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How contrasting multiple languages can support conceptual understanding: The cases of newly arrived and resident multilingual students

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Activating multiple languages as resources has been shown as beneficial for mathematics learning, with the potential to utilize students' multiple languages for facilitating conceptual insight. However, it is yet unclear how students can be supported to utilize their multiple languages as epistemic resource in such a way, particularly in superdiverse classrooms where students do not necessarily share a home language. To better understand the conditions for utilizing multiple languages as epistemic resource, we investigate the promising design principle of contrasting multiple languages in a classroom of newly arrived students and a group of resident multilingual students. Our findings show how this design principle was realized in different ways by students with different language backgrounds, yet that home languages were crucial for students' meaning making. This informs how to realize the said design principle in superdiverse classrooms with differing language constellations.

Keywords: Multilingual repertoire, newly arrived students, contrasting multiple languages.

Introduction

The rise in the number of multilingual students in European mathematics classrooms calls for teaching strategies to better accommodate the students' multiple languages as resources. Previous research shows the potential of multiple languages to become a resource for communication (Planas, 2018) and conceptual insight (Barwell, 2018; Prediger et al., 2019). Anecdotally, many teachers working in classrooms with a majority of multilingual students, e.g., in classrooms with newly arrived students, already accept students' use of their home languages, because it is a relevant part of their students' identity but it also constitutes a valuable resource for students to communicate and collaborate with each other. However, it is yet unclear which teaching strategies are conducive to students using their multiple languages not only as communicative resource, but as an epistemic resource for conceptual understanding, particularly in classrooms where students do not share a home language. In this paper we are investigating the effects of a specific design principle of harnessing students' multiple languages for their epistemic potential. Particularly, we investigate the design principle of contrasting multiple languages. Contrasting multiple languages can highlight specific nuances of a mathematical concepts and hence, when harnessed as learning opportunity, can facilitate students' conceptual insight (Schüler-Meyer et al., 2023). This design principle was realized in two specific superdiverse language contexts, in a secondary school for newly arrived students and a school with resident multilingual students. In this paper, we investigate the research question: *How is the design principle of contrasting language differences realized in the two contexts?*

Enacting language as resource for conceptual insights

In mathematics classrooms with non-shared multilinguality, there are many language constellations for participating in classroom discussions, from individual use of home languages (e.g., during

reading a task), use of home languages or English as lingua franca in groups, towards whole-classroom discussions which can encompass multiple languages. Accordingly, to frame students' languaging in different constellations, we conceptualize it with individual repertoires-in-use. Following Barwell (2018) and Uribe and Prediger (2021), we define a language repertoire as "the collection of ways individuals use language and literacy and other means of communication to function in the multiple communities in which they participate, focusing on the resources deployed by individuals" (Blackledge et al., 2014, p. 487). Repertoires-in-use are the multiple languages, literacy, and representations that an individual mobilizes to think mathematically in the above-described constellations. A promising way for how multilingual students can be facilitated to utilize their repertoires-in-use as an epistemic resource is to promote the connection of multiple languages and representations. Through connecting languages and representations, students can combine different language-specific facets of a concept to develop a deeper understanding (Prediger et al., 2019). The facilitation of connecting multiple languages and representations has been translated into concrete design principles for designing tasks that promote conceptual understanding in such a way (Schüler-Meyer et al., 2023), within the framework of didactical design research (Gravemeijer & Cobb, 2006).

Methods

The selected task

The design of the task adapts the design principle of contrasting language differences for facilitating conceptual insight for the algebraic concept of functional relationship. This task is a further development of a language-responsive task developed in Korntreff and Prediger (2022). Initially, students investigate the problem of how much it costs to rent an e-scooter to visit their relatives. The task is designed to utilize the didactical potentials of relating registers and representations for meaning making (Prediger, Clarkson, & Bose, 2016; similarly, Prediger, Uribe & Kuzu, 2019; Prediger & Uribe, 2021) by connecting the verbal everyday- and technical register with representations and by prompting language production in the home languages and in the language of instruction.

