Bilingual students' learning in science

Language, gestures and phyiscal artefacts

Zeynep Ünsal

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Abstract

The objective of this thesis is to examine how language, gestures and physical artefacts are used in science classes with emergent bilingual students who do not share the same minority language as their classmates or teachers. The purpose is to contribute to findings that can enhance emergent bilingual students' learning in science. The data consist of classroom observations in one 3rd grade (9–10 years old) and one 7th grade (13–14 years old) science class. In addition, the students in the 7th grade were interviewed. Whole-class instruction was carried out monolingually in Swedish. The students typically made meaning of the activities without any language limitations during conversations following an initiation, response and evaluation pattern (IRE). However, during longer conversations the students' language repertoire in Swedish frequently limited their possibilities to express themselves. During group-work activities, students with the same minority language worked together and used both of their languages. One strategy used among the students to overcome language limitations was translating unfamiliar words into their minority language. In general, this supported the students' learning in science. Occasionally, the students made incorrect translations of scientific concepts. The interviews with the students demonstrated how monolingual exams may limit emergent bilingual students' achievements in science. When students' language proficiency limited their possibility to express themselves, the students showed what they meant by using gestures. This resulted in the continuation of the lessons as both other students and teachers drew on the used gestures to talk about the science content. The physical artefacts implied that the students experienced the science content by actually seeing it, which the teacher then drew on to introduce how the phenomena or process in question could be expressed in scientific language. When students' proficiency in the language of instruction limited their possibilities to make meaning, using physical artefacts enabled them to experience unfamiliar words being related to the science content and learn what they mean.

Keywords: *science education, bilingual students, mediating means, language, gestures, physical artefacts, learning, meaning-making, practical epistemological analysis, translanguaging, continuity.*

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To Efe and Mert

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Keywords: science education; bilingual students; mediating means; language; gestures; physical artefacts; learning; meaning-making, practical epistemological analysis; translanguaging; continuity

List of Papers

This thesis is comprised of a summary of the following four papers:

1. Ünsal, Z., Jakobson, B., Molander, B-O. & Wickman, P-O. (2017). Language use in a multilingual class: A study of the relation between bilingual students' languages and their meaning-making in science. *Research in Science Education.* doi: 10.1007/s11165-016-9597-8

2. Ünsal, Z., Jakobson, B., Molander, B-O. & Wickman, P-O. (2016). Science education in a bilingual class: problematising a translational practice. *Cultural Studies in Science Education*. doi: 10.1007/s11422-016-9747-3.

3. Ünsal, Z., Jakobson, B., Wickman, P-O. & Molander, B-O. (2017). Gesticulating science: Emergent Bilingual students use of gestures. *Journal of Research in Science Teaching*. doi: 10.1002/tea.21415

4. Ünsal, Z., Jakobson, B., Wickman, P-O. & Molander, B-O. Jumping pepper and electrons in the shoe: Physical artefacts in a multilingual science class. In review. Accepted to be submitted for consideration in a special issue in *International Journal of Science Education*.

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Contents

1 Introduction

This thesis is about the use of language, gestures and physical artefacts in science class with bilingual students who do not share the same minority language (also called mother tongue and first language) with their classmates or teachers. The choice of topic is based on five main reasons. In the following, I will describe them and argue for the importance of this study. I start by giving some overviewing information and then continue by focusing specifically on Sweden, since it was here this study was conducted.

First, bilingualism is an important subject that educators need to pay attention to and have knowledge about. There are about 200 countries and 7 000 languages spoken in the world (Simons & Fennig, 2017). For instance, approximately 21% of the students in the United States (National Center for Education Statistics, 2011) and 25% of the students in Sweden (The Swedish National Agency for Education, 2016a) are bilingual. Furthermore, bilingualism is increasing in several countries around the world (Buxton & Lee, 2014; Eurostat, 2017). About 4.7 million people immigrated to the European Union in year 2015 (Eurostat, 2017). The annual number of immigrants in Sweden was around 44,800 for 20 years ago. Today, it has risen to 163,000 (Statistics Sweden, 2017). Accordingly, many science teachers will during their careers meet students from diverse linguistic backgrounds (Kibler & Roman, 2013; García, 2009).

Second, some bilingual students are *emergent bilinguals*, that is, not yet fluent in the language of instruction (García & Kleifgen, 2010). A literature review has shown that many teachers need more knowledge about how to support these students (Buxton & Lee, 2014). For example, Cho and McDonnough (2009) conducted a survey study with 33 high-school science teachers from 6 different schools. About 21% of the teachers stated that they were challenged by the lack of guidelines and/or support systems at various school levels when teaching emergent bilingual students. 51% of the teachers needed more time and resources to support the students. In addition, the authors' analysis of the teachers' survey answers showed that many of them needed more knowledge about how to support emergent bilingual students in science class.

Teachers' lacking knowledge about bilingualism has repeatedly resulted in bilingual students being excluded from science class. Although researchers have emphasised that learning a new language is facilitated when it is combined with content learning, many teachers still assume that bilingual students need to learn the language of instruction before learning science. As a consequence, many emergent bilinguals are given additional lessons in language at the expense of science lessons (Buxton & Lee, 2014). The purpose of the review above is not to denigrate science teachers, but to point to a concern in teacher education and in-service courses to support professional development. One reason for science teachers' lacking knowledge is that bilingual students' language development and learning in science are rarely integrated in teacher education and curriculum development (Cho &McDonnough, 2009; Lee, 2005). Accordingly, the topic of this thesis is relevant for both science teacher educators and science teachers attempting to gain more knowledge about emergent bilingual students.

A third reason is that studies and reports from different countries have shown how the achievements of bilingual students not yet fluent in the language of instruction on average differ negatively from the ones of their peers. In the United States, 4 % of students in the 8th grade categorised as 'English language learners' achieved at or above the proficient level in science education on the 2015 National Assessment of Educational Progress. The number for 'non-English language learners' was 36% (National Center for Education Statistics, 2015). The Programme for International Student Assessment (PISA) results from year 2015 showed that in most countries both so-called first generation (foreign-born students whose parents are also foreign-born) and second-generation immigrants (students born in the country, but with foreign-born parents) achieve lower scores than students without an immigrant background (The Organisation for Economic Co-operation and Development - OECD, 2016). In Sweden, students complete standardised national tests in biology, chemistry and physics in 9th grade, which is the last year of compulsory school. In the year 2016, about 12% of the students immigrated before starting school, 28% of the ones immigrated after starting school and 37% of the newly arrived students (less than four years in Sweden) did not pass the tests. The number of students who did not pass the test, regardless of linguistic background, was approximately 9% (The Swedish National Agency for Education, 2016b, 2016c, 2016d).

A body of research has investigated why emergent bilingual students achieve lower than their peers. Unsurprisingly, unfamiliar words are one of the reasons (see Buxton & Lee, 2014; Lee, 2005 for an overview). Nevertheless, studies have shown that the language proficiency required in science class goes beyond knowing the meaning of words. To exemplify this, Nygård Larsson (2011) examined bilingual students' learning possibilities in science. The study was conducted in a biology class in a Swedish upper secondary school. The class consisted of both monolingual and bilingual students. The lessons were carried out monolingually in Swedish. At the end of the semester, all monolingual students passed the course, while several bilingual students did not. Several monolingual students and none of the bilinguals received the highest grade. An examination of the written exams on which the grades were predominately based revealed a general pattern: bilingual students managed to reproduce factual knowledge, but were less successful with certain conversation types, such as arguing, discussing and generalising. These skills were necessary to receive the higher grades. Based on these study findings, Nygård Larsson (2011) concludes that producing abstract science texts requires advanced language mastery, which is a limitation for many bilingual students. When emergent bilingual students' learning and achievements in science are limited because of their proficiency in the language of instruction, a relevant question to ask is how educators can support the students in overcoming these limitations (Lee, Miller & Januszyk, 2014). The purpose of this thesis is to contribute to knowledge in this area by examining how emergent bilingual students can use other resources alongside the language of instruction to learn science.

A fourth reason is that emergent bilingual students in multilingual classes have rarely been concerned in research about science education. One major approach proposed to support both linguistic development (Cummins, 2005) and science learning (Buxton & Lee, 2014; Msimanga & Lelliott, 2014) is making use of students' minority language. Studies in this area have predominately been conducted in classes where teachers and students share the same minority language (e.g. Goldberg, Enyedy, Welsh & Galiani, 2009; Salleh, Venville & Treagust, 2007; Reyes, 2009). However, class composition in many countries or geographical areas are not bilingual, but rather *multi*lingual. Several minority languages are represented in the same class, and/or teachers do not speak their students' minority languages. To give some examples, there are approximately 150 languages spoken in Sweden, and it is not uncommon that several of them are represented in the same class (The Swedish National Agency for Education, 2016a). Another example is England, where there are more than 300 languages and varieties (Blackledge & Creese, 2010). Accordingly, although studies conducted in bilingual classes have contributed to important knowledge about the inclusion of students' minority languages (e.g. Goldberg, et al., 2009; Salleh, et al., 2007; Reyes, 2009), classes with teachers and students who do not speak the same minority language is a relatively unexamined area in science education. The purpose of this study is therefore to take a step further and study language use in these class compositions.

A fifth reason is that, even if language constitutes the most important resource for communication and learning, it is not the only one (Säljö, 2005). Hence, another approach suggested to support emergent bilingual students' learning in science class is paying attention to the use of other resources beside language (Hammond & Gibbons, 2005; Kamberelis & Wehunt, 2012). Nevertheless, research about emergent bilingual students in science class mainly focus on language and other resources has so far received little attention (Zhang, 2016). The focus on language at the expense of other resources is not exceptional for bilingual students, but rather a general issue in science education. Scientific knowledge has traditionally been seen to be gained and expressed through language (Kress, et al., 2001). In recent years, researchers have begun to question this view by showing that science education involves the use of a range of resources, such as drawings, diagrams, gestures and physical artefacts (Knain; 2015; Kress, Jewitt, Ogborn & Tsatsarelis, 2001). For example, Kress et al. (2001) conducted a case study in an 8th grade science class. The study findings showed that the teacher used several recourses to teach about the blood circulation in the human body, such as, images illustrating blood circulation and gestures to show how the blood flows in the human body.

Paying attention to other resources beside language is important regardless of the students' linguistic background (Hubber, Tytler & Haslam, 2010). However, when bilingual students are not yet fluent in the language of instruction and have limited possibilities to use their minority languages due to the class composition, the importance of using other resources becomes even more urgent. This is addressed in this thesis as it concerns not only language use but also other resources. Since there are numerous resources used in science class (Kress, et al., 2001), I needed to make a choice. I could either make a general examination of all resources used in the classrooms where data were collected, or I could focus on some of them and make a more detailed and deeper examination. I decided to choose the second alternative. The reason was that the examination of students' both languages (Paper 1 and 2), indicated that two other resources had an important role in students' learning: gestures and physical artefacts.

To summarise, today it is more common to be bilingual than monolingual and bilingualism continues to increase (García, 2009). Hence, it is reasonable to assume that most science teachers will meet bilingual students during their careers (Kibler & Roman, 2013). However, since bilingualism has been rarely addressed in teacher education and professional development for science teachers, many teachers need more knowledge in this area (Cho & McDonnough, 2009). Simultaneously, the achievements of emergent bilingual students differ negatively from those of their peers (Buxton & Lee, 2014; The Organisation for Economic Co-operation and Development, 2016; The Swedish National Agency for Education, 2016b, 2016c, 2016d). To address this issue, scholars have suggested several improvements and interventions (Lee & Buxton, 2014). One approach concerns making use of bilingual students' minority language in science class. Indeed, several studies have already been conducted in this area, but most of them concern classes where the students and the teachers are bilingual in the same languages (e.g. Goldberg et al., 2009; Salleh et al., 2007; Reyes 2009). In many countries and geographic areas, class compositions are multilingual. Several minority languages are represented in the same class, but the students do not share the same minority language as their classmates or teachers (Blackledge & Creese, 2010; The Swedish National Agency for Education, 2016a). Another suggestion to support emergent bilingual students learning in science is the use of other resources alongside language (Hammond & Gibbons, 2005; Kamberelis & Wehunt, 2012). However, studies that concern learning and teaching science in classes with bilingual students have predominately focused on language, while other resources have received little attention (Zhang, 2016).

Aim and Research Questions

Based on the research gaps described above, the purpose of this thesis is to contribute to an increased understanding of how language, gestures and physical artefacts are used in science classes with emergent bilingual students who do not share the same minority language with their teacher or classmates. This can be used to promote emergent bilingual students' learning in science. The thesis seeks to do so by answer two overarching research questions:

1. How are language, gestures and physical artefacts used in science classes with emergent bilingual students who do not share the same minority language with their teacher or classmates?
2. What are the consequences of the resources used for the students' learning in science?

These questions are addressed in four papers that focus on different resources. Paper 1 concerns language use and is based on the following research questions:

A. How do bilingual students use their languages in a multilingual science class?

B. What are the consequences of bilingual students' language use for their meaning-making in science?

Paper 2 presents findings on the relation between bilingual students' everyday languages and the language of science. It addresses the following research question:

C. 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?

Paper 3 concerns how gestures are used as mediating means in science classes with emergent bilingual students by addressing the following research questions:

D. How do emergent bilingual students use gestures in science class?

E. What are the consequences of the gestures for the students' learning in science when their language repertoire limits their possibilities to express themselves?

Lastly, in paper 4 physical artefacts are examined through the following research question:

F. How can teachers use physical artefacts to support bilingual students' learning in science class?

2 Previous Research

Language Use in Science Class

In every subject, communication is conducted in a specific 'language'. There is a language for economics, literature, mathematics, music, etc. Learning a subject involves learning its language, and science is certainly not an exception (Lemke, 1990). The importance of language for learning science has been emphasised in many studies showing how language use in science class differs from how students typically talk and write in their everyday life (e.g. Carlsen, 2007; Knain, 2015; Norris & Philips, 2003; Wellington & Osborne, 2001). The terms *everyday language* and *the language of science* or *scientific language* are often used when describing these differences (Lemke, 1990). The terms have their limitations as there is no clear line between everyday and scientific language. Nevertheless, at the same time, they are needed when describing how students' ways of expressing themselves frequently differs from the language used in science class (Lemke, 1990; Wellington & Osborne, 2001). Therefore, the terms will be used throughout this study.

