Cult Stud of Sci Educ (2018) 13:317–340
https://doi.org/10.1007/s11422-016-9747-3

ORIGINAL PAPER

Science education in a bilingual class: problematising a translational practice

Zeynep Ünsal[1] · Britt Jakobson[1] · Bengt-Olov Molander[1] · Per-Olof Wickman[1]

Received: 1 April 2015 / Accepted: 22 March 2016 / Published online: 12 October 2016

Abstract In this article we examine how bilingual students construe relations between everyday language and the language of science. Studies concerning bilingual students language use in science class have mainly been conducted in settings where both the teacher and the students speak the same minority language. In this study data was collected in a class consisting of students aged 13–14. All students had Turkish as their minority language, whereas the teacher's minority language was Bosnian. The class was observed when they were working with acids and bases. In addition, the students were interviewed in groups. They were asked about how they use their languages during science lessons and then asked to describe and explain scientific phenomena and processes that had been a part of the observed lessons. For the analysis, practical epistemology analysis and the theory of translanguaging were used. The results show how the students' everyday language repertoire may limit their possibilities to make meaning of science. In particular, the teacher's practice of facilitating and supporting students' understanding of science content by relating it to concrete examples took another direction since the everyday words he used were not a part of the students' language repertoire. The study also shows how the students used their minority language as a resource to translate words from Swedish to Turkish in order to proceed with the science activities. However, translating scientific concepts was problematic and led to the students' descriptions of the concepts not being in line with how they are viewed in science. Finally, the study also demonstrates how monolingual exams may limit bilingual students' achievements in science. The study contributes by presenting and discussing circumstances that need to be taken into consideration when planning and conducting science lessons in classes where the teacher and the student do not share the same minority language.

Keywords Bilingualism · Everyday language · Scientific language · Science education · Translanguaging

Lead Editor: S. L. Ramos de Robles.

✉ Zeynep Ünsal
zeynep.unsal@mnd.su.se

[1] Department of Mathematics and Science Education, Stockholm University, 106 91 Stockholm, Sweden

Özet Bu makalede çift dilli öğrencilerin günlük hayatlarında kullandıkları dil ile fen derslerinde kullanılan dilin arasında nasıl bağlantı kurdukları araştırılmaktadır. Çift dilli öğrencilerin fen derslerinde dillerini nasıl kullandıklarını konu alan araştırmalar çoğunlukla öğrencilerin ve öğretmenin ayni dilleri konuştuğu sınıflarda gerçekleştirilmiştir. Bu makalede konu edilen araştırma 13-14 yaşlarında öğrencilerden oluşan bir sınıfta gerçekleşmiştir. Öğrenciler İsveççe dışında ayrıca Türkçe de konuşurken öğretmenin ana dilli Boşnakça olmaktadır. Öğrenciler asitler ve bazlar konusu işlenirken gözlemlenmiştir. Ayrıca, öğrencilerle grup halinde görüşmeler yapılmıştır. Bu görüşmelerde ilk olarak öğrencilere fen dersleri esnasında hem İsveççe'yi hem de Türkçe'yi nasıl kullandıkları sorulmuştur. Daha sonra öğrencilerden gözlemlenen derslerde işlenen bilimsel kavramları ve süreçleri tarif etmeleri ve açıklamaları istenmiştir. Elde edilen veriler pratik epistemolojik analiz ve the theory of translanguaging (translanguaging teorisi) kullanılarak analiz edilmiştir. Öğretmen günlük bir dil kullanarak ve günlük hayattan somut örnekler vererek öğrencilerinin derslerde ele alınan konuları kavrayabilmesine yardımcı olmaya çalışmış, fakat öğrencilerin kullanılan kelimelerin anlamını bilmemeleri öğretmenin bu davranışının yeterli olmamasına neden olmuştur. Araştırma ayrıca böyle durumlarda öğrencilerin derslerde işlenen konuları anlamak için İsveççe'den Türkçe'ye çevirmeler yaptığını göstermektedir. Günlük kelimeleri çevirmek öğrencilere yardım ederken bilimsel kavramları çevirmenin onlar için daha zor olduğu tespit edilmiştir. Bazı durumlarda öğrencilerin bilimsel kavramları yanlış çevirmeleri sonucunda bilimle örtüşmeyen tanımlamaların ortaya çıktığı gözlenmiştir. Son olarak bu araştırma, tek dilde yapılan sınavların çift dilli öğrencilerin fen derslerindeki başarılarını sınırlayabileceğini göstermektedir. Bu makale, çift dilli öğrencilere verilecek fen derslerinin planlanması ve uygulanması sırasında dikkate alınması gereken durumları ele alarak fen eğitimi alanına katkıda bulunmaktadır.

Sammanfattning I denna artikel undersöker vi hur tvåspråkiga elever skapar relationer mellan vardagsspråket och det naturvetenskapliga språket. Studier som behandlar hur tvåspråkiga elever använder sina språk under naturvetenskapslektionerna har huvudsakligen bedrivits i tvåspråkiga klassrum där både läraren och eleverna talar samma minoritetsspråk. I denna studie har data har samlats in i en klass bestående av 13-14 år gamla elever. Samtliga elever hade turkiska som minoritetsspråk medan lärarens minoritetsspråk var bosniska. Klassen observerades när de arbetade med syror och baser. Därefter genomfördes gruppintervjuer med eleverna där de fick berätta om hur de använde sina språk under naturvetenskapslektionerna samt beskriva och förklara naturvetenskapliga fenomen och processer som hade behandlats under de observerade lektionerna. Materialet analyserades genom praktisk epistemologisk analys och teorin om translanguaging (the theory of translanguaging). Studien visar hur lärarens strävan att stödja elevernas lärande i naturvetenskap genom att använda ett vardagligt språk och vardagliga exempel tog en annan riktning eftersom de vardagsord han använde inte var en del av elevernas språkrepertoar. Studien visar också hur eleverna använde sitt minoritetsspråk som en resurs för att översätta ord från svenska till turkiska. Att översätta naturvetenskapliga begrepp var mer problematiskt och ledde till att elevernas beskrivningar av begreppen inte var i linje med hur de betraktas inom naturvetenskapen. Slutligen visar studien även hur enspråkiga prov kan begränsa tvåspråkiga elevers resultat i de naturvetenskapliga ämnena. Undersökningen bidrar med att presentera och diskutera omständigheter som behövs tas i beaktande när man planerar och genomför naturvetenskapliga lektioner i klasser där lärare och elever inte delar samma minoritetsspråk.

Bilingual students' learning in science

In this study we examine how bilingual students construe continuity between their everyday language and the scientific language. The study is based on three main assumptions. First, it is well established that science has its own language. To develop scientific knowledge, students need to understand the specific use of language in science class (Lemke 1990). Second, earlier studies have shown the importance of establishing relations between everyday and scientific language (Lee 2005). Third, researchers from the bilingual field agree that bilingual students' minority language is a resource that supports students' knowledge development and their understanding of all school subjects (e.g. Cummins 2005).

Being bilingual means having two languages that are used in everyday life (García 2009). Although the languages of bilinguals are intertwined and belong to the same language repertoire (García 2009), a bilingual student's everyday language in itself consists of two national languages, e.g. Swedish and Turkish in this instance. When bilingual students enter science class they encounter one more language variety, that is, the language of science. Depending on where and how the lessons are conducted the scientific language may be in one or both of the student's languages (see e.g. Msimanga and Lelliott 2014). Accordingly, it is relevant to ask what the encounters between everyday languages and the language of science may mean for bilingual students' learning in science.

Language and science education

Several scholars have examined the relation between language and science education in general that is, without any specific focus on bilingual students (e.g. Norris and Philips 2003). Language use in science class differs from how language is used in everyday life. Hence, the terms 'everyday language' and 'the language of science' or 'scientific language' is used in order to emphasise this difference (Lemke 1990). According to Jay Lemke (1990, p. 1) "learning science means to *talk* science". In order for the students to make meaning of the science content, they need to understand how language is used in this specific context. Consequently, language is one of the most important aspects when studying students' learning in science (Roth and Duit 2003). However, that students use scientific concepts in speech and writing does not necessarily imply that their understanding of the concepts is in line with scientific descriptions or explanations. Indeed, they may even have developed a strategy to deal with language demands. An awareness of how language is used can in some situations enable students to proceed with science activities without actually understanding what some concepts or words mean (Wellington and Osborne 2001).

