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► To cite this version:

David Kollosche. Towards guidelines for the analysis of teaching materials in linguistically and culturally diverse mathematics classrooms. Eleventh Congress of the European Society for Research in Mathematics Education, Utrecht University, Feb 2019, Utrecht, Netherlands. hal-02421343

HAL Id: hal-02421343

<https://hal.science/hal-02421343>

Submitted on 20 Dec 2019

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Towards guidelines for the analysis of teaching materials in linguistically and culturally diverse mathematics classrooms

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An ongoing research project aims at analysing and improving materials for teaching mathematics at German community colleges to non-native speakers of German. This paper first gives details on the circumstances of the study. Because of a lack of empirical research on the analysis and design of appropriate teaching materials for multilingual mathematics classrooms, this paper then discusses research findings from socio-political, linguistic and socio-linguistic perspectives and theoretically deduces guidelines for the analysis and improvement of the teaching materials.

Keywords: Multilingualism, learning problems, instructional materials, sociolinguistics, community colleges.

Analysing teaching materials for multilingual mathematics teaching in Germany

As a basis for teaching elementary mathematics to adults who experienced difficulties with mathematics, the German Community College Association had both a curriculum and teaching materials developed for corresponding courses (Deutscher Volkshochschul-Verband, 2017). Course contents are organised in three different entry levels, beginning with a therapeutic approach to dyscalculia, covering basic arithmetic operations with bigger numbers, and arriving at secondary school mathematics contents which are considered useful in private and vocational environments. The development was pursued on the basis of empirically founded theories of learning mathematics but the materials were not themselves tested in practice. In a follow-up project, which is headed by the author of this paper, the practical usefulness of the materials is to be evaluated theoretically and empirically with the aim to guide and implement improvements. It is paramount to understand that the teaching materials constitute the central manifestation of the idea of the course, for teachers in German community colleges, even those teaching mathematics, are usually laypersons in mathematics who orient their teaching by the materials available. Apart from the questions in how far the available materials mirror the educational philosophy of the curriculum and whether they are practical to use with students who experienced difficulties with mathematics, the evaluation project lays a special focus on the suitability of the materials for learners whose first language is not German. Irrespective of the other goals of the project, this paper will illuminate *how teaching materials in mathematics can be analysed for their suitability for non-native speakers of German*.

Despite a substantial increase in research publications on multilingual mathematics classrooms during the last two decades (e.g., see the edited volumes of Barwell, 2009; Barwell et al., 2016; Halai & Clarkson, 2016; or, for the German case, Prediger & Özdil, 2011), insights on suitable material is still scarce. In her recent meta-study of all 51 anglophone journal articles on mathematics education in multilingual classrooms published between 1970 and 2012, Setati Phakeng (2016) found only six articles that explicitly discuss didactical and methodological aspects of teaching in such environments, whereas the majority of the publications focusses on linguistic explanations for critical moments in the learning process. As Prediger and Wessel (2011) argue, the

same is the case for the German research community, “for up to now there are relatively few empirically founded insights on the question what constitutes special linguistic and subject-related obstacles for multilingual learners of mathematics and with which support (of empirically tested efficacy) such obstacles can be overcome” (p. 163, my translation). Clearly, the question of material-use in multilingual mathematics classrooms has yet to be studied, a task that cannot be achieved in this project. As the goal of this project is to analyse available teaching materials from the perspectives of multilingual learners, *the following discussion sets out to synthesise the results from previous studies on multilingual mathematics classrooms and to deduce guidelines for the analysis of teaching materials*. Accordingly, it can be understood as an early theorisation of material use in multilingual classrooms.