Communication is a social process. When people communicate they often use patterns created by a community. The same goes for science education. Science teachers already belong to a community that has become acquainted with scientific language. Students, especially the younger ones, have not yet learnt this language. Consequently, language use in science class makes demands on students regardless of linguistic background (Lemke, 1990). For instance, the lessons involve words that are totally new to some students and some words, for example energy, power and work, are used differently in everyday life than in science. Moreover, knowing the meaning of scientific concepts is not enough to learn science. Students also need to understand the relationship between the concepts and how they create larger patterns (Wellington & Osborne, 2001; Lemke, 1990). Different activities in science class are carried out in a specific *genre.* Knain (2015, p. 9) defines a genre as '*standardized ways of doing things by language in similar situations*'. For example, a laboratory report is written by following a certain pattern (Knain, 2015). Thus, Lemke (1990, p. 153) maintains that 'the mastery of science is mainly a matter of learning how to talk science'. The idea of 'talking science' goes beyond speech. It is an expression to emphasise a specific language use. The scientific language also involves writing and reading. In addition, science education is an activity, involving the use of other resources besides language, for example physical artefacts (Lemke, 1990).

Developing a deeper understanding of science beyond basic factual knowledge requires participating in more complicated conversations such as, argumentations, discussions, explanations and generalisations. However, many science classrooms lack these kinds of conversations (Lemke 1990; Webb & Treagust, 2006). Instead, communication is dominated by a reproduction of factual knowledge, often in an *Initiation, Response and Evaluation (IRE*) pattern. The teacher *initiates* the conversation, typically with a question to which he/she already has the answer. The aim is to check the students' knowledge in a particular subject. The question results in a short student *response*, which is then *evaluated* by the teacher (Bellack, Kliebard, Hyman & Smith, 1966; Knain, 2015). Even if IRE have certain functions, such as checking students' factual knowledge, the lack of more advanced conversations limits students' possibilities to develop a deeper understanding of the science content (Bleicher, Tobin & McRobbie, 2003; Erduran, Simon & Osborne, 2004; Lemke 1990; Osborne & Wellington, 2001).

The question is then, how can students learn to talk science? According to Lemke (1990, p. 1) the answer is '…in much the same way as we learn any other (language): by speaking it with those who have already mastered it and by employing it for the many purposes for which it is used'. This does however not mean most students will learn the language of science sooner or later if teachers just continue to use it. Two important findings need to be repeated here. First, students, especially the younger ones, do not speak the language of science when they enter science class. Second, many students find the language of science to be difficult. However, students do not enter to science class as tabula rasa either. Rather, they have developed an everyday language to make sense of their world (Lemke, 1990; Axelsson & Jakobson, 2010). Hence, students' own ways of reasoning in everyday language needs to be appreciated and valued in science class simultaneously as the students are offered possibilities to construe relations to the language of science (Reveles & Brown, 2008; Wellington & Osborne, 2001). Accordingly, science teacher needs to act as a '*mediator* between everyday language and descriptions and the formal language of science with its ways of conceptualising the world' (Wellington & Osborne, 2001, p. 119).

The use of everyday and scientific language has been examined in several empirical studies. For example, Brown and Spang (2008) made an ethnographic study in a 5th grade class to examine how the teacher's use of scientific language influenced the students' language use. The teacher was involved in a professional science reform development. Together with a research team, the teacher developed an approach aimed at teaching students the language of science. Basically, the teacher used both everyday and scientific language by relating them to each other during the lessons. The authors use the term 'double talk' when referring to this process. In one example, the students worked in groups and organised a pile of rocks into smaller piles, which enabling them to study each pile separately. The teacher then drew on the activity to talk about classification in science. 'Double talk' was also present in the students' conversations. To exemplify, one of the units during the data collection concerned the difference between living and non-living things. When a student shared his ideas about this, he used the everyday words 'it just sits there' to explain the scientific term 'vegetate'. Based on their study findings, the authors argue that teachers need to explicitly work with the language of science and not take it for granted that the students understand it:

> Currently, academic language learning is considered a neutral medium that all students experience in science classrooms. As a result, those who quickly grasp the language of science are seen as more intelligent and better capable of learning science. What becomes evident in this study is the fact that the discourse patterns associated with instruction can have an impact on how students use language as a learning tool. (Brown & Spang, p. 730).

Enabling students to use everyday language and draw on their earlier experiences is not, however, a prerequisite to learn science. Rather, students' own ways of reasoning need to be related to the purpose with the lessons. Johansson and Wickman (2011) made observations in a science class with 12 years old students (5th grade) to examine the interplay between the teacher's and students' purposes with the activities. The authors analysed if and how the teacher related the students' language use and experiences to the purpose of the lessons, which was learning how friction facilitates or impedes motion. The study findings are exemplified with two excerpts. In the first situation, the students dominated the conversation by retelling their earlier experiences and using everyday language, whereas the second one was dominated by the teacher who used a more scientific language. Nevertheless, neither of the conversations were related to the overall purpose of the lesson. The authors conclude that it is important that students have the possibility to use everyday language and their own experiences during the lessons. This makes it possible for the students to place the science content in a context that make sense to them. However, it is also important that teachers relate the students' language use and experiences to the purpose of the lessons. A discussion of how students' words and experiences overlap the purpose of the lessons and the involved scientific concepts is, according to the authors, critical to develop a scientific understanding. If this does not happen, the students' learning risks being fragmented and discontinuous with the overall purpose of the lessons.

Bilingual Science Education

Scholars are agreed on the importance of construing relations between students' everyday language and the language of science (Lemke, 1990; Johansson & Wickman, 2011; Wellington & Obsorne, 2001). However, some bilingual students are not yet fluent in the language of instruction, implying that not only scientific language, but also everyday language, is a challenge (García & Kleifgen, 2010). Accordingly, educators need to ask what other resources besides the language of instruction can be used to support emergent bilingual students' learning in science (Buxton & Lee 2014). Bilingual students 'everyday' language consists in itself of at least two languages. For example, the students in this study speak Turkish and Swedish in their everyday lives. Several empirical studies in science education have shown that it is important to construe relations between scientific language and bilingual students' both languages (Goldberg et al., 2009; Msimanga & Lelliott, 2013; Reyes, 2009). Using bilingual students' both languages at school is supported by findings from the bilingual field and is called *bilingual education* (Cummins, 2000; 2005). Hence, I will refer to the practice of using bilingual students' both languages in science class as *bilingual science education*.

Before reviewing previous research about bilingual science education, I find it of importance to mention the fact that science education for bilinguals is often conducted monolingually (Lee & Luykx, 2007). Although emergent bilingual students are not yet fluent in the language of instruction, this is the only language that they can use in science class. There are several reasons for the exclusion of bilingual students' minority language in science. A main issue is that science education and bilingualism are rarely integrated in teacher education and curriculum development. Many teachers hence lack knowledge about the importance of bilingual science education and view students' minority languages as irrelevant for their learning in science (Lee, 2005). Another reason is the class composition. In many countries, several minority languages are represented in the same classroom, and the teachers do not share the same minority language as their students (Blackledge & Creese, 2010; The Swedish National Agency for Education, 2016a). Even if this is not a reason for abandoning bilingual science education, it obviously makes it more difficult. Moreover, due to political decisions, teachers are in some regions or countries required to teach predominately in the official language for education (e.g. García, 2009; Msimanga & Lelliott, 2014).

A body of research have investigated bilingual science education (see Buxton & Lee, 2014; Lee, 2005 for an overview). For instance, Goldberg, et al. (2009) made observations in a 6th grade with a teacher and students bilingual in English and Spanish. 91% of the students at the school were Latino/a and 61% of them were emergent bilinguals. During the data collection, the students worked with humidity, soil and air temperature, and soil nutrition. The school was located in California, where teachers are obligated speak predominantly English during the lessons. The students had the possibility to speak both of their languages during group-work activities. Since the teacher introduced scientific concepts in English, this was the language the students used as well. Nevertheless, Spanish was a legitimate resource for several other purposes, for example, to present, analyse and explain new concepts. Moreover, the students translated instructions into Spanish for their classmates. Based on these observations and the students' results in the written tests, the authors conclude students' minority language is an important resource for their learning in science.

Reyes (2009) investigated what bilingual students can achieve when they have the possibility to use their minority language. The study was carried out in a 4th grade class working with different subjects in science. Four students, who all spoke Spanish and had immigrated to California at the age of five, were chosen to participate in the study. The students had achieved a competent oral level in English according to their test results. Still, their parents had chosen to place them in a bilingual programme with a teacher bilingual in English and Spanish. Data were collected by making field notes and observations of students' interactions with each other. The study indicated that students' minority language had an important role when learning scientific language. Both the teacher and the students used Spanish for several different purposes. For instance, Spanish made it possible for the students to understand the science content and pose questions that they were likely not ready to construct in English. Reyes (2009) states that students' minority language not only enhanced their understanding of the science content but also helped them to develop scientific language and inquiry skills.

Another example (Msimanga & Lelliott, 2014) is from South Africa. The constitution of South Africa recognises 11 languages, and most of the inhabitants are multilingual. The department of education promotes multilingualism, but schools typically prefer to use English as the language of instruction. For most teachers and students, however, English is a second language.

Earlier studies have shown how teachers worry that students may not be engaged in the science content when speaking their minority languages (see Msimanga & Lelliott, 2014 for an overview of these studies). Thus, Msimanga and Lelliott (2014) conducted observations in a 10th grade chemistry class to examine if and how the students' used their minority languages to discuss the science content. Three groups of students were observed as they carried out different activities about reactions of acids. In two of the groups the students spoke isiZulu and English to make sense of the activities. In the third group, an additional language, seSotho was used alongside the already mentioned ones. The analysis of the data showed that the students spent over 90% of their time on task when talking in their minority languages. They made and supported claims, challenged each other's ideas, questioned each other's thinking, discussed the proceeding of the activities and made conclusions.

The Use of Gestures in Science Education

A literature review made by Roth (2001) has demonstrated that gestures is a well-investigated area in anthropology, psychology and other related fields, but not in science education. More recent studies have confirmed that this continues to be valid. Research in science education, both in general (Kress, 2010) and with a focus on bilingual students (Zhang, 2016), has predominantly focused on language. To address this issue, Hubber et al. (2010) examined the use of different resources, including gestures, in three 7th grade science classes by working with forces. The data consisted of videotaped classroom interactions, students' work, field notes, and interviews with students and teachers. The teachers cooperated with a research team to make their lessons more representational rather than focusing predominantly on language. For example, gestures were used to demonstrate pushes, pulls, and lifting forces, as well as show the size of forces and indicate direction. According to the interviewed teachers, the inclusion of other resources besides language implied richer discussions, increased the opportunity to consider inquiries and resulted in a deeper understanding of the science content.

Carter, Wiebe, Reid-Griffin and Butler (2006) conducted a study aimed at examining how students use gestures to help their classmates understand the science content during group-work activities. Classroom observations were made in one 6th and one 8th grade science class. The science content was about mapping concepts. The students used gestures in four different ways. First, gestures were parallel to or highlighted oral communication. Second, gestures added information that was not expressed orally. Third, gestures were used to illustrate phenomena students were not able to express in words. Fourth, the students adopted each other's gestures as shared means of communication.

Givry and Roth (2006) argue for a revised way of conceptualising scientific concepts. They state that concepts cannot be treated only as linguistic since several resources are used to represent them. The authors provide empirical findings to support their claims from seven 11th grade science classes working with the physics of gases. The data consist of 420 questionnaires and students' worksheets. In addition, classrooms observations and student-interviews were made in two of the classes. The study findings showed how students' use of gestures provided meaning to the communications. In some situations, it was not possible to understand students' talk without the gestures. There were also other resources used alongside gestures and language that need to be taken into consideration when analysing communication in science class. To exemplify, two students used language and gestures to discuss whether or not it is possible to add air into an already air-filled bottle. All three resources were used alongside each other and added complementary information to the communication. The students pointed (deictic gesture) at the bottle (physical artefact) while simultaneously making explanations and claims (oral language). The authors argue for the recognition of all means that students use when expressing themselves in science class.

Other studies have focused on teachers' use of gestures in science class. Pozzer-Ardenghi and Roth (2007) made observations during lectures about the human body in a 12th grade biology class. Gestures were an essential part of the teacher's lectures and used for different purposes: relating words to the physical setting, visualising concrete phenomena or processes and illustrating abstract things. For instance, the teacher presented the anatomy of the heart by using speech, a 3D-model of the human heart and gestures. He pointed upwards and downwards to show how the blood flows to the head and the toes. The gestures simultaneously illustrated the continuous dynamic process regarding how the blood flows. Based on their study findings, Pozzer-Ardenghi and Roth (2007) reason that science lectures were not only told, but performed. Understanding the science content required the students to make sense of not only what was said, but also how language interplayed with other resources.

In a study concerning emergent bilingual students, Zhang (2016) investigated the teacher's use of different resources in relation to students' content learning and language development in a 6th grade science class. The data consisted of audio and video recordings of lessons, interviews with the teachers and students, textbook pages, the teacher's and students' products, and field notes. Other resources, alongside language, were continuously part of the teacher's instructions. For example, she used gestures to illustrate the movements of sea sponges. However, the author's analysis indicated that the science content was not well communicated to the students despite the multimodal character of the lessons. The students were often engaged in off-task activities during the lessons. Typically, they also failed to answer questions about the science content both during the lessons and in the interviews. One probable reason for the students' lack of learning progress was, according to the author, the character of the lessons. In general, the teacher dominated the conversations with the students having a more passive role. Two different language practices were observable during the lessons, the teacher's scientific language and the students' way of making sense of the science content in everyday language. However, these two language practices were seldom related to each other.