Students, especially in their earlier years at school, are not yet familiar with scientific language. They often use an everyday language and reasoning to make sense of science (Axelsson and Jakobson 2010). Accordingly, science lessons need to offer students possibilities to relate everyday language to the language of science (Reveles and Brown 2008). At the same time, science education implies learning how different phenomena are viewed in science. Hence, endeavouring connections between everyday language and the science content is not the same as encouraging students to develop their own ideas

about science (Scott, Mortimer and Aguiar 2006). As stated by Jerry Wellington and Jonathan Osborne (2001, p. 119), "the teacher acts as a *mediator* between everyday language and descriptions and the formal language of science with its ways of conceptualizing the world."

The use of everyday and scientific language is examined in several empirical studies. For example, Bryan Brown and Eliza Spang (2008) compared the teacher's and the students' language use in a class with 5th grade students showing high academic performance in science. The study showed that the teacher combined both everyday and scientific language in her conversations with the students. The same pattern was visible in the students' talk. In another study, Wolff-Michael Roth and Reinders Duit (2003) investigated the development of scientific language by videotaping lessons and interviewing students in the 10th grade. The students initially used an everyday language and based their discussions on their earlier experiences. Over time, they gained new experiences and developed a more scientific language. Similar results are presented in Eduardo Fleury Mortimer's (1998) study where the conversations of students aged 14–15 years old were analysed. It was clear that two different language varieties were present in the classroom: the teacher's scientific language and the students' everyday language. However, the students' language became more scientific over time.

Bilingual students and science education

Today, it is more common to be bilingual than monolingual. The world consists of approximately 200 countries and 6809 languages (Grimes and Grimes 2000). Hence, teachers need to take bilingualism into account when planning and conducting their lessons (García 2009). Studies have shown that the achievements of bilingual students, studying in a majority language different from their minority language, are in general lower than the achievements of monolingual students (Lee and Luykx 2007). This is a result of many intertwined aspects, e.g. language proficiency (Snively and Corsiglia 2001) and cultural or identity conflicts (Gilbert and Yerrick 2001). This article focuses on the relation between language and learning science. Although studies have shown that bilingual students' minority languages are not only positive when developing a second language, but also benefit their overall learning at school (Cummins 2005), research has revealed that science education for bilingual students is often conducted monolingually, that is, only in the majority language of the society or country (Lee, Luykx, Buxton and Shaver 2007). As a consequence, many bilingual students do not have the possibility to use their whole language repertoire in science, meaning that not only the scientific language, but also the everyday language is a challenge (Lee 2005).

A literature review made by Okhee Lee (2005) has shown that bilingual students' learning in science is directly related to the language of instruction. Several studies concerning the relation between bilingual students' language proficiency and achievements in science have demonstrated how sentences with a complicated syntactic structure, unfamiliar vocabulary and words with multiple meanings result in bilingual students achieving a lower score than monolingual students in written tests (see Lyon, Bunch and Shaw 2012 for a literature review). Nygård Larsson (2011) compared monolingual and bilingual students' achievements in biology. The study was conducted in an upper secondary school where all lessons were carried out in Swedish. All monolingual students pass the course, whereas several bilingual students did not. In addition, half of the monolingual students and none of the bilingual students achieved the highest grade. When the students' performance during the lessons and the written exams were studied, a general pattern was

observable. Bilingual students' answers included factual knowledge and definitions, whereas comparisons, discussions, explanations, etc., necessary for the higher grades, were missing. The author concludes that bilingual students' language proficiency in the language of instruction may prohibit them from expressing more advanced levels in science. There are also occasions in which language has indirect consequences for bilingual students' learning possibilities in science. Research has shown that some teachers assume that bilingual students need to learn the language of instruction before learning science. Hence, they tend to focus on language learning and literacy development at the expense of science lessons (Bryan and Atwater 2002). There are several reasons for the exclusion of bilingual students' minority language in science. Interviews with teachers have revealed that some of them view minority languages to be irrelevant for the students' learning in science (Lee 2005). One explanation may be that bilingual students' language development and learning in science are rarely integrated in teacher education and curriculum development (Stoddart, Pinal, Latzke and Canaday 2002). Hence, many teachers need more knowledge about how they can support bilingual students' learning in science (Cho and McDonnough 2009). Another reason is the composition of classes. In many countries, several minority languages are represented in the same classroom and/or the teachers do not share the same minority language as their students (see e.g. Blackledge and Creese 2010). Moreover, in some countries or regions, the teachers are obligated to teach science predominately in the official language for education (see e.g. Msimanga and Lelliott 2014).

Students' everyday languages and the language of science

The relation between students' everyday languages and the language of science has been examined in some studies concerning science education with bilingual students. It is well proved that bilingual students, when they have the opportunity to do so, use both their languages to make sense of science lessons (Warren, Ballenger, Ogonowski, Rosebery and Hudicourt-Barnes 2001). For example, Jennifer Goldberg, Noel Enyedy, Kate Muir Welsh and Kathryn Galiani (2009) conducted a case study in the 6th grade. Both the students and the teacher were bilingual in English and Spanish. The school was located in California, where teachers are obligated to conduct their lessons predominantly in English. The authors made classroom observations in order to study the consequences of the language prohibition. The results showed that the teacher mostly used English in her teaching. Occasionally, she spoke Spanish when talking about the science content in an everyday language. The students had the opportunity to speak both their languages in the group activities, which they also did. It was revealed that the students predominantly spoke English when talking about scientific concepts, whereas everyday words were in both languages. Since Spanish was used to make relations between everyday language and scientific concepts, the authors argue that it contributed to the students' understanding of the science content. Similar results have been shown in another study (Msimanga and Lelliott 2014). The authors conducted observations in a 10th grade chemistry classroom in South Africa, which has 11 official languages. The language of instruction is English, a language that many students seldom use outside the school-context. The purpose of the study was to investigate if and how the students used their minority languages during science lessons. The study showed that the students used their minority languages during group-work activities. In doing so they made claims, challenged each other's ideas, discussed how they could continue with the activities and made conclusions.

To summarise, studies have emphasised the importance of relating science content to everyday language (e.g. Wellington and Osborne 2001). However, most of the empirical

studies concerning this issue have been conducted in monolingual school settings (e.g. Brown and Spang 2008). The few studies that do concern the relation between bilingual students' languages and the language of science have been carried out in classrooms where both the teacher and the students are bilingual in the same languages (e.g. Goldberg et al. 2009). This is however not the situation for all bilingual students. In many countries several minority languages are represented in the same class and/or the students and the teacher do not share the same minority language (see e.g. Blackledge and Creese 2010). The purpose of this study is to present findings that give an increased understanding of the relation between bilingual students' everyday languages and the language of science in a classroom where the teacher and the students do not speak the same minority language. The study aims to answer the following question:

> How is continuity between everyday language and the language of science construed in a bilingual science classroom where the teacher and the students do not speak the same minority language?

Learning and language as action

In this study, learning is approached as a social action that takes place when students encounter other individuals and the physical world (see e.g. Lave and Wenger 1991). The study takes its stance in John Dewey's (1938/1997, p. 35) *principle of continuity*:

> … every experience both takes up something from those which have gone before and modifies in some way the equality of those which come after.

This means that students make meaning of a new situation by relating it to their earlier experiences (Wickman 2006). Bilingual students have two languages that they use within this process (García 2009). Accordingly, students' earlier experiences, mediated by both their languages, need to become continuous with the language of science (see Dewey 1938/1997). Moreover, the principle of continuity involves gaining new experiences, which implies learning (Wickman and Östman 2002). Hence, learning can be defined as 'construing new relations to what is immediately intelligible' (Wickman 2006, p. 131).

