?*

Methodological framework for the learning-process study

The research question was pursued in a learning-process study that was part of the larger mixed-methods project, MuM-Multi (Schüler-Meyer, Prediger, Kuzu, Wessel, & Redder, 2019), based on a teaching-learning arrangement developed by Prediger and Wessel (2013).

Methods of data gathering

Intervention. The project investigates a bilingual teaching intervention for developing multilingual students' conceptual understanding of fractions (especially organized for the research project). The intervention was conducted in small groups of 2-5 students each, and all groups were videotaped. The teaching material was provided in German and Arabic (or Turkish in the previous study), teachers spoke both languages.

Sample. The intervention addressed newly arrived Syrian students ($n = 18$, 12-15 years old) who are emergent German speakers (abbreviated as emergent multilinguals). Their prior formal education in Syria (5-8 years) took place in their Arabic. We present a case study of three students, Manal, Malik, and Zarah, who have learned German for 1.5-2.5 years and reached a German proficiency level of A2.2 in the Common European Framework of Reference for Languages. Among the three, Malik has the strongest mathematics achievements in the pre-test, and Zarah is slightly more proficient in German language than the others. The data was later compared to findings from the first intervention with native residents who spoke both German and Turkish ($n = 41$, 12-14 years old) who had grown up in Germany with no prior experience in activating their home language, Turkish, for institutionalized mathematics learning situations.

Selected task for the case study. While many episodes from the video data corpus were analyzed in order to identify the students' repertoires, the case study presented here is focused on the task in Figure 2. It stems from the second session of the intervention, when students had already worked on the part-whole concept. The task aims at consolidating the students' part-whole concept by addressing shares for different wholes (10 GB and 5GB) and at preparing the comparison of fractions. Subtask C follows the variation principle: Students usually solve it by either lengthening the bar in the graphical representation (the teacher then asks them to also relate this to the symbolic representation, e.g., articulating that $7/10$ is less than $8/10$ or that $7/10$ must be added by $1/10$ to reach $8/10$) or starting in the symbolic representation and formally adding $1/10$ (the teacher then asks them to also show what this means in the graphical representation). The relation of meaning-related, formal language registers and different representations is at the core of developing conceptual understanding.

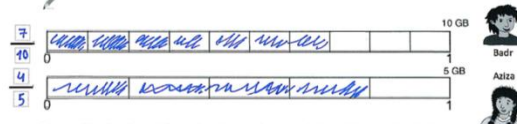
Finding equal-sized parts in the fraction bars

Badr has already downloaded 7 GB of a 10 GB film.
Aziza has downloaded 4 GB of a 5 GB film.

- A Draw Aziza's and Badr's parts into the fractions bars and write down the fractions for their shares.

7 Gleich große Anteile in Streifen finden

- a) Male Azizas und Badrs Anteile vom Ganzen aus Aufgabe 6 in die Streifen und schreibe die Brüche links neben die Streifen.



- b) Wer hat den größeren Anteil vom Ganzen geladen? Woran siehst du das im Streifen?

- c) Was musst du ändern, damit die Anteile gleich groß werden?

- B Who has loaded the larger part of the whole?
How do you see that in the bar?
- C What do you have to modify so that the parts become equal size?

Figure 2: Fraction tasks in the case study and its preliminary solution by Zarah

Methods of qualitative data analysis

The transcripts of the selected videos were qualitatively analyzed in two steps with respect to students' conceptual development across languages, registers, and representations:

- In Step 1, teachers' questions and students' answers were analyzed turn by turn with respect to the uttered individual theorems- and concepts-in-action (Vergnaud, 2016) on the part-whole concept and the students' emergent ideas for comparing fractions.
- In Step 2, each utterance was coded by the register and/or representation the speaker refers to and with a "+" if two registers/representations were related within the utterance or between two utterances. For example, "multiply," "denominator," and "times" are coded as terms from the technical register, "part of whole," "colored bar," and "equally long" as terms from the meaning-related academic register (Prediger & Wessel, 2013). Although some terms appear in different registers, their use is specific to the different registers, for example, "equally large" as a technical term vs. "equal" as an everyday term. As some English translations of terms do not exactly reflect the register character of the German or Arabic original, the original language was focused.