Physical Artefacts in Science Education

Before reviewing earlier studies about the use of physical artefacts in science education, there is a need to describe a concept that is frequently used in these studies: *hands-on activities*. Hands-on basically refers to activities where the students perform practical tasks, enabling them to experience the science content. The hands-on activities are often conducted by using physical artefacts (Rutherford, 1993). For instance, this was the case in one of the classes observed for this thesis. The science content was electricity and the students were involved in different hands-on activities performed by using different physical artefacts, such as bulbs, batteries, lamp-holders, rulers and wires.

Buxton and Lee (2014) have listed four benefits with conducting hands-on activities in science classes with emergent bilingual students. First, using physical artefacts means that the science content is not communicated exclusively through language. Hence, it is less dependent on students' proficiency in the language of instruction. Second, using physical artefacts and actually observing the science content enables emergent bilingual students to develop their language proficiency in the context of science practice. Third, when students have conducted a hands-on activity, they often report their results to the rest of the class and teachers. Typically, this implies that the students do not have the physical artefacts at hand, but are encouraged to use other resources, such as scientific language. Fourth, using physical artefacts and conducting hands-on activities implies possibilities to develop communication skills, such as, arguing, explaining and hypothesising (Buxton & Lee, 2014). As mentioned earlier, these skills are necessary to gain a deeper understanding of the science content and go beyond replicating factual knowledge (Lemke, 1990).

Holstermann, Grube and Bögeholz (2010) examined the influence of hands-on activities on students' interest in biology. In total, 140 11th grade students completed surveys by answering questions about their interest in experimentation, dissection, microscopy and classification. The students were asked to rate their interest in different topics within biology, mark their experience of conducting hands-on experiments on these topics, and rate the quality of them. In general, the study findings indicated a positive correlation between conducting hands-on activities and students' interest in these topics. However, the study also showed that the influence hands-on activities had on students' interest varied. For instance, it seemed that performing experiments increased students' interest in specific experiments or topics rather than experiments in general. Hence, the authors conclude that the quality of experiences are essential for the students' interest development.

Amaral and Garrison (2002) summarise the result of a four-year project carried out in California. Over 1200 emergent bilingual students in the 4th and 6th grade and their teachers participated in a kit- and inquiry based science instruction. The programme involved several different topics, for example growing things, the solar system and measuring time. In general, the students' achievements increased in relation to the number of years they had participated in the programme. For example, the mean raw score in science assessments for the students that had not yet participated in the programme was 17.39 in the 4th grade and 16.88 in the 6th grade. The numbers for the students that had participated in the programme for four years were 26.29 in the 4th grade and 26.02 in the 6th grade. Based on these numbers, the authors argue that the project supported bilingual students' achievements at school.

However, using physical artefacts does not per se support emergent bilingual students' learning in science. Teachers need to use explicit strategies, integrating the development of everyday and scientific language (Buxton & Lee, 2014). In a study examining teachers' knowledge and practices in teaching science while supporting language development, 38 science teachers were interviewed and observed in science class. All the teachers worked in a school district in which 60% of the students were Hispanic. The teachers explained that almost all their lessons included scientific inquiry. The observations revealed that the hands-on activities seldom implied more than basic skills or tools use. Therefore, the authors question if the use of physical artefacts really supported students' learning in science (Lee, Lewis, Adamson, Maerten-Rivera & Secada, 2008). Krange and Arnseth (2012) describe how two students in an upper-secondary science class used a computer programme when working with energy. At the end of the unit, the students had developed knowledge about different energy resources, but their talk during the activities was about how the activities were supposed to be conducted and not about the science content. The authors argue for making the connection between the science content and the resources used more explicit to students.

To summarise, scientific language is demanding for all students, regardless of linguistic background. Scholars have suggested teachers to construe relations to everyday language to enhance students learning of scientific language (Lemke, 1990; Wellington & Osborne, 2001). However, for emergent bilingual students, not only scientific language, but also everyday communication in the majority language, is a challenge. Researches have proposed bilingual science education (Buxton & Lee, 2014) and the use of other mediating means beside language (Hammond & Gibbons, 2005; Kamberelis & Wehunt, 2012) to support emergent bilingual students. Here, two main research gaps are discernible. First, studies about bilingual science education have in general been conducted in classes were the students and the teachers speak the same minority language (e.g. Goldberg et al., 2009; Salleh et al., 2007; Reyes 2009). Second, emergent bilingual students' learning in science has predominately focused on language, and other resources have so far received little attention (Zhang, 2016). In this thesis, these research gaps are addressed by examining how emergent bilingual students use their minority language and other resources in classes where they do not speak the same minority language as their classmates or teachers.

3 Theoretical Framework

In this thesis, emergent bilingual students' learning in science has been examined from a pragmatic (Dewey, 1925/1998; Wittgenstein, 1958/1967) and sociocultural perspective (Leontev, 1981; Vygotskij) and by using the theory of translanguaging (García, 2009). In all three of them, language and learning is regarded as *action situated in a historical, cultural and social context.* A pragmatic perspective on learning has enabled an analysis of language, gestures and physical artefacts by focusing on their *use* and *consequences* in a specific context. Sociocultural perspectives have made it possible to approach these resources as *mediating means*, having both affordances and constraints for emergent bilingual students' learning in science. The theory of translanguaging has provided knowledge about the '*multiple discursive practices* in which bilinguals engage in order to *make sense of their bilingual worlds' (*García (2009, p. 45).

Learning as Action

Learning is seen as *action* situated in a historical, cultural and social context (Dewey, 1925/1998; Leontev, 1981; Vygotskij, 1978). This view is underpinned by 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 quality of those which come after.

According to Dewey (1925/1998), an experience is not a representation of the external world, and it is more than an internal process taking place 'inside' individuals. An experience refers to the interaction between the individual and the surrounding context as an inseparable unit. An experience is thus *of* as well as *in nature*, gained by acting in different situations. The principle of continuity implies viewing learning as a process intimately related to meaning-making:

> …meaning- making always involves learning, which in turn amounts to establishing relations between immediate entities of experiences (Wickman, 2006, p. 73).

Meaning-making then implies *learning in action*. Individuals make meaning of new situations by relating to their earlier experiences and the purpose of the activity. This means that earlier experiences are *reactualised.* Simultaneously, the meaning- making process also involves acting in the situation and reflecting on the consequences of actions. The combination of action and reflection results in learning, which in turn is a *transformation* of earlier experiences (Wickman, 2006). Dewey did not view learning as being acquainted with how phenomena and processes in the world 'out there' look like or work. Instead, learning concerns developing new patterns of actions to make meaning of different situations, or *habits* as Dewey defines it (Biesta & Burbules, 2003).

Since we gain experiences in all situations in which we are involved, Dewey (1938/1997) makes a distinction between educative and mis-educative experiences. He calls this *the category of continuity* or *the experimental continuum*. According to Dewey, only experiences that lead to continuous growth from a social point of view are educative. He explains this idea by giving an example: as burglars gain new experiences, they might gradually become an expert in burglary. However, we would not classify the experiences of burglars as educative. When applied to a school context, teachers need to create social and physical situations resulting in educative experiences by observing how students' experiences are growing and direct them towards the goal of the particular activity. Students make meaning of classroom activities by drawing on their earlier experiences. Teachers cannot regulate, at least not in the current situation, what kind of experiences students enter the classroom with[1]. Additionally, students' earlier experiences differentiate from each other. However, teachers are in charge of the lessons. Therefore, the ultimate concern for teachers is making students' earlier experiences continuous with the lessons (Dewey, 1938/1997):

> Those to whom the provided conditions were suitable managed to learn. Others got on as best as they could. Responsibility for selecting objective conditions carries with it, then, the responsibility to understand the needs and capacities of individuals who are learning at a given time (p. 45).

A question to untangle is whether students are viewed as having individual cognitive capabilities and how this in that case relates to the situatedness of learning. Undoubtedly, we are biologically equipped with cognitive capabili-

[1] To avoid misunderstandings, Dewey's principle of continuity does imply that a transformation of earlier experiences is possible, but only if they are continuous with the current activity.

ties. However, learning can never be *only* a question of students' biologically-given capacity to learn. Earlier knowledge and proficiencies need to be related to the context in which the lessons take place. This involves paying attention to how students cooperate with other individuals and the use of different intellectual and physical resources (Vygotskij, 1978; Säljö, 2000). The following is an example written by Säljö (2005) that aims at concretising the situatedness of learning: It is quite likely that a child growing up in the Western world will learn how to read and write and use different digital tools. It is, however, less likely that the child will learn to build boats or hunt. This does not mean that the 'modern child' is incapable of learning these abilities. Accordingly, the cultural context decides what and how to learn. However, culture is not an entity that exists on its own, rather it is shaped, changed and maintained by human beings (Säljö, 2000; Wickman, 2006). This interaction implies that people are 'coming into contact with, and creating their surroundings as well as themselves through the actions in which they engage' (Wertsch, 1993, p. 8).

Viewing learning as action, inseparable from the context in which it occurs, enables the avoidance of extremes in educational research; studies examining students' learning as a cognitive process, regardless of situational aspects, and studies focusing on the environment by regarding students' as passive recipients (Wertsch, 1993). Furthermore, when learning is regarded as situated action, taking place in interaction with others and the surrounding context, communication gains a central role (Vygotskij, 1978; Säljö, 2000).

Communication - Using Mediating Means

Sounds, body movements and written symbols constitute the basic material for communication. When communication occurs, events gain meaning, sounds turn into language, body movements into gestures and symbols into written language (Dewey, 1925/1998). Language and other actions used to communicate do not have fixed or universal meanings and exist on their own. They gain meaning *through their use and consequences in a specific context* (Dewey, 1925/1998; Wittgenstein, 1953/1967). Viewing communication as situational should not be interpreted as denying or disregarding the existence of a shared understanding of actions. Although the meaning of actions is situational, they also result in *customs* (Wittgenstein, 1953/1967) or *standardised habits of social interaction*, as Dewey (1925/1998, p. 190) defines it. The existence of a shared understanding is a basic condition for communication to occur. If we constantly had to explain what we meant with all of our actions, communication would stall and we would not be able to continue with our shared undertakings (Wickman, 2006; Wittgenstein, 1953/1967). For instance, if we refer to an object by pointing at it, we typically do not say 'I mean the object I am pointing at' since this is expected to be intelligible in the current situation.

We use different resources – for example, language, gestures and physical artefacts – to learn. Resources hence mediate meaning and can be approached as *mediating means* and learning is *mediated action* (Leontev, 1981; Vygotskij, 1978). Accordingly, mediating means are a part of, and simultaneously shape, our actions (Säljö, 2000). As also described earlier, the term 'action' implies viewing the learning process as an activity inseparable from the social, historical, and cultural context in which it occurs. When learning and communication are seen in this way, the meaning of students' and teachers' actions, and the mediating means used, cannot be examined in isolation from each other (Wertsch, 1993).

A main concern when studying learning as situated action is how individuals, groups or societies appropriate and use different mediating means (Säljö, 2000). Communication, both in general and in science class, involves the use of a range of resources, all contributing to students' learning in specific ways (Hubber, et al., 2010). This has especially been addressed in social semiotics, and researchers within this field have made important contributions concerning the affordances of different resources for students' learning in science (e.g. Kress, 2009; 2010; Kress, et al., 2001; Jewitt, 2013). In social semiotics, resources are defined as *modes*, and the concept *multimodality* is used to draw attention to the use of several resources in a certain situation. There are many commonalities between social semiotics and the theoretical framework approached for this thesis. For example, all modes (or mediating means) are viewed as contributing to communication and learning in different ways. However, there are also some differences. In social semiotics, all modes are valued as equally important (Kress, 2009; Jewitt, 2013). Although the importance of all mediating means is acknowledged in this thesis, language is viewed as the most important resource for communication and learning (Dewey, 1925/1998; Säljö, 2005; Vygotskij,1978). Consequently, the two other mediating means addressed: gestures and physical artefacts, are examined by being related to language use. In the following, a further description of these mediating means is made.

Language

According to Säljö (2005) language is the most important mediating means for learning. Similarly, Dewey (1925/1998, p. 168) describes language as the

'the tool of tools' for communication. Using language involves participating in different situations and interacting with others. It enables communication about phenomena and processes that do not exist or take place in the current situation. Knowledge is shared and lives on because of language (Dewey, 1925/1998). When other resources are used to communicate, they are in general combined with, or related to, language (Dewey, 1925/1998; Vygotskij, 1978).

Like all other resources, a word or an utterance acquires its meaning as a result of its use in a certain practice (Dewey, 1925/1998). Wittgenstein (1953/1967, § 7) describes the situatedness of language by using the concept *language game*, which he defines as *the whole, consisting of language and the actions into which it is woven*. Taking an active part in a language game involves learning its specific rules and the culture to which it belongs (Harré & Gillet, 1994). Language can then be approached as a social practice and speakers as social actors (Heller, 2007). Wickman (2006) suggests that the language of science could be approached as an example of a language game since students need to understand how words are used in a particular activity in order to make meaning of science lessons.

In sociolinguistics, the term *languaging* is used to emphasise how language is action emerging in a social context (Canagarajah, 2007; García & Wei, 2014; Makoni & Pennycook, 2007). The term was coined by the Chilean biologists Maturana and Francisco in year 1973 and has been developed by linguists since then. García and Wei (2014, p. 8) argue for the importance of the term by writing:

> … *languaging* is needed to refer to the simultaneous process of continuous becoming ourselves and our language practices, as we interact and make meaning in the world.

Accordingly, learning a new language involves more than acquiring new words and a grammatical system. It entails successfully becoming part of a cultural and historical practice. Language learners develop not only their way of speaking, but also their being, knowing and doing (Becker, 1995).

Gestures

Gestures are defined as *hand movements that accompany and are directly tied to speech* (Goldin-Meadow, 2004, p. 314). However, not all hand-movements, but only the ones that carry meaning, are considered as gestures (McNeil, 1992). Kendon (1980, 1996) suggests four characteristics to distinguish gestures from other hand-movements. First, gestures have a *beginning and end*. They start from a position of rest, move away from this position, and then return to rest. Second, gestures have a *peak structure*, an accented movement emphasising the meaning of the gesture. Third, the movements before and after the peak structure function as *onsets* and *offsets*. Fourth, gestures are *often symmetrical*. It is, for instance, difficult to determine in a video recording if the tape is running forward- or backward when a gesture is used.