According to John Dewey (1925/1998) and the later Ludwig Wittgenstein (1953/1967) language is *action* produced through social relations rather than a set of structures with fixed or universal meanings. The meaning of words is constantly transformed and changed during people's lives (Stenlund 2000). Wittgenstein (1953/1967) states that talk and other actions get their meaning through their use in different *language games*. He defines a language game as "the whole, consisting of language and the actions into which it is woven" (Wittgenstein 1953/1967, § 7). Taking an active part of a language game involves learning its specific rules and the culture to which it belongs (Harré and Gillet 1994). The language of science and how it is used in science education in particular, can be approached as an example of a language game. Science lessons imply learning new scientific words and how to use them to cope with various encounters when participating in a scientific practice. The process also involves experiencing how words are used differently in science lessons and everyday life (Wickman 2004).

Since Dewey and Wittgenstein's ideas about learning and language presented above, do not concern bilingualism in particular, we have chosen to combine them with the *theory of translanguaging*. The theory was developed to describe bilingual students' language practice (García 2009). Translanguaging has been defined differently in educational

research (García and Wei 2014). This study is based on Ofelia Garcías (2009, p. 45, emphasis original) description of the term: "translanguaging are *multiple discursive practices* in which bilinguals engage in order to *make sense of their bilingual worlds.*" According to this view, bilinguals' meaning making process are not limited to oral and written language, but also involves other resources, e.g. gestures and drawings (García and Wei 2014). García (2009) argues that education for bilinguals has been characterised by a *monolingual view of bilingualism*. The only difference between a monolingual and a bilingual student has been regarded to be that bilinguals speak one more language. Furthermore, bilingual students' languages have been seen as two separate systems that are independent from each other and used for different purposes. However, García (2009) maintains that a comparison between bilingual and monolingual students' language practices is not possible. Bilingual students' languages belong to the same language repertoire and they are intertwined in a dynamic way. How bilingual students use their languages depends on their purpose and the situation. It is mostly in monolingual situations that bilingual students use only one of their languages. Generally, when opportunity is given, they use both their languages. Traditionally, the term translation has been used to separate languages and to emphasise that one language is prioritised before the other (García 2009). However, the theory of translanguaging concerns how the languages of bilinguals interact with each other (Lewis, Jones and Baker 2012). Accordingly, in this study both of the students' languages are equally valued and the term translation is used to describe how bilingual students use both of their languages to make meaning of the science content.

According to García (2011), some of the established terms used to describe bilingualism, e.g. mother tongue, first language and second language, are a consequence of the monolingual view of bilingualism. Hence, they are insufficient to describe bilingual students' language practices. For example, all bilinguals are not second language learners and categorising bilingual students' languages as first and second language may not always be possible. In addition, several different definitions of these terms exist within the bilingual field (see e.g. Skutnabb-Kangas 1981). In this study we will follow García's suggestions and use the term *minority language in a society* instead of terms like first language, mother language and heritage language, and the term *majority language in a society* instead of second language and additional language.

Practical epistemological analysis

The data have been analysed by using *practical epistemological analysis* (PEA), which is a well established approach developed to study students' learning in science (Kelly, McDonald and Wickman 2012). It takes its stance in the ideas of Dewey, the later Wittgenstein and sociocultural perspectives. The unit of analysis is people's actions, including speech, when participating in different activities (Wickman and Östman 2002).

PEA consists of four operational concepts: stand fast, encounter, relation and gap (Wickman and Östman 2002). The term *encounter* refers to different meetings between individuals and between individuals and physical objects. In an encounter certain actions, including words and language use, *stand fast*, implying that their meaning is immediately intelligible. Analytically, actions standing fast are observable by that there are no hesitations, further questions or explanations regarding their use. That actions stand fast does not necessarily imply that that they are true or right from a third person perspective. In

addition, standing fast is temporal, meaning that things standing fast in an activity may later be questioned by the same participants. In an encounter, gaps are frequently occurring. These are filled by construing *relations* to what is already standing fast. Filled gaps are visible from their consequences, which means that the activity continues in line with its purpose. In some situations gaps cannot be immediately filled and there is a need for *additional encounters*, observable as further questions or explanations. However, sometimes gaps cannot be filled despite additional encounters. Then, the gap *lingers* and the activity stops or takes another direction. Moreover, PEA always has to start from the participants' own purposes of the activity, that is, from a first person perspective. It is not until this is done that the examination can continue with a third person perspective, meaning that the researcher analyses what the participants' actions means in relation to the purpose of the study (Wickman 2006).

We will illustrate how PEA is used with a short example from the data for this study. Since the example does not cover all parts of PEA we will extend it with some hypothetical examples. The purpose of the lesson was to learn how BTB (Bromothymol blue) is used to determine if liquids are acidic, basic or neutral.

Teacher:	(Fills a beaker with water and drops BTB into it) Titta på droppen (holds up the beaker). Vilken färg? *(Fills a beaker with water and drops BTB into it) Look at the drop (holds up the beaker). Which colour?*
Selma:	Grön. *Green.*
Teacher:	Varför är det grönt? *Why is it green?*
Sevgi:	För att det är neutralt. *Because it's neutral.*
Teacher:	Precis, nu ska vi fortsätta med att testa… *Precisely, now we will continue by testing…*

In this situation there are several *encounters* that are observable; between the students and the teacher and between the students and the content of the beaker. That Selma answered the teacher's question 'Which colour?' implies that she noticed a *gap* that she filled by construing a *relation* to her earlier experiences of colours. Similarly, the teacher's next question, 'Why is it green?' also made a gap explicit, which Sevgi filled by construing a relation to her earlier experiences of learning that when BTB is dripped into a liquid and the colour changes into green, the liquid is neutral. It should be emphasised that not only questions, but all situations in which the participants notice a need to construe a relation implies a gap. Selma and Sevgi answered the teacher's questions without asking further questions and the teacher did not question their utterances. Hence, both the teacher's questions and the students' answers *stood fast* in the encounters and all gaps were immediately filled. However, this may not be the case in all situations. For example, when the teacher asked 'which colour' the students could have asked what the word 'colour' meant. Similarly, the teacher could have reacted to Selma's answer 'green' by saying 'no, it is blue'. Or, when the teacher asked the students why the drop was green, they could have answered 'because it is acidic' or not answered the question at all. All of these hypothetical examples would have meant that the teacher's question and the students' answers did not stand fast in the encounters. Probably, this would have implied that the participants had asked further questions and made further explanations, which are defined as *additional encounters*. However, the gaps might not have been filled, that is, *lingered*

despite the additional encounters. For example, the students and the teacher could have discussed the colour of the drop without agreeing on a common answer.

The analysis above is made from a first person perspective, meaning that it concerns the participants' actions in relation to the purpose of the lesson. The next step is taking a third person perspective by asking what the analysis means for the purpose of the study. For example, if Sevgi had answered that the drop turned into green because the solution was acidic, and the teacher had confirmed it, her answer would have stood fast in the encounter between her and the teacher (from a first person perspective). However, from a third person perspective this would have meant that both the student's and the teacher's ideas were not in line with how the process is viewed in science.

To summarise, in this study we examine bilingual students' encounters in order to study how they construe continuity between their everyday languages and the language of science. In doing so, we analyse how the students fill gaps and proceed with science activities. We argue in line with Per-Olof Wickman (2004) that filling gaps always entails continuity since it means construing new relations between earlier experiences and the present ones. Filling gaps also involves transformation of earlier experiences and demonstrates that learning has taken place (Wickman 2006). Since bilingual students' everyday language in itself consists of two languages, that is, a majority and a minority language, we adopt García's (2009) theory of translanguaging in order to study the relation between the students' languages and varieties of them.

Bilingual students in Sweden

Data was collected in a linguistically heterogeneous school, located in a suburb outside a larger city in Sweden. Approximately 20 % of the students in Sweden are bilingual and there are about 150 different languages represented at schools (The Swedish Agency for Education 2014). The number of bilingual students varies between different geographic areas. In some schools 90 % of the students are bilingual (The Swedish Agency for Education 2008).