Insights into learning processes of newly arrived emergent multilinguals: Case study of Manal, Malik, and Zarah and equal-sized parts of the bars

In the episode in view from the first session, the newly arrived students Manal, Malik, and Zarah work with a German- and Arabic-speaking native resident bilingual pre-service teacher (TeaA) and a German-speaking teacher (TeaG) on the comparison of fractions (tasks printed in Figure 2). In earlier tasks, the fraction bars were introduced in the download context. Prior to seeing the printed part of the transcript, the students solved Task A (see Figure 2 for Zarah's solution), drew the colored parts of the bars and wrote down the fractions. They then discussed Task B with TeaA in Arabic: Which child has downloaded a larger part of the whole, Badr's share of $7/10$ or Aziza's share of $4/5$. Although the graphical representation was drawn, their discussion with TeaA in Task B mainly refers to the technical Arabic register and the symbolic representation and less to the download context and related everyday language. In contrast, neither the graphical representation nor any meaning-related term, such as "share," "part," or "whole," are explicitly addressed. TeaG takes over when students arrive at Task C.

45	TeaG	Now, we want to think about, how can we make this equal [<i>points at the end of the colored parts of the bars</i>]? How can we make $7/10$ and $4/5$ equally large? Do you have an idea?	T	graphical repr. + technical reg. + everyday reg.
46	Zarah	Five times two and four times two.	Z	symbolic repr.
47	TeaG	Yeah, you have an idea how to do this by [symbolic] calculations. But then, they are not yet equal, I think, because there is $8/10$ [<i>points at the bar of $4/5$</i>] and $7/10$ [<i>points at the shorter bar</i>]. Do you have an idea, perhaps, when you look at the picture? Manal, you look as if you have an idea.	T	(<i>explicit</i>): not symb., but graphical repr.
48	Manal	Aziza is very, pretty large [<i>points at the $4/5$ bar of Aziza</i>]	Mn	graphical repr.

In Turn 45, the teacher asks how to modify $7/10$ so that the colored part of the bar becomes equally long as the colored part in the $4/5$ bar. He uses the everyday terms "make equal" and the technical term "equally large" while pointing at the graphical representation, intending to connect these three registers and representations. But his plans are not fulfilled: Zarah (in Turn 46) does not refer to the graphical representation but only to the verbalized symbolic representation. In Turn 47, the teacher acknowledges that her procedure for finding an equally large fraction for $4/5$ is mathematically cor-

rect. He continues asking her to explain also how to modify $7/10$ so that it reaches $8/10$, and makes explicit that he wants her to refer also to the graphical representation. This repeated hint leads Manal to refer to the expected representation: Manal uses the graphical representation as the source for the comparison of fractions for the first time in Turn 48. Although she visibly struggles while searching for adequate German terms (“pretty great”) and does not complete the sentence in a grammatically correct form, her German is still sufficient to express her meaning-related ideas on the comparison, together with gestures. In contrast, Malik stays in the more familiar technical register:

49	TeaG	Exactly, Aziza is larger and what can we do so that Badr is equally large?	T graphical repr.
50	Malik	Simple, Simplify [...] 10 gigabytes.	Mk context lang. + symb repr.
...			
55	TeaG	How can you do it in the picture? [<i>hints to graphical representation</i>] [...]	T graphical repr.
56	Malik	The ten divided by two becomes five [<i>points at the longer and shorter bars</i>].	Mk technical register, hints to graph. repr.

Although Malik receives several prompts to refer to the graphical representation (Turns 49, 51, 53, 55), he talks in the technical register (Turns 50-56). His interpretation of “equally large” seems to be “of same denominator,” without satisfying the teachers’ (perhaps unusual) expectation of adding $1/10$ to the bar. In Turn 56, he finally gestures to the graphical representation. The teacher tries once more to focus students’ attention to the elongation of the colored part of the bar:

57	TeaG	[...] Then [...], but this would be until here and for Aziza this would be until here [<i>hints again to the ending points of both bars of unequal length</i>] What would we have to do so that both shares become equally large We have seen, $7/10$ is less than $4/5$. But do you have an idea how to modify $7/10$?	T graphical repr.
58	Zarah	Well, we can change this [<i>points at the eighth piece in the 7/10-bar</i>]. And then, five times two and four times two becomes eight, like that?	Z graphical + symb repr.
59	TeaG	Hmm, exactly, but what you said first, this was a very good idea. What did you say?	T strengthens graphical repr.
60	Zarah	We can here [<i>imitates the coloring of the eighth piece</i>]	Z graphical repr.
61	TeaG	Do it, actually. Because, what happens if you color this piece?	T graphical repr.
62	Zarah	That becomes equally long [<i>points at the ending points of the colored bars</i>]	Z graphical repr.
63	TeaG	Then, the shares are also equally large.	T graphical repr.
64	Zarah	Then I do this? [<i>all students now color the eighth piece in the 8/10-bar</i>]	Z graphical repr.