The task provides information about the e-scooter rental rules and consists of two problems. The first problem asks students to write a description (optional in their home language or the language of instruction) on how they would explain the rental rules to a family member. This aims to provide students with an opportunity to start with the everyday register in their home language or in the language of instruction. In this problem, students also calculate the cost they must pay for certain rental times and explain their strategy in the language of instruction. It also includes a table to investigate the cost of different rental times followed by questions that guide them to think about a formula that represents the given rental rules (Figure 1). The second part of the task provides students with speech bubbles showing several phrases on how the variable term "any riding time" is expressed in different languages (Polish, Indonesian and Turkish, Figure 2). This aims to contrast multiple languages and to make connection between the meaning-related academic register in the home language and in the language of instruction, in relation to the variable terms. Particularly, it is intended to facilitate students to make sense of crucial meaning-related phrases for the concept of the variable (Prediger & Uribe, 2021).

Recently, Till has frequently rented an e-scooter. In the table you can see how long his ride was and how much he had to pay. You can also find a summary of the prices.

Service costs
 Till's e-scooter: 0,15 € per hour and 1 € for unlocking
 Standard rate (0.15€/hour) applies whenever the scooter is unlocked.

Fill in the missing values to Till's table. Add headings to the columns and fill in the last line.

Day	Riding time (in hour)			
May 16	20	$20 \cdot 0,15$	$20 \cdot 0,15 + 1$	4,00
May 19	12	$12 \cdot 0,15$	$12 \cdot 0,15 + 1$	
May 25	18			
May 29		$13 \cdot 0,15$		
For any riding time				

Figure 1: Introduction of e-scooter rental rule in the task (English translation of Dutch task)

How do you say for "any riding time" or for "any time" in a language other than Dutch, such as the language you speak at home? Each member of the group can fill in a speech bubble in his/her own language. Explain to the others how your speech bubble can be translated into Dutch.

Jakikolwiek czas jazdy
(voor iedere rijtijd)

Waktu tempuh tertentu
(bepaalde reistijd)

Herhangi bir kiralama süresi
(elke huurtijd)

Figure 2: Part of the task for language reflection through contrasting languages

Research context and methods of data collection

In this study, we implement the task in two superdiverse secondary school settings. The first setting is a whole-class setting in a secondary-school classroom for newly arrived students (*Internationale Schakelklassen, ISK*) in the Randstad region in the Netherlands. Newly arrived students, generally, have been living in the Netherlands for up to two years and had their previous education in their home country or elsewhere. The students usually speak some English and are identified as Dutch-language learners. The language of instruction in mathematics is Dutch, but the teacher makes use of English regularly. There are more than ten different home languages spoken by the students ($n = 25$) in this first setting. The students' ability is comparable to that of Year 1/Year 2 MAVO/HAVO Dutch secondary school students (comparable to grade 8 of middle school, 13–15-year-old). The second setting is a public secondary school also in the Randstad region, which constitutes a class of mostly resident multilingual students. In total, the school hosts students of more than 70 different nationalities. There are five different home languages spoken by the students participating in this study ($n = 8$). The students are in year 2 of HAVO level, comparable to the students in the first setting. We label both settings as superdiverse because not only do the students speak different home languages, but also likely differ with respect to socioeconomic status and migration biographies.

The students in the two classes worked individually on the task while being in a small group setting which allow them to talk to each other. As much as possible, teachers put students with a shared home language in the same group. We collected students' written work as well as video-recorded students' work on the task. In total, data consists of four videos of selected groups in the newly arrived class and two videos in the resident class.

Methods of data analysis

In this paper, we qualitatively analyze the episodes in the video recording where students work on the task described above (Figure 1 & 2) to investigate the conditions for students to utilize their multiple languages as an epistemic resource. The steps of analysis aim at characterizing students' repertoire-in-use, that is, their use of certain languages, registers, and representations and the connections among these during meaning making.

- Firstly, the transcripts of each video recording are sequenced, and episodes are labelled based on students' articulation of algebraic concepts of functional relationships.
- Secondly, the categorized conceptualizations are further coded with respect to the language used by students. The analysis also includes the language-learning opportunities realized by the students, progressing from everyday language and meaning-related vocabulary in the academic register and the technical register. These codes allow us to study the connections that students make within their repertoires-in-use (Uribe & Prediger, 2021).

In this paper, we present two episodes since they show crucial phenomena that can unfold when the designed task is realized by the students in the two language contexts.

Results

School setting: Newly arrived students

The following episode illustrates how Karl (home language Swedish) and Henryk (home language Polish) use their multiple languages in the e-scooter task. The episode illustrates an opportunity for utilizing the epistemic potential of multiple languages, which has not been fully realized.