The 'principal' language of the country is Swedish, meaning that it is the 'common language in society that everyone resident in Sweden is to have access to and that is to be usable in all areas of society' (Ministry of Culture 2009, p. 1–2). The other languages represented in the country are divided into three different categorises: national minority languages, Swedish sign language and mother tongues. The national minority languages in Sweden are Finnish, Yiddish, Meänkieli (Tornedal Finnish), Romany, Chib and Sami. All students that belong to a national minority, are deaf, hard of hearing or for other reasons require sign language have to be given the opportunity to learn, develop and use their language. However, for students that are bilingual in one of the languages categorised as 'mother tongues', schools' responsibility is limited to offer the possibility of developing and using the language. Accordingly, if students are not more or less 'fluent' in their 'mother tongue', schools are not obligated to teach them the language (Ministry of Culture 2009). Hence, the term 'minority language' is used differently in the theory of translanguaging (García 2009) and by the Swedish government (Ministry of Culture 2009). In this article, except for the description of how languages are positioned in Sweden made above, we use the term as it is defined in the theory of translanguaging (see 'theoretical framework'). In order to give bilingual students the possibility to learn, develop and use their minority languages, schools offer 'mother tongue instruction'. The lessons are optional, scheduled after the ordinary school day and given once a week for 1–2 h. In general, the

mother tongue teachers do not have any cooperation with other teachers. If 'there is a need for it', schools must also offer bilingual students support in their minority language. It is the principals' responsibility to determine if students need extra support in their minority language and how it in that case should be conducted. In general all lessons, except mother tongue instruction are conducted monolingually, that is, only in Swedish (The Swedish National Agency for Education 2008). Approximately 25 % of the bilingual students finish elementary school without being qualified to continue to upper secondary school. The corresponding figure for monolingual students is 10 % (The Swedish National Agency for Education 2008).

Addressing bilingual students' learning in observations and interviews

The class consisted of students aged 13–14 years old (7th grade). There were 16 students in the class; 11 students were born and raised in Sweden and the rest had lived in the country for less than 5 years. They all have Turkish as their minority language. According to the teacher, all students had language limitations in Swedish. The science teacher himself was bilingual in Swedish and Bosnian.

The data collection consisted of three parts. First, the students were observed during chemistry class about acids and bases. The unit consisted of seven lessons and was conducted over a period of one month. Second, the students were divided into groups of 3–4 and interviewed about their language use during science lessons. Finally, they were asked to orally describe and explain the chemical concepts and processes that had been a part of the observed lessons. The data collection was documented with audio and video recordings and resulted in approximately 30 h of recordings. The study was conducted by following the ethical considerations stated by the Swedish Research Council (2014).

The main part of the lessons was conducted as whole-class instruction whereby the teacher started by asking the students to summarise the previous lesson. Then, he continued by talking about one or two new sections in the chemistry book. The whole-class instruction and the chemistry book were in Swedish. When the students spoke with each other during lessons, their conversations were in both Swedish and Turkish. If there was time left, the teacher asked the students to answer the study questions in the chemistry book. Some students worked together by discussing and writing joint answers. The conversations were conducted in both languages, but the written answers were in Swedish. The unit ended with a written exam, which also was in Swedish.

The data analysis was guided by the research questions for this study. An initial categorisation was made in order to distinguish activities that involved construing relations between everyday language and the language of science. The next step was to make a closer examination of these activities by using PEA and the theory of translanguaging. This implied studying the encounters that the students were involved in during the lessons and during the interviews and how they construed relations in order to fill the gaps. Three different patterns were discernable and one or two excerpts from each category were chosen to illustrate these categories. The examples will be presented in the next section.

The excerpts start with the original utterances. Since the students used both their languages in some situations, we needed to make a distinction between Turkish and Swedish. Hence, Swedish is written with no emphasis and Turkish with bold letters. The excerpts continue with an English translation, written in italics. Translations from Swedish are written only in italics, while translations from Turkish are both in italics and bold letters.

The linguistic errors in the excerpts correspond to the teacher's and the students' ways of expressing themselves.

Construing continuity between everyday language and the language of science

The teacher used an everyday language and concrete examples from everyday life when describing and explaining the science content. The same pattern was also observable in the chemistry book. However, there was constantly a need for additional encounters in order for the students to fill the gaps. In other words, the students frequently asked questions, both to the teacher and each other, and needed further explanations in order to participate in the lessons. Occasionally lingering gaps occurred, that is, the gaps were not filled despite the additional encounters. Finally, it was revealed that students' minority language had a role in how they construed continuity, meaning that the students filled the gaps by translanguaging.

Additional encounters to fill the gaps

The first example chosen to illustrate an additional encounter is from a lesson concerning strong bases. The teacher talked about sodium hydroxide and gave an example of how it is used in everyday life.

Example 1:

1. Teacher: Det här är en stark, jättestark bas och det heter (writes) natriumhydroxid. Ibland era föräldrar köper den under ett annat namn för att använda som propplösare. Jag ska berätta vad det handlar om. Alltså, det andra namnet är följande (writes kaustik soda). Kaustik betyder frätande, eh, jo det används som (writes)… propplösare. Nämligen under vasken, jag vet inte hur många av er som har tittat vad finns under vasken…
   This is a very strong base and it's called (writes) sodium hydroxide. Sometimes your parents buy it under another name to use it as drain cleaner. I'll tell you what it's about. So, the other name is the following (writes caustic soda). Caustic means corrosive, eh, yeah it's used as (writes)… drain cleaner. Namely, under the sink, I don't know how many of you have looked what's under the sink…
2. Sevgi: Men vad är vasken?
   But, what's the sink?
3. Teacher: Nämligen, det finns ett rör, jag ritar så här (draws a pipe), och sen det finns (draws a sink).
   Namely, there is a pipe, I draw like this (draws a pipe), and then there is (draws a sink).
4. Özlem: Jaha, handfatet, eller?
   Oh well, the hand basin, or?
5. Teacher: Ja, precis.
   Yes, precisely.
6. Sevgi: Jaha.
   Oh well.

The teacher construed the relations 'very strong base', 'drain cleaner', 'caustic soda' and 'corrosive' to sodium hydroxide when telling the students how caustic soda is used to clean

drains (1). A gap occurred by Sevgi's question 'but, what's the sink' (2). Accordingly, the word did not stand fast in this encounter. The teacher drew a sink on the whiteboard to illustrate the word (3). Özlem responded to the teacher's drawing by asking if 'sink' meant 'hand basin' (4) and the teacher confirmed her statement (5). Sevgi reacted by saying 'Oh, well' (6), meaning that the relations construed by the teacher (3 and 5) and Özlem (4) were intelligible in the encounter and that the gap was filled.

In this example, the teacher used an example from everyday life to talk about how sodium hydroxide is used to clean drains (1). However, the everyday word 'sink' was not a part of the students' language repertoire, implying that is was not possible for the students to construe continuity between the science content and their earlier experiences (2 and 4). The teacher used another translanguaging strategy to explain the word, that is, he drew a picture of it on the whiteboard (3). The students construed a relation to another everyday word, 'hand basin', which led to a continuation of the activity (4 and 6). The teacher did not explain the difference between a sink and a hand basin, probably because such a distinction was not necessary for the purpose of the activity.

A similar situation occurred in another lesson. The lesson was conducted at the beginning of the unit and the students were working with acids in general. The purpose of the lesson was to learn about the typical qualities of acids and the students worked with the study questions in the chemistry book. Nazli and Selma raised their hands in order to ask the teacher about the second question, which was 'Which property is common to all acids?'. It should be added that the original question in Swedish (Vilken egenskap är gemensam för alla syror) is written in a more everyday language than the English translation. It becomes more problematic to illustrate this when the question is translated into English.

Example 2:

7. Teacher:	Ja? *Yes?*
8. Nazli:	Tvåan (points at the second question). *Number two (points at the second question).*
9. Teacher:	Vilken egenskap är gemensam för alla syror? (reads the question)… Alla syror är? *Which property is common to all acids? (reads the question)… All acids are?*
10. Nazli:	Sura? *Sour?*
11. Teacher:	Ja precis, det är det som är karaktäristiskt. *Yes, exactly, it's what's characteristic.*
12. Selma:	Vad menar du med karakteristiskt? *What do you mean by characteristic?*
13. Nazli:	Vi har gått igenom det! *We have talked about it!*
14. Teacher:	Jo, det gäller alltså alla syror. *Yeah, so it concerns all acids.*
15. Nazli and Selma:	(write 'all acids are sour' in their notebooks')

That both students raised their hands in order to ask the teacher about the study question shows that the question did not stand fast in the encounter. The teacher read it and construed a

relation between the question and 'all acids are' (9). By asking the students the same question in other words, the teacher made the question intelligible to the students (10 and 11). However, when the teacher confirmed Nazli's utterance (11), a new gap occurred since he used another word that was not a part of Selma's language repertoire, 'characteristic' (12). The word did stand fast in the encounter between Nazli and the teacher since she construed a relation between it and her earlier experiences of chemistry lessons (13). At this point, it should be added that the teacher used the word 'characteristic' several times during earlier lessons. However, he never explained what the word meant. In the current activity, the teacher explained the word in the same way as he had done with the study question (9), that is, by using other words (14). Both students wrote 'all acids are sour' in their notebooks (15).