The teacher’s repeated prompt to focus on the graphical representation finally leads to Zarah’s idea to relate the graphical and the symbolic representations in Turn 58 (“change this”). Again, she uses a minimal set of words to address her meaning-related ideas with gestures, deictic means, and prosody, but without explicitly articulating meaning-related terms. Once she has expressed her meaning-related ideas of modifying the part of the fraction bar, she can make explicit the meaning of “equally large” in the meaning-related register describing the graphical representation: “That becomes equally long” (in Turn 62). Here, the graphical representation is used to solve the task for the first time, not only as a diagram to read off numbers. In her solution, she considers both colored bars and their relation, as originally intended by the task. After this, the teacher asks for a justification:

65	TeaG	Yes, exactly, and why are the shares equally large, then? [...]	T graphical repr.
66	Zarah	Five times two and four times two #	Z symbolic repr.
67	Malik	#Eight	Mk symbolic repr.

The teacher’s “why” question in Turn 65 brings Zarah back to the technical register and the symbolic representations (Turn 66), and Malik joins her (Turn 67). Based on her experience with mathematical practices, justification in mathematics requires symbolic representation, as she formulates in another part of the transcript. However, this time, the symbolic procedure is related to the graphical shift from one bar to the next. Thus, Turns 58-67 indicate an activity of relating registers and representations.

Some turns later, the Arabic-speaking teacher talks to the students again and they switch to Arabic. Manal admits to have not yet understood (grey letters mark Arabic parts of the transcript):

79	TeaA	[...] You do not know how to write it?	
80	Manal	No, I have not understood it.	
...			
83	TeaA	<i>[to Malik]</i> [...] Can you explain to her <i>[points at Manal]</i> how you found the result, why you have drawn one more?	T graphical repr., meaning-rel. reg.
84	Malik	Because they are equally large.	Mk graphical repr.
85	TeaA	First, this is longer and that is why she got the idea to add one.	T + technical reg.

The Arabic discourse gives Manal the space to admit that she has not understood (Turn 80). The teacher makes sure that she constructs the meaning of the graphical representation (Turns 81, 83, and 85). Malik explains in the technical register what the graphical representation means (Turn 84), and then the teacher explains the graphical modification, also, remarkably, in technical terms (“add one”). During the whole discussion of Task C, the Arabic terms for “whole bar,” “colored part of the bar,” and “share” are not formulated by either the students or by the teacher.

In total, this episode shows that students and teachers activate different sources for meaning-making: Whereas the German teacher intends to construct meanings for the symbolic $7/10 + 1/10 = 8/10 = 4/5$ by working within the graphical representation and the meaning-related register, the students show a huge distance from the graphical representation, but a familiarity with the symbolic representation and a preference for the technical register. After longer negotiations, the teacher and the students jointly construct the meaning for the graphical representations by means of the context (not shown here) and by means of the symbolic representation. This huge difference in the students’ sources of meaning-making and felt need for meaning-making for unfamiliar representations are more influential to the situation than the missing meaning-related vocabulary, which the students compensate for by gesturing and other multimodal sources.

Contrasting the learning processes of native resident multilingual students and newly arrived emergent multilinguals

To contrast the presented case of Manal, Malik, and Zarah with native resident multilingual students, we draw upon findings in earlier publications (e.g., Schüler-Meyer et al. 2019) from native resident students who spoke both German and Turkish. The case study of Manal, Malik, and Zarah suggests drawing the emergent multilinguals’ repertoires in a different way: not in hierarchical levels of successive abstraction from bottom to top, as shown in Figure 1, but in three columns, where the symbolic, graphical, and contextual representations serve as mediators between the home language and German language in each of the registers, as shown in Figure 3.

Although theoretically the languages and registers could be related in different combinations, Figure 3 shows the combinations that were empirically identified. Native resident multilingual students in previous studies have often appeared to feel alienated from symbolic representation and prefer the everyday register and contextual representations, from which they access the graphical representation and the meaning-related academic register in both languages and, in the end (with teacher's support), also the technical register and the symbolic representation. In their processes, travelling between both languages in bilingual connective modes was a major resource for their meaning-making processes (Schüler-Meyer et al., 2019; similarly in Moschkovich, 2013; Barwell, 2018).