Gestures can be used for different purposes, implying that there are different kinds of gestures. Various terms have been use by researchers to categorise gestures. In general, there are no extensive differences between the categorisations, however. In other words, different words are used to describe the same or similar ways to gesture (see Roth, 2001 for an overview). Here, only the terms used to categorise gestures in this study are described. *Beats* are interactive gestures without an actual content such as the up and down flick of a hand or a tapping motion. They are used for different purposes, for example, to direct turn taking, seek or request a response and indicate understanding. *Deictic gestures* are used to point out concrete or abstract phenomena. Gestures describing concrete entities, for instance an electrical wire or a wall, are defined as *iconic*. *Metaphorical gestures* visualise abstract entities or events, such as getting an electrical shock or the electrostatic forces between ions. Beats are often linear, whereas iconic and metaphorical gestures are two or three-dimensional (McNeil, 1992).

The meaning of gestures is established through their use in a context (Kendon, 1996; Wittgenstein, 1953/1967). However, this does not mean that gesticulation is idiosyncratic. Even if individuals might gesticulate differently when describing the same phenomena or event, there are socially shared similarities in the pattern of gestural action (Kendon, 1996). Goldin-Meadow (2004, p. 315) argues that unlike language, which is based on codified words and a specific grammar, 'gestures convey meaning globally, relying on visual and mimetic imagery'. Simultaneously, there is a body of research demonstrating variations in how people from different ethnic cultures use gestures (Ekman & Friesen, 1972; Kita, 2009). For instance, Matsumoto and Hwang (2013) conducted a comparative study by examining how people from Sub-Saharan Africa, East Asia, Latin America, the Middle East, South Asia and the United States use emblems (gestures that can occur independent from speech). Several differences were observable. First, some messages were communicated by using gestures in all cultures, but the gesture to do so varied between the cultures. Second, several gestures occurred in all cultures but meant different things. Third, some gestures were used in some cultures but not in others. The study also showed similarities between how people from different cultures gesticulate, but they occurred rarely and concerned more 'basic' messages, such as 'yes', 'no' and 'I don't know'.

In this thesis, cultural implications or variations in gesturing are not in focus. Instead, bilingual students' use of gestures is examined by being related to their proficiency in the language of instruction. However, the cultural aspect of gestures is important to mention since the students' and their teachers' ethnic culture differed from each other (which is described later on in the thesis). This might have influenced both how the students used gestures and the consequences of the gestures for the students' learning.

Physical artefacts

The term *artefact* refers to different tools, such as language or physical objects used in communication and learning (Almqvist, 2005). Vygotskij (1978) made a distinction between *physiological artefacts* (language and gestures) and *physical artefacts* (objects). Physical artefacts have several intertwined functions in communication and learning (Säljö, 2000). First, they are used as mediating means in different learning situations. Second, learning how to use certain artefacts is a central part of education. Third, artefacts are in different ways 'knowledge bearers'. The production of them, that is, the transformation of material from one condition to another, requires knowledge about how to do so. At the same time, some of our knowledge has been 'moved' to physical artefacts. For instance, the possibility to write by using paper and pen enables us to remember things without actually memorising them. Hence, students' learning is never merely a question of cognitive capabilities. It also involves the mediating means used in the specific situation and how acquainted the students are with using them (Säljö, 2000, 2005).

The relation between artefacts and individuals is complex. We learn how to use physical artefacts and expect them to function in certain ways. For example, when we write by using paper and pen, the artefacts in question have certain roles. Accordingly, artefacts are used for certain purposes, and there are socially shared understandings of their functions. However, this does not mean the use of artefacts is fixed or socially predetermined. A pen might be used for purposes other than writing. (Quennerstedt, Almqvist & Öhman, 2011). As a researcher, one can focus on how artefacts shape peoples' actions, or how people shape artefacts. There is also a third alternative focusing on the process in which artefacts are used in a specific content to make meaning (Almqvist, 2005). This idea is underpinned by Wertsch's (1995, p.

22) view on the relationship between human beings and artefacts:

> …mediation is best thought as a *process* of involving the potential of cultural tools to shape action, on one hand, and the unique use of these tools, on the other.

Typically, our use of artefacts is influenced by socially created *habits* (Dewey, 1925/1998), or *customs* as Wittgenstein (1953/1967) defines it. Dancing on a dinner table is, for example, possible, but would in most situations seem like a strange thing to do (Almqvist, 2005). Furthermore, a physical artefact might be viewed differently depending on the viewer's earlier experiences (Säljö, 2005). To conclude, physical artefacts gain their meaning, just like language and other resources, through their use in a specific context (Dewey, 1925/1998; Wittgenstein 1953/1967).

Bilingualism - Some Definitions

The first question to untangle is how bilingualism is viewed in this thesis, as several definitions exist within educational research. The reason for the disagreement among researchers is based on a discussion concerning when a person can be considered bilingual (García, 2009). Simultaneously, several scholars are sceptical of making a general definition of the term. By showing how bilingual students are a heterogeneous group with different language practices, they argue that a detailed definition risks excluding some bilinguals (Grosjean, 1985; García, 2009). García (2009) illustrates the heterogeneity among bilinguals by using a metaphor in which the language practice of bilinguals is compared to South Asian banyan trees. These trees grow in several different directions: up, out, down, horizontally, vertically, etc. Similarly, the language practice of bilinguals grows in different directions depending on the contextual aspects. Even bilinguals speaking the same languages constitute a heterogeneous group in the sense that every individual has his/her own unique language repertoire and uses the languages differently.

Based on the heterogeneity among bilinguals, broad and inclusive definitions are used within this thesis. Bilingualism is regarded as '*the regular use of two (or more) languages*' and bilingual students as '*people who need and use two (or more) languages in their everyday lives* (Grosjean, 1985, p. 468). Accordingly, these definitions also embrace multilingualism, that is, the regular use of more than two languages (García, 2009). *All* students using more than one language in their everyday life, *regardless of language profi-*

ciency, are viewed as bilinguals. In other words, students do not necessarily need to be 'fluent' in both of their languages to be considered bilingual.

The definitions above do, however, not imply that differences in bilingual students' language proficiency are disregarded. For instance, some students are fluent in two languages while others are still learning a language. This thesis concerns the last mentioned: students not yet fluent in the language of instruction (García & Kleifgen, 2010). Different terms have been used to refer to these students. In the United States, the terms 'English Language Learners' (ELLs) or 'Limited English Proficient students' (LEPs) are used (García & Kleifgen, 2010). In Sweden, the students are called 'second language learners' (Wedin, 2011) or 'students in Swedish as a second language' (The Swedish Parliament, 2017). In this thesis, the term *emergent bilinguals* (García & Kleifgen, 2010) is preferred since it has a prospective approach, advocating educators to focus on the students' potentials rather than their limitations:

> ELLs are in fact emergent bilinguals. That is, through school and through acquiring English, these children become bilingual, able to continue to function in their home language as well as in English- their new language and that of school (García & Kleifgen, 2010, p. 14).

This term, as well as the other ones mentioned above, for example second language learners, all have some constraints. For instance, one might ask where the line between students fluent in their languages and emergent bilinguals goes. What does it mean to be 'fluent' in a language or when do students finish learning the language of instruction? Do we, regardless of whether we are monolingual or bilingual, ever stop developing our language repertoire? Still, there is a need for a terminology when referring to bilingual students. It is, for example, in some situations important to make a distinction between students 'fluent' in both of their languages and bilingual students still learning the language of instruction. Even though both these groups of students are bilingual, they have different needs, meaning that their education cannot be organised in the same way (García, 2009). Using 'bilingual students' without specifying further which group of students the term aims at is thus in some situations problematic. Based on this, the terms *emergent bilinguals*, *not fluent in the language of instruction* and *language learners* are used in this study, despite their limitations.

The terminology used to describe the language practices of bilingual students does not end here. There are also some terms used when referring to the languages of bilinguals. Traditionally, the terms heritage language, home language, mother tongue, and first- and second language are used. However, these terms are in some situations insufficient to encompass bilingual students' language practices. To provide some examples, the terms home language and mother tongue indicate that the language in question belongs to a life outside the school context, which is not always the case. Furthermore, being bilingual does not always imply that one of the languages was introduced later in a person's life. Categorising the languages of bilinguals in a chronological order as first- and second language is thus not always possible. One might, for example, ask how to draw a line between a person who has two mother tongues and a person who has a mother tongue and a second language (García, 2009; 2011). In addition, some of these terms are defined in several different ways within the bilingual field. For example, mother tongue might mean the language a person learns first, the most mastered language, the most used language, the language a bilingual identifies her/himself with or the language others identify a person with (Skutnabb-Kangas, 1981).

Based on the limitations and ambiguity concerning the traditional terms mentioned above, *majority language in a society* will be used instead of terms such as second language and additional language. In line with this, *minority language in a society* is preferred instead of terms such as first language, mother language and heritage language (García 2009). In Sweden, where this study was conducted, Swedish is regarded as the majority language and other languages spoken by the population as minority languages[2].

Different Views on Bilingualism

The monolingual view of bilingualism

Traditionally, education for bilinguals has drawn on a comparison between bilingual and monolinguals' language practices by regarding monolingualism as the norm. Bilingual students are seen as 'two monolinguals in one' with two (or more) languages growing independently from each other. Researchers in the bilingual field refer to this as *the monolingual view of bilingualism* (García, 2009; Grosjean, 1985; Hornberger & Link, 2012). Educators and policy makers, advocating the monolingual view of bilingualism, have argued for keeping the languages of bilingual students strictly separated from each other (Creese & Blackledge, 2010). Other terms use to describe

[2] These definitions differ from how languages are defined and categorised by the Ministry of Culture in Sweden. This is described later on (see Ministry of Culture 2009).

the same or similar views of bilingualism are *parallel monolingualism* (Heller, 1999), *bilingualism with diglossia* (Baker, 2003) and *separate bilingualism* (Blackledge & Creese, 2010).

The monolingual view of bilingualism has resulted in different models to educate bilingual students, for example *subtractive* and *additive bilingualism* (García, 2009; García & Wei, 2014). Subtractive bilingualism aims at gradually replacing students' minority language with the majority language of the society. Accordingly, minority languages are temporally used to introduce the 'new' language (García & Wei, 2014). Subtractive bilingualism has caused the extinction of many minority languages around the world (García, 2009). Additive bilingualism implies adding a new language, often the majority language of the society to the students' language repertoire. Accordingly, minority languages are acknowledged. Nevertheless, it is still based on a monolingual view of bilingualism since the languages of bilinguals are viewed as belonging to two different language repertoires and developing independently from each other. The educational consequence of additive bilingualism is that the languages of bilinguals are separated from each other in different ways, for example time, teacher, place or subject determines the separation (García, 2009). Additive bilingualism has also an impact on what bilingual students regard as the 'right' way to use their languages. Research has shown how bilingual students try to maintain the language separation and feel guilty when they use both their languages simultaneously (Blackledge & Creese, 2010).

Several scholars within bilingual research have questioned the monolingual view of bilingualism. By showing how the languages of bilinguals are interrelated and belong to the *same* language repertoire, they have argued that bilinguals cannot be regarded as 'two monolinguals in one' (e.g. García, 2009; Creese & Blackledge, 2010). The terms *dynamic bilingualism* (García, 2009), flexible *bilingualism* (Blackledge & Creese, 2010) and *heteroglossia* (Bailey, 2007), have, for example, been suggested to describe the language practice of bilingual students. Indeed, the monolingual view of bilingualism was already being criticised more than 30 years ago:

> The high hurdler blends two types of competencies, that of high jumping and that of sprinting. When compared individually with the sprinter or the high jumper, the hurdler meets neither level of competence, and yet when taken as a whole the hurdler is an athlete in his or her own right. No expert in track and field would ever compare a high hurdler to a sprinter or to a high jumper, even though the former blends certain characteristics of the latter two. A high hurdler is an integrated whole, a unique and specific athlete, who can attain the highest levels of world competition in the same way that the sprinter and

> the high jumper can. In many ways, the bilingual is like the high hurdler: an integrated whole, a unique and specific speaker-hearer, and not the sum of two complete or incomplete monolinguals. (Grosjean, 1985, p. 471)

The analogy unfortunately continues to be valid as bilingual students are still compared to monolinguals at schools and in educational research (García, 2009).

The theory of translanguaging

In this study, the theory of *translanguaging* is used to examine bilingual students' communication practices (García, 2009; 2011). As in pragmatic (Dewey, 1925/1998; Wittgenstein, 1953/1967) and sociocultural approaches (Leontev, 1981; Vygotskij, 1978), language is viewed as an activity produced by social relations rather than a simple system of structures giving us a set of skills (García, 2009). The term translanguaging was initially coined by Cen Williams when referring to a pedagogical practice in which bilingual students use both of their languages. For instance, the students are asked to read in Welsh and write about their reading in English (García & Wei, 2014). Today, translanguaging has been extended and is used by scholars within the bilingual field to describe the complex language practices of bilinguals (e.g. García, 2009; Blackledge & Creese, 2010; Hornberger & Link, 2012). Several different definitions of the term exist, but they are all grounded in the idea that bilingual students' both languages are intertwined, belong to the same language repertoire and support learning. Furthermore, translanguaging is not limited to language; it also involves other mediating means bilinguals use alongside their languages to communicate (García & Wei 2014). García (2009, p. 45) defines the term by writing:

> Translanguaging are multiple discursive practices in which bilinguals engage in order to make sense of their bilingual worlds.

Translanguaging concerns *the act of languaging*, which is inseparable from the social, historical and institutional context in which it occurs. Human beings are viewed as social actors moving along various socially constructed languages and construing relations between their everyday languaging and school languaging. The process of learning a language is viewed to imply *integration*. Regardless of whether it concerns a national language or an academic one, what is learnt needs to be related to students' already existing language practices. Rather than learning a 'new' or a 'second' language, bilingual students are developing their own and unique repertoire of resources, enabling them to make meaning of their worlds. Seen in this way, language practices do not belong to the home or school. The development of a new language is an act of doing. A language practice can only be developed by deriving from what is already known, that is, students' existing language practice. Accordingly, using translanguaging as an educational means offers students increased possibilities for linguistic development and content learning. Bilingual students are able to access academic content with the resources already part of their repertoire, while simultaneously acquiring new ones (García & Wei, 2014).