In this situation an additional encounter with the teacher was necessary in order for the students to continue with the activity. It was not possible for the students to answer the question by themselves (8). An examination of the conversation reveals that Nazli did not need more information about the science content in order to answer the study question. Instead, it was the meaning of the question itself that was the reason for the additional encounter with the teacher (8–11).

Taken together, both examples (1 and 2) demonstrate the relation between language and participation in science class. In particular, everyday words used by the teacher and in the chemistry book were not a part of the students' language repertoire. As a consequence, there was a constant need for additional encounters with the teacher in order to continue with the science activities. Asking and explaining the meaning of everyday words were characteristic features of the classroom practice. Since the teacher did not speak Turkish, it was not possible for him to use the students' minority language as a resource in order to explain the words. Instead, he used other strategies, drawings and further explanations.

Lingering gaps

In both examples (1 and 2) above, the students filled the gaps by additional encounters with the teacher. However, this was not how the activities always proceeded. In some situations the gaps lingered, meaning that they were not filled although the students asked the teacher and each other for help. We will now illustrate this by two examples that are related to each other. Both are from the same lesson as the first example and concern how strong bases are used.

Example 3:

16. Teacher: … Ja, vi pratade om kalciumhydroxid, eller hur? Vi använder kalciumhydroxid, eh, alltså lösning på kalciumhydroxid är basiskt, en stark bas, eller hur. Men om man blandar kalciumhydroxid med vatten då heter det inte längre kalciumhydroxid. Då används ett annat namn. Vet ni vad det används som? Det används som kalkvatten.
… Yes, we talked about calcium hydroxide, right? We use calcium hydroxide, eh, solution of calcium hydroxide is basic, a strong base, right. But if you mix calcium hydroxide with water, then it's not called calcium hydroxide anymore. Then another name is used. Do you know what it's used as? It's used as limewater.

17. Meryem: Vad är kalk?
What's lime?

18. Teacher: Jo, ni har hört talas om kalksten eller hur, det innehåller kalk.
Well, you have heard of limestone right, it contains lime.

19. Meryem: **Türkçesi ne** (to Derya)?
What is it in Turkish (to Derya)?
20. Derya: Ehh, kalk… Vad var det… alltså…
Ehh, lime… What was it… well…
21. Meryem: **Mermer deme çünkü o** marmor**. Bilmiyorsun ki sen de**.
Don't say marble cause it's *marble.* ***You don't know either.***
22. Derya: Jag vet inte.
I don't know.
23. Teacher: Det används till… lyssna nu!
It's used to… listen now!
24. Emir: Jag?
Me?
25. Teacher: Nej, Meryem.
No, Meryem.
26. Meryem: Ok.
OK.
27. Teacher: Alltså när man får kalkvatten jag skriver här kalkvatten (writes on the whiteboard) senare kan man torka den och få kalk.
So, when you got limewater, I write limewater here (writes on the whiteboard), later you can dry it and get lime.
28. Burak: Men vad är kalk (with a low voice)?
But what's lime (with a low voice)?
29. Teacher: Det används jättemycket i Sverige och i andra länder, men vi koncentrerar oss nu på Sverige. Varför? Det har visat sig att det finns många gaser som skapar syror, som svaveloxid och kväveoxid och då använder man kalk för att neutralisera dessa.
It's used a lot in Sweden and other countries, but we focus on Sweden now. Why? It has been shown that there are many gases that create acids, like sulphur oxides and nitrogen oxides, and then you use lime to neutralise these.

The teacher started by construing the relations 'solution', 'basic' and 'a strong base' to calcium hydroxide. Then, he told the students that a 'mix of calcium hydroxide and water' is used as 'limewater' (16). However, the word 'lime' did not stand fast in the encounter between the teacher and Meryem, as she asked about it (17). The teacher answered by construing a relation between 'lime' and 'limestone'. In doing so, he took it for granted that the students 'have heard of limestone' (18). However, since Meryem turned to Derya and asked how to say 'lime' in Turkish it is reasonable that the teacher's additional explanation did not stand fast in the encounter (19). Derya answered by saying 'I don't know' (22), implying that the gap was still lingering. The students' conversation ended when the teacher told them to listen to him instead of talking (23-26). Since the students were talking in Turkish, the teacher might have assumed that they were talking about something else rather than focusing on the science content. The teacher continued and was telling how to make lime from limewater (27) when another student said 'but what's lime' (28). Accordingly, the Swedish word for 'lime' was not a part of his language repertoire either. The student's utterance was very low and the teacher might not have heard it since he did not respond to it (29).

Similarly, as in an earlier example (1), the teacher used a concrete example to talk about a strong base, calcium hydroxide (16, 27 and 29). The meaning of a word did once again

not stand fast in the encounter between the teacher and the students (17, 19 and 28). The difference between the situations (examples 1 and 3) was that the word not standing fast in this example (3) was a scientific concept, 'lime'. That the students repeatedly asked about its meaning (17, 19 and 28) shows that knowing what the word meant was necessary in order for them to make meaning of the activity. As he had done before (example 2), the teacher used other words to explain what the word meant (18). This time the gap was not filled despite the additional encounters between the students and the teacher (19 and 28). The students tried to translate the word into Turkish in order to fill the gap. However, since the teacher's instructions were in Swedish, the Turkish equivalent of the scientific concept was never presented during the lessons and it was not possible for the students to make a translation (19–21). From the students' perspective, this meant that the teacher was talking about 'something' that was used to neutralise acidifications. However, what the teacher was aiming at with this 'thing' did not stand fast in the encounters (17, 19 and 28). As a consequence, the gap lingered and obstructed the students from making meaning of the science content.

The lingering gap also had consequences for how the students proceeded with the next activity. When the teacher was finished with the whole-class instruction, he asked the students to answer the study questions in their chemistry book. Derya and Meryem were working together.

Example 4:

30. Derya:	Ge exempel på hur vi använder baser för att motverka syror (reads)… Adnan (the teacher), kan du komma? *Give examples of how we use bases to counteract acids (reads)… Adnan (the teacher), can you come?*
31. Teacher:	Ja? *Yes?*
32. Meryem:	Sjuan (the number of the question), ge exempel på hur vi använder baser för att motverka syror (reads). Seven (the number of the question), *give examples of how we use bases to counteract acids (reads).*
33. Teacher:	Jo, det är ju kalk. *Well, it's lime.*
34. Meryem:	Kalk. *Lime*.
35. Derya:	Vad är kalk? *What's lime?*.
36. Teacher:	Kalk? Men jag pratade ju om det. *Lime? But I talked about it.*
37. Derya:	Jo jag vet, man vad är kalk. Vad betyder det? *Yes I know, but what's lime? What does it mean?*
38. Teacher:	Alltså här (points at the chemistry book) har du att en lösning av kalk i vatten kallas för kalkvatten. *Well here (points at the chemistry book) you have that a solution of lime in water is called limewater.*
39. Derya:	Ok? *Ok*?