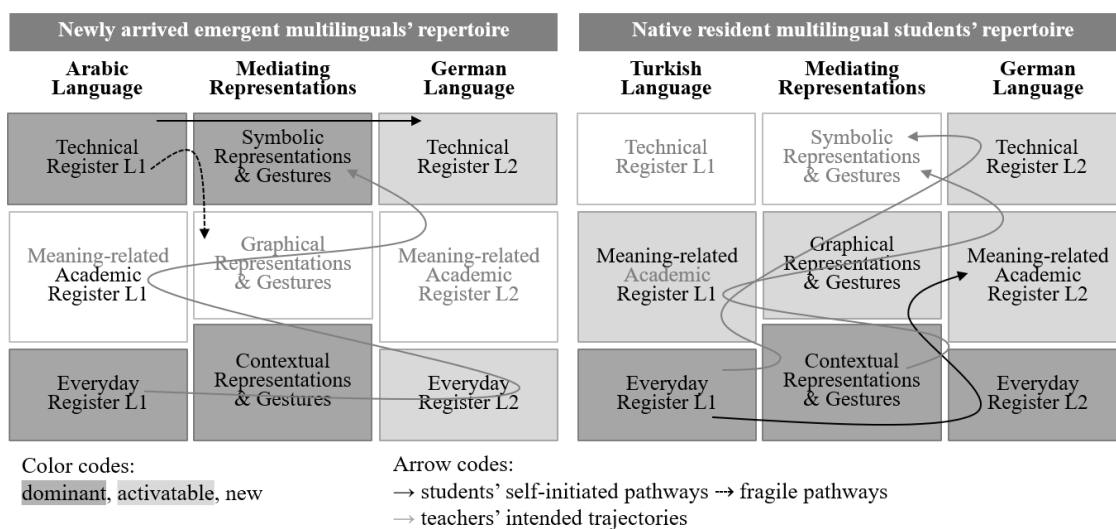


Figure 3: Contrasting the multilingual repertoires in parallel episodes

In contrast, for the three newly arrived students in the current case study, connecting both languages in either of the registers rarely occurred, mainly because they strictly reserved German for the German-speaking teacher and Arabic among themselves and for the bilingual teacher. The fact that they adopted only a dual monolingual mode with rare exceptions might be traced back to the teachers' languages (Planas & Setati-Phakeng, 2014, emphasize the language context as a crucial influence) and also to the fact that their German was not yet fluent, which shows why the term *emergent bilingual* applies. Furthermore, newly arrived students who are familiar with the symbolic representation can easily transfer the basic technical terms from their home language to German. With some teacher support, they can unpack the meaning of the symbolic elements by using implicit meaning-related references to the graphical register. In our video material, all newly arrived students were acquainted to verbalizing the symbolic representations in German, and they activated this resource to construct meanings for a more unfamiliar representation.

Hence, for the investigated students, the different prioritization of representations in Syrian and German lessons appeared to have a direct impact on different uses of students' repertoires. Those who grew up in classrooms where the technical register and the symbolic representation were more valued developed other learning pathways through their individual resources for meaning making. These pathways have not yet been considered, in either the international theoretical discourse (Barwell, 2018; Planas, 2018; Planas & Setati-Phakheng, 2018) or in classroom practices in Germany.

Discussion and outlook

As this case study has shown, students' personal multilingual repertoires can be very diverse. Whereas native resident students in Germany usually refer to contexts, graphical representations, and everyday registers as their sources for meaning-making (Moschkovich, 2013; Planas, 2013; Barwell, 2018), some of the newly arrived immigrants have strong resources in symbolic representations and thereby more quickly acquire the German technical register that their resident peers have to first get to know. In contrast, they can be unfamiliar with an emphasis on graphical representation, which is a typical shared practice in German classrooms, but not all over the world.

Although the case study is far too selective and limited in sample and scope to generalize these patterns, it already contributes to theorizing the dynamic conceptualizations of personal repertoires: repertoires are diverse and include registers and representations, beyond state languages (Barwell, 2018; Planas, 2018). We add that it should also take into account different mathematical practices in dealing with representations and registers. These theoretical extensions also have practical consequences for classrooms: Rather than planning only one learning trajectory that starts from the everyday register and concrete representations towards the formal and symbolic (Prediger & Wessel, 2013), more flexible learning trajectories should be planned. Here, we can add that for newly arrived students, it can even be beneficial to start from symbolic representations and technical registers and then continue towards graphical representations and meaning-related registers.

Acknowledgement. This paper was developed in the “MuM-Multi: Fostering Language in multilingual mathematics classrooms” project, funded from 2014-2020 by the German ministry BMBF (grant 01JM1403A to S. Prediger & A. Redder). We thank the colleagues for the interdisciplinary collaboration.

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