The questioning of the monolingual view of bilingualism, and the emergence of the theory of translanguaging, has resulted in researchers paying attention to *bilingual education*, that is, the inclusion of bilingual students' minority language at school and in other educational settings. Bilingual education is of importance for linguistic development as well as students' overall achievement (Cummins, 2000; 2005). Developing two (or more) languages implies gaining a deeper and more flexible understanding of language. A well-developed minority language is viewed as facilitating the learning of a society's majority language and supports students' overall achievements at school (Blackledge & Creese, 2010; Cummins, 2001; 2005; García, 2009; Hornberger & Link, 2012).

Unfortunately, education for bilinguals is still typically conducted monolingually in the majority language. A frequently used argument among teachers and policy makers is that giving time to students' minority language at school risks negatively affecting the development of the majority language. It is said that allowing students to speak their minority language implies less use of the majority language, and hence less practice. However, researchers are agreed on the opposite: including bilingual students' minority language at school does not obstruct or delay the development of a majority language (Cummins, 2000; 2005; García, 2009). On the contrary, bilingual education supports the development of majority language. Rejecting bilingual students' use of their minority language implies that the students can only use a limited part of their recourses to make meaning of the lessons (Cummins, 2001; 2005; García, 2009).

4 Analytical Approach

Practical epistemological analysis – PEA is well-established analytical tool used to analyse students' learning in science (Kelly, McDonald & Wickman, 2012). PEA is based on the ideas of Dewey, the later Wittgenstein, and sociocultural approaches (Wickman & Östman, 2002). The unit of analysis is similar to sociocultural approaches: actions, including speech and gestures, are analysed as situated in whole activities (cf., Harré & Gillette, 1994; Säljö, 2005; Wertsch, 1995).

Traditionally, 'epistemology' has referred to a cognitive perspective focusing how to get reality right. In PEA, the term is used in an antirepresentational sense; *practical* epistemological analysis is not made from a cognitivist point of view. It does not concern individuals' mental capacities or learning independently from the situational aspects. Actions are analysed as part of a social practice by focusing on how individuals proceed with their activities and what consequences this has for what they learn. PEA always starts from a first-person perspective, that is, the purposes that the individuals themselves pursue. This requires that the researcher is acquainted with what the teachers and students are up to. The next step is to take a third person-perspective. It is not until now the researcher can analyse what the participants' actions mean in relation to the study and research questions. The meaning made by the participants' themselves in a certain activity cannot be the same as the meaning made by researchers. Beginning with a first-person perspective enables the participants to make explicit their aims and actions and reflect on them before actually relating them to their own research interest (Wickman, 2006).

Operational Concepts

There are four operational concepts used in PEA: encounter, stand fast, gap and relations. *Encounter* refers to the meetings between people and between people and their surrounding world. In an encounter, the use of certain actions, including communication, *stand fast*. These actions are immediately intelligible to the participants, and there are no questions or hesitations regarding their meaning. That some actions stand fast in an encounter is a necessary condition for communication to occur. If we constantly had to explain what we meant with all of our actions, communication would stall and we would not be able to continue with our shared undertakings. However, sometimes actions do not stand fast and it is necessary to unpack their meaning, which results in *additional encounters* This is evident operationally as the participants asking questions and explaining the meaning of their actions. In other words, the meaning of a certain action is then not immediate, but mediated through the extra means employed to explain. Actions standing fast in an encounter is not synonymous with the right or true answer from a third-person perspective or from a scientific point of view. For instance, if two students are agreed that the moon is a star, this is said to stand fast in the encounter between them even though it is not scientifically correct. Moreover, standing fast may be a temporary state. An action standing fast in one encounter might be questioned by the same participants in another. Accordingly, the term highlights the situatedness of meaning (Wickman, 2006; Wickman & Östman, 2002).

In encounters, *gaps* occur and are filled by establishing *relations* to what already stands fast in the encounter. A prerequisite to fill a gap is noticing the need for a relation. Operationally, this is visible in two ways. First, when participants ask questions to each other or hesitate, the need for a relation becomes obvious. However, most gaps are filled without the participants asking questions or hesitating. The second way to operationally notice a filled gap is hence from its immediate consequences. When a gap is filled the activity continues in the same direction as intended, that is, in line with the participants' purpose with the activity. All gaps are not filled immediately since the participants need to try out different relations before the activity can continue. In some situations, the gaps cannot be filled despite these efforts. Then, the gap *lingers* and the activity stops or takes another direction. Accordingly, students' learning is directly related to gaps being noticed and filled. The fulfilment of a gap implies that new relations have been construed to earlier experiences. (Wickman, 2006, Wickman & Östman, 2002).

Using PEA to examine learning in science class means analysing which consequences teachers' and students' actions have for their learning. This orientation is similar to how teachers work since they also try to understand what students learn by paying attention to students' actions in the classroom. Teachers also need to ensure that their own actions, in particular the words they use, stand fast in the encounters with the students. It is also important that the students are offered possibilities to construe relations between their own ways of using language and the scientific language (Wickman, 2006).

Learning as situational, continuous and transformational

When drawing on Dewey's principle of continuity, the chosen analytical tool needs to deal with three interrelated aspects of learning; situational, continuous and transformational. These are all considered in PEA:

> The situational aspects are the unique and often contingent aspects in every situation, such that there is something new in every situation we encounter. The continuous aspects describe how these different unique situations are reconciled and reciprocally related to each other in the learning process. The transformational aspects deal with how experience and what we know is changed as situations are made continuous (Wickman. 2006, p. 53).

As in the work of Dewey, continuity is a central aspect in PEA. First, actions standing fast in encounters implies that the participants have prior knowledge of what the actions in question mean in the current activity. Second, the participants also explicitly refer to earlier experiences. Third, continuity is demonstrated by the participants' habits. Their actions are a result of their earlier experiences. Moreover, continuity is highly related to another aspect of learning: transformation. The transformational aspect is demonstrated as a part of the process of construing new relations in order to fill gaps. It is by construing relations that we learn something new, which in its turn implies a transformation of earlier experiences. Simultaneously, new relations are construed to what already stands fast, that is, earlier experiences. Accordingly, earlier experiences and current situations are made continuous. In this way, PEA makes the learning process visible (Wickman, 2006).

5 Methods

The data for this thesis consist of classroom observations and student interviews conducted in Sweden. This section hence starts with a brief presentation of bilingual students' school situation in Sweden. It is then followed by a description of how data were collected and analysed, as well as ethical aspects.

Contextualising the Study

Approximately 25% of the students in Sweden are bilingual (The Swedish National Agency for Education, 2016a). The number of bilinguals varies between different geographic areas. Almost all students are bilingual in some schools, whereas the number is less than 10% in others (The Swedish National Agency for Education, 2008). The *principal language* is Swedish, implying 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 2009a, p. 1-2). All education in Sweden, besides 'mother tongue instruction' (described later) is in general monolingually in Swedish. Besides Swedish, there are about 150 other languages represented in schools (The Swedish National Agency for Education, 2016a). These languages are divided into three categories: national minority languages, Swedish sign language and mother tongues. The national minority languages are Finnish, Yiddish, Meänkieli (Tornedal Finnish), Romany Chib and Sami. Other languages spoken by the population are regarded as mother tongues (Ministry of Culture, 2009a). The categorisation is based on the framework convention for the protection of national minorities and the European charter for regional minority languages (Ministry of Culture, 2009b, see also, Council of Europe, 1995; 1998). The term minority language is used differently by the Swedish government (Ministry of Culture, 2009a) than it is in the theoretical framework approach for this study. When drawing on the theory of translanguaging, Swedish is regarded as the majority language of the society and *all* other languages spoken are considered minority languages (García, 2009).

Whether bilingual students' languages are categorised as a minority language or a mother tongue is important as it decides students' rights to receive lessons in the language. Students belonging to a national minority, are deaf, hard of hearing or who for other reasons require sign language, have to be given the opportunity to *learn*, develop and use their language. If students' language is categorised as a mother tongue, the schools' responsibility is limited to offering the possibility of developing and using that language (Ministry of Culture, 2009a). This implies that if students do not already have learned the language at home, schools are not obligated to offer any lessons in it.

In order to fulfil the obligations concerning bilingual students' minority language or mother tongue, schools offer mother tongue instruction[3]. The lessons are optional, in general scheduled after the ordinary school day and given once a week for 1-2 hours (The Swedish National Agency for Education, 2008). If bilingual students have moved to Sweden after starting school, and 'there is a need for it', schools also offer them extra support in their minority language/mother tongue. The principal is responsible for initiating an investigation regarding the need of this extra support (The Swedish National Agency for Education, 2015). Since few schools make use of this opportunity, the Swedish National Agency for Education (2008) maintains that it is not possible to make general conclusions regarding the effect of the support. In addition, some bilingual students are offered lessons in 'Swedish as a second language' instead of 'Swedish'. The principal decides which course bilingual students should attend. The decision is based on test results and consultation with teachers and parents (The Swedish National Agency for Education, 2008).

About 90% of the monolingual students in Sweden are qualified for upper secondary school. The number for bilingual students is 70% (The Swedish Agency National for Education, 2016e). All students in compulsory school perform standardised national tests in Swedish or 'Swedish as a second language' in the 3rd, 6th and 9th grades. In general, bilingual students attending 'Swedish as a second language' receive lower grades than their peers in 'Swedish' and are overrepresented in the group comprised of those who did not pass the tests (The Swedish Agency for Education 2016f). According to The Swedish National Agency for Education (2008) the students' achievements should not be interpreted as a failure of the course 'Swedish as a second language'. Students attending the course have less developed language proficiency than their peers and are, on average, from families of low socio-

[3] Also, the lessons offered to students speaking a minority language according to the government's definition (The ministry of Culture, 2009a) are called 'mother tongue instruction'.

economic status. In addition, many schools have difficulties in interpreting and following the directions for the course. To give an example, although the course is a subject on its own, many schools interpret it as supplemental. This results in some students attending both ‘Swedish’ and ‘Swedish as a second language’ courses (The Swedish National Agency for Education 2008).

Data Collection, Participants and Settings

This thesis draws on data from two classes located in different schools in Sweden. The classes were chosen by the following three criteria. First, I was interested in conducting the study in compulsory school, which is grades 1- 9 in Sweden. Second, the classes needed to include emergent bilingual students. Since this thesis concerns how different mediating means are used in classes with students not sharing the same minority language as their peers or teachers, the third criterion was locating such classes. With the three criteria in mind, a *convenience sample* was made, meaning that two schools were located through personal contacts (Saumure & Given, 2008). Below, the data collection in the 3rd and 7th grade is described, respectively.

Data Collection 1

The class consisted of 31 students, 9- 10 years old (3rd grade). All of them were bilingual and several minority languages were represented in the class, for example, Arabic, Bosnian, Greek and Turkish. Some of the students were born and raised in Sweden, whereas others had moved to Sweden later in their lives. The teacher was monolingual in Swedish.

One of the purposes of this thesis is to contribute knowledge about how emergent bilingual students use their minority language in science class. I am bilingual in Swedish and Turkish. Therefore, the study focused on four students, all of whom were bilingual in the same languages as myself. This should not be interpreted as this thesis being primarily concerned with the specific needs or language use of students with Turkish as their minority language. The reason for this choice is practical. By focusing on bilingual students having Turkish as their minority language, I could analyse the data without first having it translated by interpreters. The four students in question were born and raised in Sweden, but the teacher stated that they all were emergent bilinguals. This was confirmed by the data collection and is described in the study findings.

During the data collection, the class worked with a unit concerning electricity and the lessons were conducted by following the Swedish version of STC (Science and Technology for Children). STC, or NTA (Naturvetenskap och Teknik för Alla) as it is called in Sweden, consists of several units in science and technology, for example, air, light and water. During the lessons, the students perform different hands-on activities by using physical artefacts. Teachers receive so-called NTA-boxes from the municipalities with teacher guides, worksheets and the equipment needed to perform the activities (NTA, 2017).

Every lesson concerned a new hands-on activity related to electricity in various ways. The teacher initiated the lessons by asking the students to summarise what they had done during the previous lesson. She continued by presenting the content of the current lesson. During the hands-on activities, the students worked in groups of two to four members. Before actually conducting the hands-on activity, the students had to make a prediction concerning the investigation. The teacher asked the students to make a prediction on their own, present and discuss it with their group-members and then agree on a joint prediction. Afterwards, the activity was carried out practically and the students talked about the results both with their group members and in whole-class. In addition, they wrote a lab-report. At the beginning of the project, the students had difficulties writing on their own. Hence, the teacher asked the students about the different steps of the hands-on activities, wrote the students' answers on the whiteboard and then asked the students to copy the text into their notebooks.

Since the teacher was monolingual and the students were bilingual in different languages, whole-class instruction and all other communication with the teacher was conducted in Swedish. During the hands-on activities, the students in focus worked together and had the possibility to use their whole language repertoire as a resource. Data were collected through *nonparticipant observations*, implying that I did not interact with the teacher and the students during the lessons (Bryman, 2016). To facilitate a correct interpretation of the observations, they were complemented with field notes. In total, eight science lessons were observed during a period of six weeks, which resulted in approximately 20 hours of audio- and video recordings.

Data Collection 2

The class consisted of 16 students 13- 14 years old (7th grade). Eleven of them were born and raised in Sweden and five students had lived in the country for less than five years. All students were bilingual in Turkish and

Swedish. The teacher was bilingual in Swedish and Bosnian. According to the teacher, all students were emergent bilinguals. This was later confirmed by the data collected and is described in the study findings. The science content during data collection was acids and bases. The lessons were conducted predominately in whole-class by following the chemistry textbook. The teacher began the lessons by asking the students to summarise the previous lessons and then continued by introducing one or two new sections in the chemistry textbook. If there was time left, the students worked with the study questions in the chemistry textbook. Some students worked together while others preferred to answer the questions on their own. Since the teacher did not speak Turkish, whole-class instruction and all other communication with the teacher was carried out monolingually in Swedish. Turkish was used as a mediating means among the students, however. The students spoke Turkish to each other during the whole-class instruction and when answering the study questions.