40. Teacher:	Så kalkning är ju när man sprider, eh, men inte i form av vätska, det vill säga torkad… Det kastas i naturen och där blandas det med vatten, eller hur? Och i och med att den är basisk då motverkar den… *So liming is then that you spread, eh, but not in liquid form, so to say dried… It's thrown in nature and there it's mixed with water, right? And since it's basic, then it counteracts…*
41. Meryem:	Syror. *Acids.*
42. Teacher:	… eh, det sura vattnet som finns i naturen. Sura, hur surt kan det bli? Det kan bli ganska surt, sex till sju (moves on to help other students) *… eh, the acidic water that is in the nature. Acid, how acidic can it be? It can be pretty acidic, six to seven (moves on to help other students).*
43. Derya and Meryem:	*(both write'lime is used to counteract acids' in their notebooks).*

A gap occurred when Derya and Meryem read the study question and the students called for the teacher in order to ask him about it (30–32). The teacher replied by construing the relation 'well, it's lime'. Hence, he told them the answer (33). Derya asked once again the teacher what the word 'lime' meant and the teacher answered that they already had talked about it (36). Obviously, he was referring to the whole-class instruction that took place earlier during the same lesson (example 3). Derya answered by saying 'Yes I know, but what's lime? What does it mean?' (37). Hence, she also construed continuity between their earlier experience of talking about how lime is used to counteract acids and the current situation. However, the gap concerning the meaning of the word 'lime' still lingered (37). The teacher pointed at the chemistry book and gave a similar explanation of the word as he had done during the whole class activity (38, see also 16). Derya reacted by saying 'ok'. However, since she raised her voice and uttered the word like a question, it is assumable that it was meant as 'and then?' or 'so?' rather than a confirmation (39). The teacher did not make any further explanations about the meaning of the word 'lime'. Instead he continued by explaining how lime is used to neutralise acidifications in nature. Meryem interrupted him by saying 'acids', meaning that she had knowledge about the fact that bases can be used to neutralise acids (41). When the teacher was finished with his explanation (40 and 42), both students wrote 'lime is used to counteract acids' to answer the question 'Give examples of how we use bases to counteract acids (42).

Several gaps were filled during this interaction; for example, it stood fast in the encounter between the teacher and Derya that they had talked about the fact that lime is used to counteract acids (32–37). Similarly, Meryem construed a relation between her earlier experiences of how bases can be used to neutralise acids and the current activity, as she filled in the teacher's explanation (41). However, the teacher's explanation about the meaning of the scientific concept 'lime' was similar to his earlier explanations (16, 18 and 27), which the students had reacted to by asking further questions. Hence, it is reasonable to assume that the gap still lingered.

Filling gaps by translanguaging

The assumption made above, that is, that the gap considering the meaning of the word 'lime' still lingered, was strengthened the next day. The lesson was about diluted and

concentrated solutions and not about liming. The following conversation took place simultaneously as the teacher's instructions.

Example 5:

44. Derya: (touches Meryem on her shoulder)… vi pratade ju om kalk, det är **kireç**. Jag sa ju till dig att jag vet (smiles).
(touches Meryem on her shoulder)…we talked about lime, it's ***lime.*** *I told you that I know (smiles).*

45. Meryem: Aha **kireç.**
Oh, ***lime.***

Derya reminded Meryem that they had talked about lime (see example 3 and 4) and then construed a relation between the scientific concept in Swedish and its equivalent in Turkish (44). Meryem's answer 'Oh, lime' (45) shows that the relation stood fast in the encounter. Accordingly, the gap concerning the meaning of the word 'lime' was finally filled.

That Derya started to talk about the meaning of the word 'lime' despite the fact that the lesson was about another topic shows how relevant the word was in order for the students to make meaning of the example with liming. It seems like Derya somehow found out what the Turkish word was after the lesson (example 4), which made it possible for the students to construe continuity between scientific language in Swedish and Turkish (example 5). This shows that words not standing fast in the language of instruction may be a part of bilingual students' minority language. Hence, students' minority language is an important resource that supports bilingual students' learning in science.

However the students also made incorrect translations of scientific concepts. The concept 'solution' had been a central part of the chemistry lessons. Hence, in the interview below, the students were asked to describe the concept

Example 6:

46. Interviewer: Ok, under kemilektionerna så har ni pratat jättemycket om sura och basiska lösningar. Ni har också jobbat med koncentrerade och utspädda lösningar.
Ok, during the chemistry lessons you have talked a lot about acidic and basic solutions. You have also worked with concentrated and diluted solutions.

47. Beren: **Evet.**
Yes.

48. Sevgi: Ja, ja.
Yes, yes.

49. Interviewer: Men vad är en lösning egentligen? Hur skulle ni beskriva det?
But what's a solution actually? How would you describe it?

50. Beren: (shrugs her shoulders)

51. Sevgi: **Çözüm ne demek?** (to Beren)
What does a solution mean? *(to Beren)*

52. Beren: **Çözüm, çözüm demek** (laughs).
A solution, means a solution *(laughs).*

53. Interviewer: Sevgi översätter ordet lösning till **çözüm** på turkiska, håller du med om det?
Sevgi translates the word solution to ***çözüm*** *in Turkish, do you agree with that?*

54. Beren:	Ja. *Yes.*
55. Interviewer:	Skulle ni kunna berätta mer om det? *Could you tell more about it?*
56. Beren:	**Bir şeyi çözüyorsun.** ***You solve something.***
57. Sevgi:	**Mesela, bir problem.** ***For example, a problem.***
58. Beren:	**Mesela, bir matematik sorusunu çözüyorsun.** ***For example, you solve a mathematical problem.***
59. Interviewer:	Ok, **peki öğretmenizin bahsettiği** sura och basiska lösningar… *Ok,* **what about** *the acidic and basic solutions* ***your teacher talked about****…*
60. Sevgi:	Alltså där man blandar olika ämnen med varandra. Det är ju kemi vi håller på med och då de blandar in kemikalier och sånt och det leder till en lösning. Alltså som ett svar *Thus, there you mix different substances with each other. It's chemistry that we are doing and then they mix chemicals and stuff like that and it leads to a solution. Like an answer, you know.*
61. Interviewer:	Som ett svar? *Like an answer?*
62. Sevgi:	Mmm **mesela**, bas plus fett är lika med tvål. Alltså om man blandar natriumhydroxid i avloppet, det finns ju hår och sånt där, och då får man tvål som man kan spola bort. Då har man fått en lösning… Det är lösningen till ett… ett problem kan man säga. *Mmm,* ***for example,*** *base plus fat equals soap. Thus, if you mix sodium hydroxide in the drain, there is hair and stuff like that there, and then you get soap that you can rinse away. Then, you have a solution… It's the solution to a… a problem you can say.*
63. Interviewer:	Men är det så med alla sura och basiska lösningar som Adnan (the teacher) pratade om? *But is it like this with all acidic and basic solutions that Adnan (the teacher) talked about?*
64. Sevgi:	Ja, för om det inte finns ett problem så finns det inget att lösa. Det måste finnas ett problem för att lösa något. *Yes, because if there's not a problem, then there's nothing to solve. There has to be a problem to solve something.*

The fact that the lessons have concerned acidic and basic solutions stood fast in the encounter between the interviewer and the students (46–48). However, a gap occurred when the interviewer asked the students to describe the concept 'solution (49). Beren shrugged her shoulders (50), implying that the meaning of the word did not stand fast in the encounter between her and the interviewer. Sevgi asked her about it in Turkish by saying 'What does a solution mean?' (59). In Swedish the word 'solution' (lösning) is used as a scientific concept, e.g. an acidic solution, but also in a more everyday sense, e.g. the solution to a problem. However, in Turkish the scientific concept solution is 'bileşikler', whereas the everyday word, e.g. the solution of a problem, is 'çözüm'. Hence, Sevgi construed a relation between the scientific concept 'solution' in Swedish and the everyday

word ‘solution’ in Turkish (51). Beren confirmed the translation (53 and 54), meaning that it stood fast in the encounter between the students. When the students were asked to tell more about it (55), they construed a relation between solving a problem and the scientific concept ‘solution’ (56–58). Since it was the everyday word ‘solution’ that the students described, the interviewer asked them about the ‘acidic and basic solutions’ the teacher had talked about during the chemistry lessons (59). Sevgi answered by construing the relation ‘mix different substances with each other’ to acidic and basic solutions (60). She also said that chemical solutions were aimed at solving problems (62 and 64) and gave a concrete example by mentioning that sodium hydroxide was used to clean drainpipes (62).

Although this study has shown that construing continuity between scientific language in the language of instruction and minority languages do support bilingual students’ meaning making in science (example 5), it has also problematised it by showing how students might make incorrect translations (example 6). In this situation, the incorrect translation implied that the students’ description of the scientific concept ‘solution’ was not in line with how it is viewed in science.