The specific situation of Germany and its community colleges

As this project is located at community colleges in Germany, some information on the local circumstances is required to interpret the following discussion from an international perspective. Although Germany knows some autochthonous languages other than German, some of which are accepted as official languages in small regions of Germany (e.g., Danish and Sorbian), plus some regional languages (e.g., Low Saxon) and a large variety of regional dialects of High German, Germany constructs its national identity as a monolingual country. Immigrants are expected to learn German and school education is almost exclusively organised in German. In most cases, multilingualism is based on immigration. Nearly every fourth German citizen has an immigration background (i.e. at least one parent born with a nationality other than German). Many immigrants, mostly but not exclusively of Turkish descent, were invited to West Germany in the 50s and 60s as so-called guest workers, stayed and founded families. In addition, people with German ancestors resettled to Germany in the last decades, mostly from the former Soviet Union. Germany has also welcomed a large variety of refugees with an especially large population from Syria, Iraq and Afghanistan arriving in the last years. Consequently, education in Germany faces a wide variety of cultural backgrounds and proficiency in the German language, with many students of immigrant background being born and educated in Germany, some speaking mostly German with their parents, and some having been learning German for a few years only. Nevertheless, the German situation differs a lot from the situations in bilingual communities (as on Malte, in French Canada or in Spanish-speaking communities in the USA), in classrooms with different regional languages (as in South Africa or India), and in classrooms with revitalised a language (as in Ireland). Therefore, it has to be checked carefully in how far research results from these socio-cultural settings can be transferred to the German situation.

The German educational system appears to be ill-equipped to face the challenges of multilingual classrooms, given that, irrespective of intellectual capability, an immigration background is highly correlated with under-average achievement in national assessment (OECD, 2007). As a lack of proficiency in the German language has been shown to influence learning negatively, the perceived achievement gap is mainly being associated with language deficits (Herwartz-Emden, 2003). Indeed, a recent study with 766 pupils of Turkish descent attending a German primary school labelled about a half of this population as not competent in German, seeing their chances to participate in the German-speaking classroom substantially limited (Dollmann & Kristen, 2010).

All in all, estimates assume the proportion of students who did not learn German as a first language to lie around 20%, thus identifying a large proportion of the student population in risk of being disadvantaged by the German school system (Chlosta & Ostermann, 2008). In regard to mathematics education, studies suggest that the under-achievement of multilingual learners can partly or even totally be explained by language deficits (e.g., Heinze, Herwartz-Emden, Braun, & Reiss, 2011). For example, differences in achievement between first and second language speakers of German disappeared when problems were presented symbolically instead of verbally (Heinze et al., 2011). Some authors go as far as claiming that “subject learning can essentially be understood as language learning”, thereby accentuating the focus on linguistic obstacles towards the learning of mathematics (Gellert, 2011, p. 98, my translation). Consequently, research in the last two decades has aimed at explaining how multilingual students in German mathematics classrooms are systematically disadvantaged and at exploring how education can create a supportive and inclusive environment for such students.

However, the situation of students in German community colleges differs from the situation of students in regular schools and has not yet been studied in relation to mathematics education: Students in mathematics courses at community college attend these courses voluntarily, as adults they have more extensive life and work experiences, and they assume to have problems with mathematics. As a consequence, different to the situation in the regular school system, mathematics courses at community college are first and foremost concerned with learning mathematics in a supportive environment rather than with simultaneously improving the mastery of German.

On the politics of multilingualism in mathematics classrooms

Discourses on language use in public education are usually ideologically biased as they closely interfere with national language, minority and immigration policies. Such bias has also been found in research. For example, Leung, Harris and Rampton (1997) revealed that the anglophone discourse on multilingual classrooms implicitly assumed that multilingual students do not use English at home, primarily learn English in school and thereby face comparable problems, altogether assumptions that do not withstand any closer analysis. Nevertheless, they constitute the group of those whose first language is not the language of instruction as a distinct group of others, sharing specific problems and needing the same kind of support. It is in such ways that the multilingual student is constructed as a deficient learner in spite of the fact that multilingual students differ a lot in their abilities and needs (Halai, Muzaffar, & Valero, 2016). As will be explained later, an alternative explanation resting on the distinction of certain language registers allows to analyse a wide range of linguistic difficulties of first and second language speakers simultaneously, leading the focus away from first language status and towards language proficiency in general.

Linguistic obstacles for multilingual learners are partly created by the classroom policy of promoting German as the only language of communication in school (except in foreign language classes). This limitation means that often students cannot use all of their language resources, not even when they work in pairs or groups with their language peers, thus denying them options of participation that have proven highly beneficial (Meyer, 2016). Instead, students learn not to use

their first language for their learning endeavours, a process that leads to a devaluation of immigrant languages (which, in an act of resistance, might be used as a solidary signs of a specific ethnic affiliation) and to the installation of German as the hegemonic language in science and politics (Setati, 2005). This attribution of social status to the different languages spoken by the students leaves its traces in the micro-structure of education. For example, Schütte (2009) revealed that mathematics teachers communicate the meaning of mathematical language almost exclusively in an implicit form, thereby systematically leaving behind many multilingual learners who rather require explicit explanations (Tshabalala & Clarkson, 2016, provide similar results from English-speaking classrooms).