- Karl: What does this mean [pointing to the first speech bubble in Figure 2]?
- Henryk: It means voor elke tijd.
It means for every time.
- Karl: Voor elke tijd? Is it just that? Voor elke keer?
For every time? Is it just that? For each time [in the sense of occasion]?
- Henryk: Yes, also.
- Karl: Then, what does bepaalde reistijd mean?
Then, what does certain travel time mean?
- Henryk: It is how much you have to pay, you know. At the beginning 1 Euro and then 15 cents.
- Karl: Wat betekent reistijd? Wat is elke reistijd? Is it every hour?
What does travel time mean? What is every travel time? Is it every hour?
- Henryk: Yes, every hour.
- Karl: So, what is bepaalde reistijd?
So, what is certain travel time?
- Henryk: This [pointing at the table shown in Figure 1] ... 1 euro to start out and then 15 cents. That is the bepaalde reistijd.
This [pointing at the table shown in Figure 1] ... 1 euro to start out and then 15 cents. That is the certain travel time.
- Karl: How do I say that? Oh, no. Is that how much, uhm? Oh, I know it is vaste prijs. In Swedish it is fast pris.
How do I say that? Oh, no. Is that how much, uhm? Oh, I know it is fixed price. In Swedish it is fixed price.
- Henryk: What is that? Oh, the first thing you pay? So, the one Euro.

In this episode, students have difficulties in understanding the Dutch words for expressing an arbitrary travel time (*elke huurtijd, bepaalde reistijd*) and tried to access the meaning through everyday language and the tabular- and symbolic representations. Karl and Henryk discuss the meanings of the phrases “elke tijd” (every time in the sense of variable ride time) and “elke keer” (every occasion, the meaning of one ride with a scooter), yet without identifying these differences in meanings. The students make progress with their understanding of the constant and variable term by discussing what the rental rules means. They identify 1 euro as constant term with the help of the table and later also with the help of Karl’s knowledge of the meaning of fixed price in Swedish.

The episode highlights how students in the newly arrived class utilize their home languages as repertoires to make sense of the Dutch academic register for describing the constant and variable terms. Since Henryk and Karl do not share any language other than English, they initially unfold the everyday Dutch language through making connections to English, e.g., by agreeing that “elke keer” and “elke tijd” have the same meaning, which is based on Henryk’s reading of the Polish speech bubble (Figure 2). In this case, this agreement is not mathematically viable because it hides the differences in meaning in the Dutch language. Then, they try to make sense of *bepaalde reistijd* (in this case “a specific riding time” for the variable term) and translate it as “how much you pay”, that is, in the meaning of the price of a ride or the dependent variable. In contrast, Karl’s knowledge of academic mathematical language for fixed price allows him to identify the constant term and its Dutch translation, “vaste prijs”. Overall, Henryk and Karl have well-developed repertoires to connect the Dutch (academic) language to their everyday home languages. Yet, in this episode, the knowledge results in imprecise meanings for the Dutch academic language, with resulting misinterpretations of the elements of the function that represents the e-scooter ride. The students can overcome this impreciseness in two ways. Firstly, they can utilize the tabular- and symbolic representation to identify the constant and variable term. Secondly, their knowledge of the academic register in the home language, particularly on the word level, allows them to recognize the meaning of “vaste prijs”, because of word similarities between Dutch and Swedish. However, it remains questionable whether they conceptualized the variable term in a viable way at this point. Hence, to further harness the potentials of the task to help newly arrived students to use their multiple languages as a resource, a teacher could have engaged his students in mathematical practices of comparing the variable term (price for the riding time), the constant term (price for unlocking) and the dependent variable (the total price for a ride) through its conceptualizations in different languages. Possibly, students could then have recognized that “elke keer” (for each ride) and “elke tijd” (for each time) have different meanings, despite of their same English translation as “each time”.

School setting: resident multilingual students

The following episode illustrates how two students, Hakim (Moroccan Arabic) and Miguel (Spanish) with good proficiency in their home languages have connected the Dutch language in the task with their home languages. The discussion between the students and the first author took place in English.

Researcher: So, looking at the three expressions [Figure 2], which one is closer to what you would say in your home language?