The students did not only use their minority language to construe continuity between scientific language in Swedish and Turkish, but also for everyday language varieties. In the interviews the students were asked about their language use during science lessons. The students told that their minority language constituted an important resource and that their meaning making in some situations was directly related to their possibilities to translanguage. They also gave a concrete example by talking about how the translation of an everyday word, ‘fly’, had led to that a student could make meaning of a question during a written exam.

Example 7:

65. Derya:	**Ada veya Beren veya Sevgi anlamadıkları zaman şey yapıyorum eh**… ***When Ada or Beren or Sevgi do not understand I do eh***…
66. Ada:	Översätta, **anlatıyorsun.** *Translate,* ***you tell.***
67. Derya:	… **eh tercüme ediyorum, anladıkları zaman da Adnan (the teacher) devam ediyor. Mesela sınavlarda falan da öyle. Anlamadıkları soruyu anlatıyoruz.** ***…eh I translate it, when they understand, Adnan (the teacher) continue. For example, it’s like that during the exams too. We tell/explain the questions they don’t understand.***
68. Interviewer:	**Türkçeye mi çeviriyorsunuz?** ***Do you translate it into Turkish?***
69. Derya:	**Evet.** ***Yes.***
70. Ada:	Men prov**larda izin vermiyor aslında.** Prov**larda Adnan** (the teacher) **kopya çektiğimizi sanıyor ama biz kopya çekmiyoruz.** Prov**larda fazla konuşmuyoruz. Anlamadığım yerleri bos bırakıyorum ben.** ***But he doesn’t allow us during the*** *exams* ***actually. Adnan*** *(the teacher)* ***thinks that we cheat during the*** *exams,* ***but we don’t. We don’t talk so much during the*** *exams.* ***I leave the parts I don’t understand empty.***

71. Derya: **Mesela geçenlerde biyoloji sınavımız oldu. Hoca Beren'e** fluganin **ne olduğunu anlatacaktı ama anlamamıştı. Ben de tercüme ettim anladı.**
For example, recently we had an exam in biology. The teacher tried to tell Beren what a** fly **is, but she didn't understand. So, I translated it and she understood.

72. Ada: **Ama adam şüpheleniyor.**
But he gets suspicious.

Derya construed a relation between situations where her classmates 'do not understand' and herself translating into Turkish (65). Ada's utterance (66) confirmed Derya's statement, meaning that it stood fast in the encounter between the students. Then, Derya told that they also translated some words for each other during the written exams (67). Ada added that translating into Turkish during exams was actually not allowed since the teacher suspected that they might cheat. She said that this resulted in her leaving some questions unanswered (70). Derya continued by construing a relation to an earlier experience of a situation where they were doing a written exam. According to Derya, one of the questions had contained the word 'fly'. However, the word had not been a part of Beren's language repertoire and resulted in an additional encounter between the teacher and the student. The teacher had explained what the word meant to the student, but the gap had still lingered. Then, Derya had used Turkish as a resource to translate the word. According to Derya, the translation led to the gap being filled (571). Ada repeated that translations into Turkish made the teacher 'suspicious' (72).

That the reason for additional encounters and lingering gaps may not always be the science content but rather the meaning of everyday words has already been shown in previous examples (1 and 2). This example (7) contributes by showing that everyday words that are not a part of the students' language repertoire do not only have consequences for their possibilities to make meaning of the science content, but also their achievements in science (67, 70 and 71). Furthermore, the students' utterances also revealed a pedagogical dilemma. According to the students, the teacher asked them to translate words into Turkish. Accordingly, he allowed the students to use Turkish as a resource when proceeding with the activities (67). However, there was an exception; the written exams (70–72). Ada's utterance, 'I leave the parts I don't understand empty' (70), demonstrates that the consequences of the prohibition in some situations meant that the students did not have the possibility to make meaning of the questions and, hence, answer them.

Supporting bilingual students' learning in science class

Occasionally, it seemed like the learning object was everyday language in Swedish instead of scientific language (examples 1 and 2). One may ask how learning new words like 'sink' (example 1) is related to science? Since the teacher used these words to concretise and describe the science content, understanding the meaning of them, that is, how they were used in the particular language game (Wittgenstein 1953/1967), was necessary in order for the students to make meaning of the lessons. This is in line with earlier research showing that creating relations between everyday and scientific language supports students' learning (Wellington and Osborne 2001).

Although the teacher could not translate words into students' minority language when answering questions regarding the meaning of words in Swedish, other translanguaging

strategies he used, e.g. drawing a picture on the whiteboard (example 1) made it possible for the students to proceed with the activities. Accordingly, the findings of this study implicate that further research concerning the use of resources other than verbal and written language in classrooms where the teacher and the students do not share the same minority language is needed.

In other situations, the gaps could not be filled despite the teacher's efforts (examples 3–5). That the resources needed in order for the students to make meaning of the science content were not available in the classroom is problematic. In the example with the scientific concept 'lime', the students had to wait until after the lesson and found out the answer by themselves (example 5). Science teachers need to consider how to offer bilingual students opportunities to make meaning of the science content as presenting it to them. If the students had the possibility to use bilingual dictionaries during the lessons (examples 3 and 4), the gaps might have been filled immediately. Similarly, according to the students, the teacher suspected that they might cheat when speaking Turkish during the written exams and prohibited them to translate to each other. However, the students could have translated everyday words like 'fly' (example 7) by themselves if they had the possibility to use bilingual dictionaries. It is important to remember that bilingualism is not a problem prohibiting students from understanding the science content. Bilingualism is a recourse and both of bilingual students' languages are important for their learning possibilities. The problem is that a monolingual science instruction limits bilingual students' possibilities to use their whole language repertoire (examples 3 and 7). We argue that this risks increasing the academic gap between monolingual and bilingual students (see Lee and Luykx 2007).

Even if this study has demonstrated that bilingual students' minority language is a resource when translating everyday words and scientific concepts in order to make meaning of the science content (examples 5 and 7), it has also demonstrated that translating scientific concepts is more problematic. When the students translated the scientific concept 'solution' from Swedish to Turkish they made an incorrect translation, which resulted in that their description of the concept was not in line with how it is viewed in science (example 6). However, the fact that the same word might mean two different things in everyday and scientific language is not a situation unique to bilingual students. It is an issue that all students have to deal with (Wellington and Osborne 2001). Considering that the word 'solution' has two different meaning in Swedish, it is possible that also monolingual students might describe a chemical solution as mixing different substances with each other for solving problems, as the bilingual students did (example 6). The question about whether or not translations of scientific concepts can be used to support bilingual students' learning in science is complex. This study has shown that it does (examples 5 and 7). However, regardless if it is an everyday word or a scientific concept, a word must be a part of students' language repertoire in order for a translation to make sense. For example, that the students made a correct translation of the scientific concept 'lime' (example 5) would not have supported their meaning making if they did not know what the concept meant in Turkish. In this study, some of the students had lived in Sweden for less than 5 years and had school experience from Turkey. Hence, it is reasonable to assume that they have encountered some scientific concepts in Turkish. Translating scientific concepts by using bilingual dictionaries, as we have suggested earlier, should probably support these students' meaning making in science. However, considering that some concepts have other meanings in everyday language (Wellington and Osborne 2001), it may also be confusing and produce similar results as the concept 'solution' (example 6). The majority of the students in this study were born and raised in Sweden though. Since the teacher's

instruction and the chemistry book were only in Swedish, these students might have not heard of the scientific concepts in Turkish. Consequently, even if the students would somehow make correct translations of the concepts, it would have implied replacing an unknown word with another. Hence, although it is positive if one knows how to say certain scientific concepts in both languages, in the sense of becoming scientifically biliterate, it would not have helped the students to proceed with the on-going activities.