Data were collected by classroom observations and interviews with the students. As in the first study, my role during the observations was *nonparticipant*, implying that I did not interact with the teacher and the students (Bryman, 2016). The observations were complemented with field notes. The unit consisted of seven lessons and was conducted over a period of one month. It resulted in about 20 hours of audio- and video recordings. The interviews with the students took place after the observations, that is, when the unit about acids and bases had finished. The students were divided into groups of three to four members. First, they were interviewed about their language use during science lessons. The interviews were *unstructured* as there were no predetermined questions (Bryman, 2016). I asked the students to tell how they used Swedish and Turkish during the science lessons and then followed up with questions depending on their answers. Second, the students were asked to describe and explain chemical concepts and processes that had been part of the observed lessons, for example, acid, base, concentrated solution and the electrostatic forces between different atoms and ions. These interviews were *semi-structured* as there were more predetermined questions. I also followed up with further questions to make the students to tell more. For instance, when the students were un-agreed about the meaning of different phenomena and processes, they were asked to discuss their ideas with each other. Sometimes they agreed on one answer, sometimes they did not. In total, five group interviews at 1,5 - 2 hours per interview were conducted and resulted in approximately 10 hours of video recordings.

Data Documentation

In total, approximately 50 hours of data were collected (Data collection 1 and 2). For the observations, both audio and video recordings were used. The video cameras enabled documentation of nonverbal communication and identification of students. Sometimes, in particular during group activities, the students talked simultaneously with each other. It was then not always possible to hear what they said in the video recordings. Using audio recorders made it possible to gain better sound quality. The number of video cameras and audio recorders differed depending on how the students were placed. 2-3 cameras were used in both classes; one camera was directed at the teacher and 1-2 cameras were directed to the students. The audio recorders were placed on the students' tables. Every cluster of one to four students had a recorder on their table. In addition, also the teachers wore audio recorders. As mentioned earlier, to facilitate the correct interpretation of the data collection, I was present in the classroom during the observations and made field notes. The group interviews with the students were conducted in a separate room. One video camera was hence sufficient.

Data Generation and Analysis

The recordings were fully transcribed. Nonverbal actions were described in brackets. In some situations, the students used both of their languages and to make a distinction Swedish was written with no emphasis and Turkish with bold letters. Translations into English are in some papers written in italics.

The analysis was influenced by Erickson (2012) and consisted of three steps. Since the transcription involved information not relevant to this study, it was initially not regarded as data, but as resources for potential data. The first step of the analysis was hence *finding the data* (Erickson, 2012). In some situations, the students communicated about topics not relevant for this study. For instance, they talked about a movie or what to do after school. Thus, *students' use of their languages, gestures and physical artefacts related to the science content* were identified and marked as data. A new analysis was made for every paper since they were guided by different research-questions. For example, Paper 1 implied searching and categorising data to show how the students' used their languages and which consequences their language use had for their meaning-making in science. In Paper 3, another mediating means was in focus: gestures. Here, finding data implied identifying situations in which gestures were used in the process of learning science.

The second step was *finding assertions* by asking what the observations and/or interviews, categorised as data, were showing in relation to the research questions. The data were read and an initial analysis about what it *possibly* could show was made by writing assertions. The third step, *searching data sources for evidence*, implied examining the data in order to find evidence confirming or disconfirming the assertions made in the previous step. Erickson (2012) highlights that this step of the analysis needs to be carried out carefully and deeply to ensure that important data are not disregarded. I read the data several times and made an initial categorisation by drawing on the assertions made in the second step. The categorisation was then checked by my supervisors (also co-authors for the papers) and jointly adjusted until an agreement was reached.

During the second step of the analysis for Paper 1, one assertion made was that the students' language limitations differed depending on the character of the conversations. The third step thus implied that the students' language limitations during different kinds of conversations were counted and compared to each other. Furthermore, to answer the first research question in Paper 3 concerning how emergent bilingual students use gestures in science class, students' use of gestures was identified, counted and categorised by using the typology presented under the theoretical framework (Kendon, 1980; 1996). The initial analysis showed the students used gestures in two different situations. First, gestures were used in a 'general sense' and second, when their language repertoire limited their possibilities to express themselves. In turn, the last-mentioned gestures included two different scenarios. First, gestures were used when the students were unable to tell the name of certain phenomena or describe a process by using words. Second, the students used words, but not the correct ones. They sometimes then showed the correct phenomena or process by using gestures. What both situations had in common was that the students' used gestures *when their language repertoire limited their possibilities to express themselves*. These gestures have been categorised as *bridging gestures*. Lastly, to answer the second research question in Paper 3, the consequences of the bridging gestures were identified and counted.

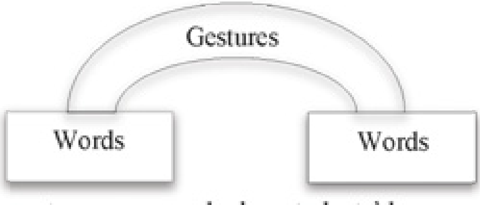

Figure 1: Bridging gestures were used when students' language repertoire limited their possibilities to express themselves.

Methodological Considerations

Data are collected in two classes and by a convenience sample (Saumure & Given, 2008). It is difficult to compare the findings of this study to others in order to examine similarities. Few studies have investigated language use in classes where students do not share the same minority language as all of their classmates and teachers. In addition, most of the studies concerning emergent bilingual students in science class have focused on language, and other mediating means, such as gestures and physical artefacts, have so far received little attention (Zhang, 2016). Based on this, the generalisability of the study findings is limited (Bryman, 2016). The validity of the study is considered to be high (Bryman, 2016). Observations of authentic classroom situations, occasionally complemented with student-interviews and the amount of data achieved, made it possible to conduct a detailed and profound analysis of emergent bilingual students' use of different mediating means. Yet, the study findings might have been influenced by my presence in the classroom and the recorders.

When the data were analysed for Paper 1, it was not always possible to determine if the students' limitations were caused by their language repertoire or something else. Hence, only situations where it was *explicitly observable* that language proficiency limited students' possibilities to express themselves were included in the counting. Accordingly, the number of situations where students' language repertoire limited their possibilities to express themselves might be higher than those presented. In Paper 3, a framework was used to determine when a gesture starts and ends (Kendon, 1980, 1996). Nevertheless, it was occasionally difficult to determine if hand movements were the continuation of an ongoing gesture or the beginning of a new one. A similar difficulty occurred when categorising the gestures, depending on gesture type. In particular, it was sometimes unclear if the gesture in question was used spontaneously and without actual content (beats) or if it illustrated a phenomena/process (iconic/metaphorical gesture) (McNeil, 1992). When these ambiguities occurred, the gesture in question was discussed with my supervisors (also co-authors in the papers) and adjusted until an agreement was reached. Moreover, it was sometimes not possible to determine whether or not a gesture was a bridging gesture. A gesture was categorised as bridging only when it was *overtly observable* that some words were not part of the students' language repertoire. Accordingly, the number of bridging gestures might be higher than those presented in the study findings. Even though it is important to mention these limitations, they rarely occurred. Hence it is reasonable to assume that their influence on the categorisation is negligible.

Ethical Considerations

The data have been collected by following the ethical considerations stated by the Swedish Research Council (2011). In order to fulfil the *information requirement*, the principals, teachers and students were informed about the purpose of the study and that the data collections would be documented by audio and video recordings. In addition, since the students were younger than 15 years old, their parents needed to be informed and approve the study as well. The *requirement of consent* implies that participants have the right to terminate their participation at any time. The teachers and the students were informed about this. The parents were told that they could regret their approval. All parties received a written agreement signed by one of my supervisors and me. They also signed a form themselves to approve participation. As stated in the *confidentiality requirement,* only I and my supervisors will have access to the data collection and the participants are guaranteed anonymity in the presentations of the study findings. The recordings are restricted to my supervisors and me and the findings are/will be published in research articles and this doctoral thesis, which means that the *requirement of restricted use* are achieved (The Swedish Research Council, 2011).

6 Results

Language, gestures and physical artefacts were often entwined and used together during the lessons. To make a deep and profound analysis, they have been examined respectively in the four papers. Paper 1 and Paper 2 are about language use, Paper 3 is about gestures and Paper 4 about physical artefacts. In the following, the findings of each paper are described and then summarised by being related to each other.

Paper 1: Language Use in a Multilingual Class: A Study of the Relation Between Bilingual Students' Languages and Their Meaning-making in Science

The data from the 3rd grade were used for this paper (Data collection 1). The students' language use depended on the context in which the conversations took place. During whole-class instruction, the students' translanguaging possibilities were limited. The teacher was monolingual in Swedish, and there were several minority languages represented in the class. Hence, whole-class instruction and all other conversation with the teacher was carried out in Swedish. Two different ways of conducting conversations were observable: *IRE* and *longer conversations*, for example, argumentations and generalisations. When conversations characterised by an IRE-pattern and longer conversations were compared to each other, a general pattern was observable. During the eight observed lessons (20 hours), 103 conversations with an IRE pattern and 12 longer conversations took place between the teacher and the students in whole class. In 96.1% of the conversations with an IRE-pattern, the students' meaning-making proceeded without any visible language limitations. However, when the students made a longer utterance, the result was different. In 83.3 % of the longer conversations the students' language repertoire limited their possibilities to participate and make meaning of the activities.

One example of a situation involving a longer conversation and language limitations took place during a lesson about closed electrical circuits. The teacher gave each group a worksheet with pictures showing different connections. In some pictures, a battery, a bulb and a wire was connected to each other in a closed electrical circuit; in others, the opposite prevailed. The students connected the equipment as shown on the worksheet and noted whether or not the bulb lighted up. Afterwards, the teacher asked the students to summarise the hands-on activity. The conversation began with an IRE-pattern, but it changed character when it was revealed that the students' results differed from each other. Some students said that the bulb did light up when the equipment was connected as shown on a certain picture on the worksheet, while others claimed the opposite. The class started to *discuss* their differing results. In doing so, they *argued*, *explained* and *generalised*. The four students in focus had succeeded in getting the bulb to light up, and one of them had an idea about why some of some other groups' efforts did not work. He argued that they might have connected the wire incorrectly to the socket of the bulb. However, when he should explain this, the word 'socket' was not part of his language repertoire in Swedish, and his explanation did not stand fast between him and the teacher. It was not until the brought him a bulb and asked him to show what he meant that the activity could proceed.

The students participated in longer conversations during the hands-on activities as well. Then, they had access to two other mediating means besides Swedish; physical artefacts, and their minority when talking to each other. For instance, during one lesson the students connected an open electrical circuit but did not agree on how the connection was supposed to be made. Hence, they *described* and partly *argued* for their ideas. In doing so, they spoke both their languages and used the physical artefacts to show what they meant. In 90% of the conversations during the hands-on activities, the students' conversations continued without any visible language limitations. In comparison, that number during whole-class instruction was 16.7%. In 10% of the conversations during group-work activities, language limitations were observable as the teacher used words unfamiliar to the students. For example, one lesson aimed at learning that metals conduct electricity while some other materials do not. The students were asked to connect different objects to an open electrical circuit and observe whether or not the bulb would light up. Nevertheless, the names of several objects did not stand fast in the encounters between the students. As a result, figuring out the names of the objects became the main focus of the activity at the expense of the science content.

Paper 2: Science Education in a Bilingual Class: Problematising a Translational Practice

In Paper 2, the teacher's and the students' ways of construing continuity between everyday and scientific language was examined by analysing the data from the 7th grade (Data collection 2). Language limitations were also observable in this class. The teacher used everyday language and concrete examples from everyday life when describing and explaining the science content. The same pattern was also apparent in the chemistry textbook. However, the students' proficiency in Swedish limited their possibilities to understand the examples. This was observable as the students frequently asked questions about the meaning of the everyday words used. Since the teacher did not speak Turkish as the students, it was not possible for him to translate the words the students were asking about. Hence, he explained what words meant in Swedish and illustrated them by using other mediating means, for instance, drawings. For example, the science content during one lesson was strong bases. The teacher construed a relation to everyday life and explained that sodium hydroxide can be used to clean drains that are placed under sinks. However, the meaning of the word 'sink' did not stand fast in the encounter, and the students had difficulties in making sense of the teacher's example.

A strategy used among the students to understand unfamiliar words was translating into Turkish. Accordingly, the students construed relations between everyday and scientific language in Swedish and Turkish. The students did not have access to dictionaries and had to make the translations by asking each other. In some situations, the meaning of the Swedish word in question did not stand fast to the student asked. As a consequence, although the word was part of the students' language repertoire in Turkish, a translation was not always possible. In some situations, this implied that the students were not able to make meaning of the science content. For instance, during the lesson about strong bases, another mentioned base was calcium hydroxide. The teacher told the students that the base was used in limewater to counteract acidifications in nature. The word 'lime' in Swedish was not part of several students' language repertoire and prevented them from making meaning of the teacher's example. The teacher explained the meaning of the word, but some of the students still had difficulties in understanding what the word meant. As a consequence, two students intended to translate the word into Turkish, but since neither of them knew what the word meant in Swedish, a translation was not possible. The word in question, 'lime', continued to be used in the forthcoming activities during the lesson and the students had difficulties in making meaning of these activities as well. The next day and during a lesson about another scientific topic, one of the students told her classmate that she had translated the word ‘lime’ into Turkish. The student had somehow found out what the Turkish word was after the lesson. It was shown that the word was part of both students’ language repertoire in Turkish, but the absence of dictionaries during the lessons made it impossible for the students to construe a relation.

The students occasionally also made incorrect translations. This was observable especially when the students translated scientific concepts from Swedish to Turkish. The incorrect translations resulted in the students’ descriptions of phenomena and processes not being line with proper science. To exemplify, the scientific concept ‘solution’ was translated into Turkish as solving problems. Moreover, the teacher allowed the students to help each other by translating unfamiliar words into Turkish during the lessons. However, they were not allowed to make any translations during written exams. Since the teacher did not speak Turkish, he could not determine if the students were helping each other or cheating. Sometimes unfamiliar everyday words implied that the students could not make sense of the exam-questions.