Hakim: I think the first and the third ones. Because this is the time [pointing to the Polish expression, left speech bubble in Figure 2]. The time that you use. This is how much it is [pointing to the Turkish expression, third speech bubble in Figure 2]. So it is

- both. But it is more this one [the Turkish expression] because it is about how much it costs, and you are trying to get the point about how much you need to pay. [...]
- Researcher: OK. Hakim said when he thinks [in his home language], ‘voor iedere rijtijd’ sounds more natural, but when he calculates he is using the third one, ‘elke huurtijd’. What about you, Miguel?
- Miguel: I only use the first one [pointing to his writing ‘para cada vez’ (*for each time*)].
- Researcher: You’re using the first one. And when you calculate the scooter cost, can you also use this expression?
- Miguel: No, I use the second one [pointing to his writing ‘cierto periodo de tiempo’ (*certain period of time*)].

Upon asking how he approached the task of contrasting languages (Figure 2), the student (Hakim) reports that he sees speech bubbles one and three as being closest to his home language. Furthermore, he reports how he sees differences in meaning, between “the time that you use” (*voor iedere rijtijd*) and “it is about how much it costs” (*elke huurtijd*). Accordingly, the students were able to make a connection between the expressions in Dutch and in their home language, presumably because they are proficient in both languages. With respect to their repertoires in use, the task generally seems to encourage students in resident classes to use multiple languages to think about the meanings of the variable terms both in the language of instruction and in their home language.

While Hakim and Miguel can use their home languages to identify differences in meanings in the speech bubbles and relate them to the meaning of the variable term and the dependent variable, their use of everyday language does not seem to support their meaning-making for the variable nature of the e-scooter rental cost. Particularly, the students do not investigate the differences between *elke*, *bepaalde* or *voor iedere [tijd]*, focusing instead on the difference between time and costs, with the latter seemingly being treated as a fixed value to be calculated. Clearly, the students’ repertoires are a communicative resource, both for communicating with each other and with the teacher, and allows them to recognize distinctions between time and costs. Accordingly, despite no progress being made to recognize the variable nature of the variable term, the students’ repertoires show potential for further meaning making based on their fine-grained distinctions between the given multilingual utterances in the task (Figure 2) for expressing the variable term and dependent variable.

Compared with the previous school setting of newly arrived students, the students in resident classes seem to have more developed repertoires for connecting languages which could potentially be utilized for making meaning for the variable in the e-scooter context. Yet, the students do not attend to the variable nature implied in the speech bubbles (Figure 2). Here, as in the previous context, a more explicit comparison of language for expressing variable and constant terms could support students in recognizing the co-variation of time and costs. We suspect, however, that – in line with principles of early algebra (Mason et al., 1985) – expressing change in connection to the given table could turn out more important than expressing the variable and constant terms on their own. This suspicion is substantiated by findings that languaging has to be conceptualized in connection to students’ mathematical practices that they are engaged in (Moschkovich, 2015).

Discussion and conclusion

This paper shows the specific demands for the realization of the design principle of contrasting multiple languages in the two language constellations of newly arrived classrooms and resident

multilingual classrooms. While this design principle could potentially be realized in each constellation, its full realization seems to depend upon further situational demands, such as 1. socio-mathematical norms of using multiple languages that could prevent students from utilizing their full language repertoires, 2. previous classroom experiences of how multilingualism is utilized, and 3. the perceived value of a specific language. Here, students' proficiency in the language of instruction and in the home languages influence whether students can recognize language specific nuances of a concept. If these nuances are not recognized, contrasting languages might not yield a particular potential for epistemic insight beyond the communicative benefit of comparing different ways to express a specific concept. Accordingly, our findings give a more detailed account of the requirements to activate multilingual resources for epistemic purposes during mathematics learning in different settings, which adds depths to findings from previous research in multilingual mathematics learning (e.g., Barwell, 2018; Planas, 2014, Prediger & Uribe, 2021; Prediger, Uribe & Kuzu, 2019).

Facilitating students in making connections between everyday registers in the home language and the language of instruction is a first viable step and can be a way to acknowledge student's identity, but it is not sufficient for students to realize the epistemic potentials of contrasting the languages. On the one hand, it might guide students to adopt imprecise everyday meanings of mathematical language, which in newcomer classrooms could be alleviated through connections to the symbolic register. On the other hand, for the resident multilingual students, the use of home languages enabled students to recognize conceptual differences between different language conceptualizations. These two realizations of the design principle thus hint at the need to realize the design principle of connecting languages hand in hand with mathematical practices, as these practices seem to be influential for how students make meaning when contrasting languages. Also, the teachers' recognition of students' repertoires for contrasting and connecting languages and registers are needed to facilitate students in harnessing multiple languages as epistemic resource for meaning making.

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