In an attempt to discuss the situation of multilingual mathematics learners from a perspective that does not construct under-average achievements as an issue of individual deficits, recent studies have promoted the ideas to valorise multilingualism as a resource (Barwell, 2018). Indeed, several studies prove that competent multilingualism is closely related to achievement in mathematics, probably because of meta-cognitive abilities either pre-existent or acquired by the learning of multiple languages (e.g., Clarkson, 1992). In German mathematics classrooms with students of Turkish background and a policy of free language use, code-switching between German and Turkish has proven beneficial for the understanding of mathematics (Meyer, 2016; Özdil, 2011). However, Swain und Cummins (1979) found that positive effects of the use of multiple languages in class depend on a language-friendly atmosphere where the learners' first languages share the same privileges as the language of instruction. In this respect, Meyer (2016) reports that he needed to have students teach him how to count in Turkish before they would feel comfortable to use Turkish in classroom conversation.

The impact of differences in language proficiency

Instead of focussing solely on the traditional categories of lexicon and grammar, a considerable part of differences in languages proficiency can more appropriately be explained by the analysis of different language registers. Already in the 50s, Bernstein (1996) started to analyse how the English language is used rather differently in different discursive situations and among different groups of society. He found that speakers of the working class often use a “horizontal code” which uses a particular set of vocabulary, rather easy grammatical constructs, and organises knowledge along personal stories and shared experience, while middle class speakers rather use a “vertical code” which uses more loanwords and nominalisations, more complex grammatical structures and an organisation of knowledge along universal logics. Above all, Bernstein also showed that students often lack the means to recognise the structure of the meaning-making process in the code they are not used to. This phenomenon results in substantial disadvantages for the participation of horizontal speakers in the primarily vertically organised discourse of school and mathematics education (Cooper & Dunne, 2000). In an adaption to the German situation, Gogolin (1988) differentiated between everyday language (*Alltagssprache*), erudite language (*Bildungssprache*) and subject-specific language (*Fachsprache*, in our case mathematical language), with each of them differing in their use of vocabulary, grammar and knowledge-organisation. For example, “if and only if” is a phrase that is typical for mathematical language but hardly used in everyday and erudite language.

While proficiency in everyday language can be obtained in about two years (Cummins, 2010), erudite and subject-specific German language takes four to eight years to learn for second language learners (August & Shanahan, 2006), creating a barrier for understanding and participation in the mathematics classroom (Gellert, 2011; Özdil, 2011). Vertical discourses in German can be extraordinarily difficult to decipher because of its synthetic grammar and extensive use of nominalisations, compounds, dependent clauses, prepositional phrases and participial attributes – at times even causing German native speakers to pose linguistically problematic tasks as teachers (Rösch & Paetsch, 2011). Deseniss (2015) could show that students in Germany can much more easily describe the characteristics of erudite and mathematical language if their first language is German instead of any other language. However, proficiency in the vertical registers of the first language has been shown to support the acquisition of the vertical registers in the language of instruction (Celedón-Pattichis, 2004). It becomes clear that language-related learning barriers are not only a matter of immigrant background but to a large extent a question of a learner's socio-economic background. *En passant*, the same holds true for the learners' familiarity with situational context which might differ tremendously between learners of different socio-economic conditions, for example when it comes to planning a bicycle trip or reading the bicycle's speedometer (Rösch & Paetsch, 2011). So, while it is true that everyday vocabulary might pose a barrier for non-native speakers of German, for example when words such as "to remove", "to spend" or "to disappear" are used to explain subtraction, large parts of the mathematical language are equally unknown to speakers of the language of instruction, starting already with the quantity-based conception of words such as "more" and "less" (Walkerdine, 1988). The same is certainly true for the understanding and use of register-specific grammar. Consequently, a language-sensitive teaching of mathematics education should explicitly address the characteristics of the vocabulary, phrases and grammatical structures involved in erudite and mathematical language, for the sake of both non-native and native speakers of German (Gellert, 2011).