So, should science teachers who do not share the same minority language as their students allow the students to translate scientific concepts or not? This is not a decision for the teacher to make. We need to remember that translanguaging, that is, combining two languages, is a natural part of bilingual students' lives. This *is* how bilingual students communicate and make meaning. This study has produced empirical evidence for this. Translating the concept 'lime' into Turkish was not a decision that the teacher was a part of (example 5). Similarly, the interviewer did not ask the students to translate the concept 'solution' (example 6). Moreover, in the interviews with the students, it was revealed that the students spoke Turkish also in situations where the teacher actually did not allow them to (example 7). In fact, this is how we all, regardless if we are monolingual or bilingual make meaning. We use our *whole* language repertoire (García 2009) in order to construe continuity between a new situation and our earlier experiences (Wickman 2006). Consequently, the question science teachers need to ask themselves is how they can support bilingual students within this process. Although including bilingual students' minority language in science class is a bigger challenge when the teacher and the students do not share the same minority language than, we argue that this is what teachers need to do in order to offer bilingual students equal opportunities as their monolingual peers to learn science. To do so, teachers need some guidance based on empirical research. This study contributes by presenting findings from a class where the teacher and the students do not share the same minority language and by problematising the process of translating the science content in such settings. Hence, it might constitute a starting-point for further research examining different ways of including bilingual students' minority language in similar settings.

References

Axelsson, M., & Jakobson, B. (2010). Yngre andraspråkselevers meningsskapande i naturvetenskap genom tre analysverktyg. *Nordand. Nordisk Tidskrift for Andrespråksforskning, 5*, 9–33.

Blackledge, A., & Creese, A. (2010). *Multilingualism: A critical perspective*. London: Continuum.

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education, 92*, 708–732. doi:10.1002/sce.20251.

Bryan, L. A., & Atwater, M. M. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education, 86*, 821–839. doi:10.1002/sce.10043.

Cho, S., & McDonnough, J. T. (2009). Meeting the needs of high school science teachers in English language learner instruction. *Journal of Science Teacher Education, 20*, 385–402. doi:10.1007/s10972-009-9136-9.

Cummins, J. (2005). A proposal for action: Strategies for recognizing heritage language competence as a learning resource within the mainstream classroom. *The Modern Language Journal, 89*, 585–592.

Dewey, J. (1925/1998). *Experience and nature*. New York: Dover Publications Inc.

Dewey, J. (1938/1997). *Experience and education*. New York: Simon & Schuster.

García, O. (2009). *Bilingual education in the 21st century: A global perspective*. Malden, MA: Blackwell.

García, O. (2011). Theorizing translanguaging for educators. In C. Celic & K. Seltzer (Eds.), *Translaguaging: A CUNY-NYSIEB guide for eductors* (pp. 1–6). New York: CUNY-NYSIEB, The Graduate Center & The City University of New York.

García, O., & Wei, L. (2014). *Translanguaging. Language, bilingualism and education.* New York: Palgrave Macmillan.
Gilbert, A., & Yerrick, R. (2001). Same school, separate worlds: A sociocultural study of identity, resistance, and negotiation in a rural, lower track science classroom. *Journal of Research in Science Teaching, 38*, 574–598. doi:10.1002/tea.1019.
Goldberg, J., Enyedy, N., Welsh, K. M., & Galiani, K. (2009). Legitimacy and language in a science classroom. *English Teaching: Practice and Critique, 8*, 6–24.
Grimes, B. F. & Grimes, J. E. (red.) (2000). Ethnologue. Vol. 1, Languages of the world (14th ed.) Dallas, TX: SIL International.
Harré, R., & Gillet, G. (1994). *The discursive mind.* London: Sage Publications Inc.
Kelly, G. J., McDonald, S., & Wickman, P. O. (2012). Science learning and epistemology. In K. Tobin, B. J. Fraser, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 281–291). Dordrecht: Springer.
Lave, J., & Wenger, E. (1991). *Situated learning. Legitimate peripheral participiation.* Cambridge: Cambridge University Press.
Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research, 75*, 491–530. doi:10.3102/00346543075004491.
Lee, O., & Luykx, A. (2007). Science education and student diversity: Race/ethnicity, language, culture, and socioeconomic status. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 171–197). Mahwah, NJ: Lawrence Erlbaum Ass. Publ.
Lee, O., Luykx, A., Buxton, C., & Shaver, A. (2007). The challenge of altering elementary school teachers' beliefs and practices regarding linguistic and cultural diversity in science instruction. *Journal of Research in Science Teaching, 44*, 1269–1291. doi:10.1002/tea.20198.
Lemke, J. L. (1990). *Talking science: Language, learning, and values.* Norwood, NJ: Ablex.
Lewis, G., Jones, B., & Baker, C. (2012). Translanguaging: developing its conceptualisation and contextualization. *Research and Evaluation, 18*, 655–670. doi:10.1080/13803611.2012.718490.
Lyon, E. G., Bunch, G. C., & Shaw, J. M. (2012). Navigating the language demands of an inquiry-based science performance assessment: Classroom challenges and opportunities for English learners. *Science Education, 96*, 631–651. doi:10.1002/sce.21008.
Ministry of Culture. (2009). *Language Act (2009:600).* Downloaded from http://www.regeringen.se/contentassets/9e56b0c78cb5447b968a29dd14a68358/spraklag-pa-engelska.
Mortimer, E. F. (1998). Multivoicedness and univocality in classroom discourse: an example from theory of matter. *International Journal of Science Education, 20*, 67–82. doi:10.1080/0950069980200105.
Msimanga, A., & Lelliott, A. (2014). Talking science in multilingual contexts in South Africa: Possibilities and challenges for engagement in learners' home languages in high school classrooms. *International Journal of Science Education, 36*, 1159–1183. doi:10.1080/09500693.2013.851427.
Norris, S. P., & Philips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*, 224–240. doi:10.1002/sce.10066.
Nygård Larsson, P. (2011). *Biologiämnets texter: Text, språk och lärande i en språkligt heterogen gymnasieklass.* Malmö: Malmö högskola.
Reveles, J. M., & Brown, B. A. (2008). Contextual shifting: Teachers emphasizing students' academic identity to promote scientific literacy. *Science Education, 92*, 1015–1041. doi:10.1002/sce.20283.
Roth, W. M., & Duit, R. (2003). Emergence, flexibility, and stabilization of language in a physics classroom. *Journal of Research in Science Teaching, 40*, 869–897. doi:10.1002/tea.10114.
Scott, P. H., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*, 605–631. doi:10.1002/sce.20131.
Skutnabb-Kangas, T. (1981). *Bilingualism or not: The education of minorities.* Clevedon: Multilingual Matters.
Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education, 85*, 6–34. doi:10.1002/sce.20283.
Stenlund, S. (2000). *Filosofiska uppsatser.* Skellefteå: Norma Bokförlag.
Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching, 39*, 664–687. doi:10.1002/tea.10040.
The Swedish Agency for Education. (2008). *Med ett annat modersmål - elever i grundskolan och skolans verksamhet.* Stockholm: Skolverket/Fritzes.
The Swedish Agency for Education. (2014). *Tabell 8B.* Downloaded from http://www.skolverket.se/statistik-och-utvardering/statistik-i-tabeller/grundskola/skolor-och-elever.

The Swedish Research Council. (2014). http://www.vr.se/inenglish.4.12fff4451215cbd83e4800015152.html.
Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38*, 529–552. doi:10.1002/tea.1017.
Wellington, J., & Osborne, J. (2001). *Language and literacy in science education*. Buckingham: Open University Press.
Wickman, P. O. (2004). The practical epistemologies of the classroom: A study of laboratory work. *Science Education, 88*, 325–344. doi:10.1002/sce.10129.
Wickman, P. O. (2006). *Aesthetic experience in science education: Learning and meaning-making as situated talk and action*. Mahwah, NJ: Lawrence Erlbaum Associates.
Wickman, P. O., & Östman, L. (2002). Learning as discourse change: A sociocultural mechanism. *Science Education, 86*, 601–623. doi:10.1002/sce.10036.
Wittgenstein, L. (1953/1967). *Philosophical investigations* (3rd edn). Oxford: Blackwell.

Zeynep Ünsal is a Ph.D. Student in Science Education at the Department of Mathematics and Science Education, Stockholm University, Sweden. Her research is about science education with bilingual students.

Britt Jakobson is a Senior Lecturer in Science Education at the Department of Mathematics and Science Education, Stockholm University, Sweden. Her main research interest is elementary school students' meaning-making in science.

Bengt-Olov Molander is Adviser to the Vice-chancellor and Associate Professor in Science Education at Stockholm University, Sweden. His research interest is teaching and learning of science in multicultural and multilingual school settings.

Per-Olof Wickman is a Professor at the Department of Mathematics and Science Education, Stockholm University, Sweden. His main research interest is the constitution of science content and its values in social interaction.