Paper 3: Gesticulating Science: Emergent Bilingual Students Use of Gestures

For Paper 3, classroom observations from both classes were used (Data collection 1 and 2). The students used gestures to communicate about the science content in two different situations. First, gestures were used in a ‘general sense’, meaning no language limitations were observable. Second, the students used gestures when their language repertoire limited their possibilities to express themselves, these were categorised as *bridging gestures*. The four students observed in the 3rd grade used gestures 73 times when they communicated with the teacher and 284 times when they communicated with each other. In total, 20 of these gestures were categorised as bridging gestures. In the 7th grade, the 16 students observed used gestures 195 times when they communicated with the teacher and 336 times when they communicated with peers. The number of bridging gestures was 11. In both classes, all analysed types of gestures, that is, *beats*, *iconic*, *metaphorical* and *deictic gestures*, were used.

Three consequences of the bridging gestures were observed. First, when a student used a bridging gesture, their classmates drew on it to communicate about the science content. In some situations, the students used the same gestures as their peers; in others, they used only language. An example of the last-mentioned scenario took place during a lesson in the 3rd grade. The teacher asked the students about how people who do not have access to electricity prepare their food. A student intended to answer the question by describing how to make up a fire. The Swedish word for ‘firewood’ was not a part of her language repertoire, and she used an iconic bridging gesture to illustrate it. Another student then drew on the gesture and told that the word in question was ‘firewood’. Accordingly, when the first student’s language repertoire limited her possibility to express herself about the science content, using a bridging gesture and the interaction with the second student resulted in the continuation of the science activity.

Second, the teachers also drew on the students’ bridging gestures to communicate about the science content. Like the students, the teachers sometimes adopted the gestures in use. In others situations, they only used language. For instance, the teacher in the 7th grade asked the students to describe the electrostatic forces between two positively charged ions in scientific language. A student answered the question by saying that the ions ‘repaired each other’ while simultaneously showing how the ions repelled each other by using a metaphorical bridging gesture. In other words, the student did not use the scientifically correct terminology, but she showed the correct process. The teacher then used the same gesture as the student and told how the process could be described in scientific language.

Third, the meaning of the bridging gestures sometimes did not stand fast in the encounters and needed to negotiated. A student in the 3rd grade, for example, told the teacher about one of her earlier experiences concerning electricity. She had observed that blue flame can appear when wires are put in wall outlets. The word ‘wall outlet’ was not part of her language repertoire, and she pointed at one to continue with her utterance. Since she sat a couple of meters away from the wall outlet, she was not pointing directly at it. The teacher needed to asked her about what she was pointing at. When the meaning of the deictic bridging gesture eventually stood fast in the encounter, the teacher introduced how the process could be expressed in scientific language.

A general consequence for all three situations mentioned above, was that bridging gestures resulted in the continuation of the science activities. When students’ proficiency in the language of instruction limited their possibilities to express themselves, using gestures enabled them to show what they meant. The teachers then drew on the students’ bridging gestures and introduced how the phenomena and processes gesticulated could be expressed in everyday and scientific language. This resulted in the students learning how to talk science. Gestures were legitimate mediating means among the teachers and the students during the science lessons, and they offered the students an alternative way to communicate. Occasionally, though, using gestures was not enough to fill the gaps and other mediating means, for example drawings, were needed. For instance, during a lesson in the 7th grade, the teacher gave an example of how calcium hydroxide is used in mortar. The meaning of the word 'mortar' did not stand fast in the encounter between the teacher and the students. A student intended to explain the word to her classmate by using a gesture. She made a square with her hands, but the meaning of the gesture did not stand fast either. The teacher drew bricks walls on the white-board to show how mortar was used, which resulted in the students understanding the meaning of the word.

Paper 4: Jumping Pepper and Electrons in the Shoe: Physical Artefacts in a Multilingual Science Class

The last study concerned how teachers can use physical artefacts to support emergent bilingual students' learning in science. Since the lessons in the 3rd grade involved hands-on activities, data from this class were used (Data collection 1). The study findings showed that the physical artefacts supported the students' learning in two different ways. First in a 'general sense', implying that even though there were no language limitations observable, using physical artefacts implied a certain way of introducing scientific language. They made it possible for the students to experience the science content by actually observing and talking about it in everyday language. The teacher then drew on students' experiences of performing the hands-on activities to teach how the phenomena and processes in question were expressed in scientific language. For example, one lesson aimed at learning about static electricity. The students were asked to rub a ruler against their hair and clothes and then hold it above a paper with black pepper on it. The students experienced how the rubbing caused static electricity and resulted in the black pepper sticking on the ruler. Afterwards, the teacher asked the students to summarise the results of the activity without having the physical artefacts at hand. The students described their experience in everyday language by saying that the pepper 'jumped', 'stuck to the ruler' and 'flew'. The teacher then drew on these utterances and explained how the process could be described in scientific language. She introduced the concepts 'static electricity', 'electrons' and 'shock'. The physical artefacts constituted the origin of the conversations. Even if they were not always present, they implied that the student gained a joint concrete experience, which the teacher could then draw on to teach science.

Second, when the meaning of words did not stand fast in the encounters and limited the students' possibilities to make meaning, using physical artefacts enabled the students to understand these words. This will be exemplified by occasions from a lesson about closed electrical circuits. The students received a worksheet with pictures of a bulb, a battery and a wire connected in different ways. This is the same lesson as the one used previously to exemplify students' language limitations during longer conversations (Paper 1). In this particular activity, the students were asked to discuss whether or not the bulb would light up when the equipment was connected as shown in the pictures and then write 'on' or 'off' above each picture. However, these words were not part of one student's language repertoire and hence limited her possibilities to make sense of the science activity. As a result, the student copied her classmates' answers. Later on, when the students conducted the hands-on activity the student experienced the words being used together with the physical artefacts. For example, she observed the bulb not lighting up, simultaneously as her classmate said 'wrong' in Turkish and wrote 'off' under the picture. The use of physical artefacts in combination with everyday language in Swedish and Turkish resulted in the student learning the meaning of the words. This in turn enabled her to actively participate in the science activities.

The common pattern, both when physical artefacts were used in a 'general sense' and when the students' language repertoire limited their possibilities to make sense of the science content, was that the teacher construed relations between students' experiences of using physical artefacts and the scientific language. Hence, the development of scientific knowledge and language proficiency were simultaneous and intertwined. The purpose of Paper 4 was contributing to knowledge about how teachers can use physical artefacts to *support* emergent bilingual students' learning in science. However, the study also displayed a constraint. In the example with static electricity referred to above, a student was unable to cause static electricity when performing the activity. She observed her group-members succeeding and participated when the activity was summarised in whole-class, but the fact that she was not able to cause static electricity herself caused frustration. In addition, as mentioned when describing the findings of Paper 1, it was occasionally the name of the physical artefacts that were unfamiliar to the students.

Summary

In both classes, the whole-class conversations were conducted in Swedish, meaning that the students' translanguaging possibilities were limited. Since the students were emergent bilinguals, they had to make meaning of the science content in a language that they were still developing. This had consequences for their learning in science (Papers 1-4). In the 3rd grade, whole-class conversations characterised by an IRE-pattern generally proceeded without language limitations. However, when the students participated in longer conversations, requiring them to use language in a more advanced way, their language limitations increased (Paper 1). In the 7th grade, the teacher intended to support the students' understanding of science content by construing relations to everyday language. Nevertheless, the meaning of some of the words he used did not stand fast in the encounters, and the students' possibilities to make sense of the science content became limited. The students used different strategies to overcome language limitations. They translated words to their minority language (Paper 2) and used bridging gestures by, for instance, pointing out physical artefacts whose names were unfamiliar (Papers 1 and 3). The use of bridging gestures in general resulted in the continuation of the lessons as both other students and teachers drew on the used gestures to talk about the science content. During group-activities, the students used both their languages to make sense of the science content (papers 1 and 2). In the 3rd grade, the students also had access to physical artefacts, which resulted in a decrease in their language limitations (Paper 1). The physical artefacts implied that the students experienced the science content by actually seeing it, which the teacher then drew on to introduce how the phenomena or process in question could be expressed in scientific language. Additionally, when the meaning of some words did not stand fast, using physical artefacts enabled the students to experience these words being related to the science content and thereby learn the meaning of them. This in turn enabled the students to make meaning of the science content (Paper 4).

7 Discussion and Implications

Bilingualism - A Problem or a Resource?

Research has shifted from viewing bilingualism as a problem to regarding it as a resource. This is an important development. The idea of bilingualism as a problem among researchers implied investigating what bilingual students were *not* capable of because of *their* language difficulties. Typically, the investigations did not go any further. The question of how to support bilingual students were often disregarded since the 'problem' was the students' language difficulties and not how the teachers conducted their lessons. In line with this, scholars questioned if the students could even be regarded as *bi*linguals. After all, they did not have a fully developed proficiency in the language of instruction (see e.g. García. 2009 for an overview).

Viewing bilingualism as a resource has resulted in studies about what bilingual students *can achieve*. For example, bilingual students' progress in science class when they have the opportunity to speak their minority language has been addressed in several studies (e.g. Goldberg, et al., 2009; Msimanga & Lelliott, 2014; Reyes, 2009). However, the shift from viewing bilingualism as a problem to a recourse have also resulted in the fact that few studies, both in general and in science education, have concerned emergent bilingual students' language limitations. The findings of this thesis disaffirms with this either-or situation. In both classes observed, the students' proficiency in the language of instruction limited their possibilities to express themselves and make meaning of the science content (Papers 1-4). This was also confirmed by the students themselves during the interviews (Paper 2). Furthermore, reports from different parts of the world show that emergent bilingual students'achievements in science continue to differ negatively from the ones of their monolingual peers. One of the reasons for this gap is language proficiency (Buxton & Lee, 2014; The Swedish National Agency for Education, 2008). Accordingly, even if bilingualism per definition, that is, the regular use of two (or more) languages (Grosjean, 1985), is not a problem in itself, bilingual students *might* have language limitations that influence their learning and achievements.

In order to create equity in science class, educators need to discern how language proficiency limits emergent bilingual students. This is not enough, however; we also need to take a step further and consider different strategies to support emergent bilingual students' learning. In doing so, the idea of bilingualism as a resource needs to be kept in mind. Being bilingual is not a problem, but some *contextual aspects* might limit bilingual students' learning. The question is then how science teachers can create educational contexts promoting emergent bilingual students' learning in science. This is what this thesis is about (Papers 1-4).

Bilingual Science Education

Research has shown how *bilingual science education*, that is, making use of students' both languages in science class, enhances learning. This is an important finding, especially since emergent bilingual students in general achieve lower than their monolingual peers (Buxton & Lee, 2014). Still, education for bilingual students is typically conducted monolingually in the majority language (García, 2009). Sweden is certainly not an expectation (The Swedish National Agency for Education, 2008). Nevertheless, bilingual science education is easier to accomplish in some geographic areas than in others. For instance, there are about 150 languages spoken in Sweden, and it is not uncommon that several of them are represented in the same class (The Swedish National Agency for Education, 2016a). As educators in countries where students do not share the same minority language as all of their classmates and teachers, we need to make a choice. We can either argue that bilingual science education does not fit the contextual aspects in our classes and ignore it, or we can investigate how bilingual science education can be conducted despite the mentioned contextual aspects. I think that it is obvious that this thesis is based on the second alternative. However, as demonstrated (Papers 1-4), it is also important to remember that our possibilities to conduct bilingual science education is limited in comparison to classes where teachers and students share the same minority language.

Whole-class instruction in the majority language

When teachers and students do not share the same minority language, whole-class instruction *primarily* in the majority language is reasonable as it is the only language all participants speak, at least to some extent. The findings of this thesis do not contradict this. However, I do here want to draw attention to two main findings. First, the fact that teachers and students do not share the same minority language does not mean that students' minority languages need to be abandoned completely. Second, there are some constraints with monolingual whole-class instruction that educators need to keep in mind. Monolingual whole-class instruction means that bilingual students can only use a limited part of their language repertoire. If the students are not yet fluent in this language, the occurrence of language limitations is not unexpected. Consequently, not just scientific language, but also everyday language used during whole-class instruction, becomes demanding for emergent bilingual students. Even though teachers concretise the science content by using everyday language, as suggested by scholars (Lemke, 1990; Osborne & Wellington 2001), emergent bilingual students' proficiency in the language of instruction might limit their possibilities to make meaning of what is said (Papers 1-4).

Students certainly do not merely listen to the teachers during whole-class instruction; they make some utterances themselves. Here, a general pattern was observable in this study. When the conversations were characterised by an IRE-pattern (Bellack, et al., 1966), the students answered the teacher's questions mostly without language limitations (Paper 1). This is not unexpected; the conversations did not require advanced language mastery since the teachers' questions could be answered with simple and short phrases. However, conversations conducted by following an IRE-pattern implies a reproduction of factual knowledge, which is insufficient to develop a deeper understanding of science. Students need to be engaged in more advanced conversations, such as discussions, explanations and generalisations (Lemke, 1990). This is where whole-class instruction strictly in the majority language becomes problematic. Longer conversations require a language mastery on a certain level, which many emergent bilingual students lack. As a result, the students' meaning-making possibilities in science can be limited because of their proficiency in the majority language (Paper 1). The questions are then: Is it possible for emergent bilingual students to engage in longer conversations in their minority language even though they do not share the same minority language with all of their classmates and teachers? If yes, what are the consequences of the students' language use for their learning in science?

Using minority language

The questions above are still relatively unanswered. Studies about bilingual science education are predominantly conducted in classes where the teachers and students speak the same languages (e.g. Goldberg, et al., 2009; Salleh et al., 2007; Reyes, 2009). Hence, there is a need for further studies that examine different ways of conducting bilingual science education in classes where the students and teachers do not share the same minority language. The findings of this thesis are contributive in this sense. First, it has shown that bilingual science education is possible even if all students and teachers do not speak the same languages. Second, *one* approach to conduct bilingual science education has been examined and proposed: Letting bilingual students with the same minority language interact in different ways (Papers 1 and 2). Before discussing this approach further, it should be added that it is not applicable to all science classes as it requires at least two students to speak the same minority language.