Finally, another problem arises from linguistic interferences, that is from the confusion of seemingly similar but functionally different linguistic structures in two languages. Confusion begins at the pre-verbal level, for example with different number symbols or with differences in marking bundles of thousands and the beginning of decimals (for "3,835.4" Germans write "3.825,4"), and extend to verbal constructions of numbers (Germans literally say "seven-and-fifty" instead of "fifty-seven") and other mathematical objects ("three-fifth" literally translates to "in five three" in Turkish) (Frenzel, 2017).

Consequences for the analysis and design of teaching materials

Instead of a summary of the ideas discussed above, the last section of this paper will deduce guiding questions for the analysis and design of teaching materials in multilingual mathematics classrooms. The underlying assumption is that, especially in educational environments where teachers are usually laypersons in mathematics, materials and the comments provided on them can provoke or hinder certain activities in the classroom and thus influence teaching substantially. In this sense, the question is in how far materials can constitute or induce new barriers for multilingual learners and in how far materials can be designed to include and support multilingual learners. The guiding questions are:

(1) *Does the text of the material include everyday language words of German which are used to clarify the meaning of mathematical content but might be unfamiliar to some learners?* Research in language-sensitive education proposes to collect and discuss the relevant vocabulary, to illustrate it in labelled pictures, to document it in various forms of word lists and to train its use by filling word puzzles or writing mathematics-related texts (Leisen, 2011).

(2) *Does the text of the material feature unnecessarily complex grammatical forms?* While such grammatical features can be understood as attempts to introduce learners to vertical registers of the language of instruction, they pose a barrier for the understanding of mathematics for many students. Often such text can be reformulated into more comprehensible versions (see, e.g., Griebhaber, 2011).

(3) *Does the material allow or provoke an explicit discussion of the new mathematical vocabulary and phrases that come with the covered mathematical content?* If not, materials such as mind-maps with appropriate words and phrases or building sets with chunks of mathematical phrases can help (Leisen, 2011). Mathematical writing appears to be an activity that strongly supports learners in building up competence in vertical registers (Morgan, 1998), probably because it grants students more time and chances for revisions for the struggle with the language than verbal communication does. Reports from an unexpectedly successful Latino classroom in the United States, where a culture of mathematical writing was cultivated, support this assumption (Chval & Licón Khisty, 2009).

(4) *Does the material encourage learners to compare German formulations and notations with other languages in order to identify possible misunderstandings based on linguistic interference?* Even monolingual students may profit from an explicit comparison of different possibilities of expressing mathematical ideas. Such a comparison may be introduced by easy prompts: “If you speak any other language than German, do you know how to say this in the other language? Which way do you prefer?”

(5) *Does the material allow or provoke the use of other languages in the learning process?* As Meyer (2016) discovered that students have often internalised the German-only policy of the classroom and are inhibited from the use of other languages, more or less detailed prompts to provoke the use of other languages seem necessary if the resources of other languages are to be used in the classroom.

(6) *Does the material build on situational contexts which might not be well-known to some students, especially because of cultural and socio-economic differences?* If it does, it would be worth to check if the context can be changed to one all students are familiar with, or if the situational contexts can be clarified before proceeding with the mathematical analysis of the situation.

These theoretically deduced guidelines do only constitute a first approach towards the research-based analysis and design of teaching materials for multilingual mathematics classrooms. They refer more closely to the situation in German community colleges than to other localities of mathematics education. Its usefulness will be tested when the available teaching materials of the German Community College Association are analysed first on-the-paper and then in practice. For reasons of word limitations, this paper could not include a closer discussion of ethno-cultural

obstacles towards the learning of mathematics, which Setati Phakeng (2016) sees in danger of being neglected in the mostly language-focussed discourse in academia. For example, Deseniss (2015) could identify different beliefs about the usefulness of mathematics and mathematics education between native and non-native speakers of German and even between different groups of non-native speakers. More research will be needed to apply the insights from cultural, linguistic, sociolinguistic and socio-political perspectives on multilingual classrooms to the analysis and design of appropriate teaching materials.

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