The students observed interacted by using their minority language in two different ways. They spoke Turkish to each other simultaneous to the whole-class instruction and during group-work activities (Papers 1 and 2). For instance, the students in the 7th grade commented what the teacher had said, made further explanations or asked questions to each other in Turkish. Another way was translating words from Swedish to Turkish. During the interviews, the students told that this helped them to understand the science content. However, the classroom observations showed that asking other classmates to translate unfamiliar words did not always work out. Sometimes the word in question was not a part of the classmate's language repertoire either, and a translation was not possible (Paper 2). Hence, there is a need for further strategies enabling emergent bilingual students to make use of their minority language to make translations. I argue that bilingual dictionaries might be helpful in this sense. Although this is a relatively easy way to support emergent bilingual students' learning in science, the students did not have access to dictionaries in either of the classes (Data collection 1 and 2).

Bilingual dictionaries can also be supportive during written exams. During the interviews, the students told that they sometimes did not understand what the questions in the exams meant. Nevertheless, they were not allowed to translate words to each other. Since the teacher did not speak the same minority language as the students, he could not determine if they were helping each other or cheating. Although using dictionaries would have enabled the students to translate words without cheating, this was not the case. As a result, language limitations sometimes obstructed the students from expressing scientific knowledge and hence influenced their achievements in science (Paper 2). Bilingual dictionaries would, of course, not solve all language limitations. For instance, unfamiliar words in the majority language might not be part of students' minority language either. In addition, the students not only translated words to each other by speaking Turkish, they also explained them, which is not possible to achieve with dictionaries (Paper 2). Still, it is reasonable to assume that dictionaries would have helped the students to overcome language limitations to some extent.

Occasionally, the students made incorrect translations. In some situations, this implied that the students' descriptions of phenomena and processes were not in line with science proper. The teacher could not verify or disaffirm the translations since he did not speak the same minority language as the students (Paper 2). Is it then a supportive strategy to allow students to translate words for each other? Perhaps bilingual dictionaries are enough and students should not be allowed to make translations at all? Even if we disregard that translations among the students generally supports their learning in science for a moment (Paper 2), there are other circumstances that speak against a prohibition. The incorrect translations observable in this thesis are not exclusive for bilingual students. The fact that some words means different things in everyday and scientific language is confusing for all students, regardless if they are monolingual or bilingual (Lemke, 1990; Wellington & Osborne, 2001). When the students occasionally made incorrect translations, they construed relations between scientific language in Swedish and everyday language in Turkish. For instance, the scientific concept 'solution' was translated as the everyday word 'solution' in Turkish. The word in question is a homonym in Swedish, hence the students could have interpreted the word incorrectly by using only Swedish as well. Scholars suggest that teachers make the meaning of scientific concepts explicit for students by talking about the concepts (Lemke, 1990; Wellington & Osborne, 2001). This strategy can be used in classes with emergent bilingual students as well. Talking about the meaning of the scientific concepts would reasonably increase students' possibilities to understand them and simultaneously prevent incorrect translations. The students' incorrect translations were observable during the interviews when they were asked to talk about the concepts. The incorrect translation of the scientific concept 'solution' resulted in the students claiming that scientific solutions were aimed at solving problems. If the teacher would have asked the students to describe the concept in Swedish, it is reasonable that they would have made a similar description, which would have given the teacher the possibility to correct the students (Paper 2). Even if it is possible that bilingual students might also make incorrect translations of everyday words, this never occurred in this particular study (Papers 1-4).

Furthermore, translanguaging is a natural part of bilingual students' lives. Indeed, using our *whole* language repertoire is how we communicate and make meaning regardless if we are monolingual or bilingual (García, 2009).

The interviews with the students revealed that the students also translated words for each other in situations when they were not allowed to do so (Paper 2). Hence, a prohibition does not seem to be the solution. Instead, the question science teachers need to ask is how they can decrease the risk of making incorrect translations. Based on empirical findings, I have made some suggestions above: using bilingual dictionaries and talking about the meaning of scientific concepts. Nevertheless, since bilingual science education in classes where the students and teachers do not share the same minority language is a relatively uninvestigated area, further research is needed.

Another way of enabling bilingual students to use their minority languages is allowing students who are bilingual in the same languages to work together during group activities. In the 7th grade, all students were bilingual in Turkish and could use their minority language with all of their classmates (Data collection 2). In the 3rd grade, several minority languages were represented in the class. Hence, students with the same minority language were asked to worked together during the hands-on activities (Data collection 1). A comparison between the longer conversations that involved the entire class and those conducted during the group-activities revealed a general pattern. Language limitations occurred more or less during group-activities (Paper 1), but this cannot be interpreted only as a result of students' possibility to speak their minority language. There were several other differences between the conversations. During whole-class instruction, the students in general listened to what was said and answered the teachers' questions. When the students were engaged in group-work activities, they were the ones directing the conversations by interacting with each other. Furthermore, the group-activities involved another mediating means: physical artefacts (Paper 1). The study findings of this thesis have shown that not only minority language, but also the use of physical artefacts, support emergent bilingual students' learning in science (Paper 4). Hence, the decrease in language limitations during group-work activities is a combination of these mentioned aspects, and not only of students' possibility to use their minority language.

The conversations during group activities were conducted predominantly in everyday language in Turkish and Swedish. Occasionally, the students used scientific terms, but these were mostly in Swedish (Papers 1 and 2). The scientific language gained more space during whole-class instruction (Papers 1-4). Hence, one could by drawing on the absence of scientific language in Turkish argue that conversations in the minority language represent a lack of scientific meaning-making. Based on the findings of this study and earlier research, I claim that this would be a misinterpretation of this study. The conversations in everyday Turkish represents students' ways of making meaning of the science content (Papers 1 and 2) Studies have shown that students' everyday reasoning is important for further scientific meaning-making (Lemke, 1990; Wellington & Osborne, 2001). Accordingly, teachers need to construe relations between group-work activities in which bilingual students' minority language gains space and whole-class instruction conducted in a scientific majority language. In this way, students' own experiences can be made continuous with the language of science (see Dewey 1925/1997; Wickman, 2006).

To summarise, conducting bilingual science lessons is more demanding in classes where the teachers and students do not speak the same minority language. At the same time, the findings of this study are coherent with earlier studies showing that emergent bilingual students' minority language is an important resource for their learning in science (Papers 1 and 2, Goldberg et al. 2009; Reyes 2009; Warren et al. 2001). This study contributes to new findings by showing that it is possible to include bilingual students' minority language in science class even though all students and teachers are not bilingual in the same language. It suggests one approach to accomplish this: letting students bilingual in the same minority language work together. The study findings do not end here. The deep and profound analysis also displays the consequences of this approach, including both benefits and constraints (Papers 1 and 2). Nevertheless, science class is a multimodal enterprise, involving other mediating means alongside language (Kress, et al., 2001). In the forthcoming section, I discuss how gestures and physical artefacts can be used in science classes with emergent bilingual students.

Broadening the Scope- Using Other Mediating Means

Bilingual science education is possible in classes where teachers and students do not speak the same minority languages, and it supports students' learning (Papers 1 and 2). However, the possibility to conduct bilingual science education in these class compositions is limited in comparison to classes where all students and teachers are bilingual in the same language. The fact that bilingual students might not yet be fluent in the language of instruction and at the same have time limited possibilities to use their minority language calls for a consideration of other resources *besides language*, for example, gestures, pictures and physical artefacts (Hammond & Gibbons, 2005). The findings of this thesis contribute knowledge about how gestures (Paper 3) and physical artefacts (Paper 4) can be used in classes with emergent bilingual students.

In some situations, such as during whole-class, the students' proficiency in the language of instruction limited their possibilities to express themselves. Since the teacher did not speak the same minority language as they did, they could not use Turkish either. In such cases, bridging gestures and physical artefacts enabled the students to show what they meant. The students illustrated different scientific phenomena and processes, such as the electrostatic forces between two positively charges ions, by using bridging gestures (Paper 3). In some situations, the students used bridging deictic gestures and pointed out physical artefacts whose names were unfamiliar to them. Accordingly, the use of gestures and physical artefacts, alongside language, is continuous with learning science (Papers 1, 3 and 4). Based on these study findings, I argue that there is a need for an increased *attention* to and *appreciation* of *all* mediating means emergent bilingual students use to express scientific knowledge. This concerns both researchers and teachers. So far, research about emergent bilingual students' learning has focused on language, and other mediating means have been overlooked (Zhang, 2016). Hence, the findings of this thesis address a research gap in this sense (Papers 3 and 4). When it comes to teachers, the findings of this thesis can hopefully make them pay more attention to how their students use other mediating means alongside language to express scientific knowledge. The teachers observed set examples on how this can be accomplished. Both of them accepted gestures as legitimate mediating means in their science classes. For example, a student described the electrostatic forces between positively charged ions by saying that the ions 'repaired' each other. Instead of dismissing the student's answer as incorrect, the teacher observed that she actually was illustrating the correct answer by a bridging gesture. So, he used the same gesture as the student and introduced how the electrostatic forces between positively charged ions is expressed in scientific language (Paper 3).

Furthermore, teachers also need to *actively create* learning contexts, giving emergent bilingual students the opportunity to use other mediating means beside language. One way of doing this is *encouraging* the students to use bridging gestures and physical artefacts. For instance, during a hands-on activity in the 3rd grade, the students ended up with different results. When a student should explain what he thought was the reason for this, one of the needed words, 'socket' was not part his language repertoire. As a consequence, his explanation was not understandable to the teacher. Here the teacher could have told him that she did not understand what he meant and continued with another student. However, she did not. Instead, she brought him another mediating means: a physical artefact. She asked him to point to a bulb and show what he meant. Accordingly, the student was encouraged to use deictic bridging gestures. The student explained his idea by pointing to the socket of the bulb, which made it understandable to the teacher and resulted in the continuation of the science activity (Paper 1).

The example above with the word 'socket', together with similar ones, was what gave birth to Paper 4. All lessons in the 3rd grade were conducted by using physical artefacts, and since Paper 1 had indicated that this supported the students' meaning making, a deeper analysis of the physical artefacts was made. It was shown that the teacher instead of starting her lessons in scientific language, began by letting the students experience the science content by using physical artefacts. Static electricity was, for instance, described as 'jumping pepper' or 'pepper sticking to a ruler'. Talking about the science content in this way was legitimate in the teacher's class. She did not dismiss or correct the students' ways of expressing themselves. Rather, she even confirmed them by saying that it actually looked like the 'pepper jumped' (Paper 4).

The use of physical artefacts also resulted in the students learning new words and overcoming language limitations. Here, everyday words like 'on' and 'off' might seem unrelated to learning science. However, these words were part of the lessons and understanding their meaning was hence necessary to make meaning of the science content (Paper 4). The fact that unfamiliar everyday words might limit or even obstruct bilingual students' meaning-making and achievements has also been addressed in Paper 2. Paper 4 examines how physical artefacts can support students in overcoming these language limitations. In particular, the physical artefacts in use made it possible for the students to experience the unfamiliar words being related to the science content. Eventually, this resulted in the students understanding the meaning of them and to actively participate in the activities, which in turn lead to scientific learning.

All mediating means might have some constraints. For instance, using their minority language implied that the students made incorrect translations of scientific concepts (Paper 2). Bridging gestures were not always enough to overcome language limitations, and other mediating means such as drawings were sometimes needed (Paper 3). Similarly, using physical artefacts also had some limitations (Paper 4). For instance, the students were occasionally unable to perform the hands-on activities as intended (Paper 4) and had difficulty naming the physical artefacts in use (Paper 1). The choice of focusing on how physical artefacts support bilingual students' learning in science class in Paper 4 does not imply that these limitations are disregarded. However, the benefits or constraints with physical artefacts, as with all other mediating means, are not a result of their existence per se but rather a consequence of how they are *used* in a specific context (Jakobson & Wickman, 2008; Wertsch, 1993; Wittgenstein, 1953/1967). For instance, the names of the physical artefacts in use were occasionally unfamiliar to the students in the 3rd grade. However, the artefacts in question, for example, tee peg, cooper wire and wire nail, are not what 9-10 old students typically encounter in their everyday life, regardless linguistic background. Considering that the students in this study were emergent bilinguals, the physical artefacts could have been replaced with other objects. A pencil made of wood could, for example, have been used instead of a tee peg (Paper 1). Accordingly, instead of asking whether or not different mediating means support emergent bilingual students' learning, we need to ask how teachers can *use* them in their science class to promote learning.

Construing Relations to the Language of Science

The purpose of thesis is to contribute findings about how different mediating means, in particular students' minority language (Papers 1-2), gestures (Paper 3) and physical artefacts (Paper 4), can be used to support emergent bilingual students' learning in science class. However, it should also be remembered that science lessons aim at learning how different phenomena and processes are expressed in scientific language (Lemke, 1990). The question is then if and how emergent students' own ways of expressing themselves, for example, by using everyday language in Turkish and bridging gestures, can be related to the language of science. This study contributes to the field by showing that this is possible and demonstrates how it can be accomplished. For instance, illustrating an electrical shock with a bridging gesture (Paper 3) or observing static electricity as 'jumping pepper' by using physical artefacts (Paper 4) was not enough. The teacher drew on the students' ways of expressing themselves and construed relations to the scientific language (Papers 1-4). However, it was different with students' minority language. In both classes, the students used everyday language in Turkish to make sense of the science lessons, but whole-class instruction was conducted in Swedish. Scientific terms were used mostly during whole-class instruction, whereas students' minority language was given room in the group activities. Meaning-making occurred in both whole-class instruction and group work, but language use in the different forms of instruction became disconnected (Papers 1 and 2). This is a dilemma since emergent bilingual students' minority language has an important role in learning science (Paper 1 and 2; Buxton & Lee, 2014). Accordingly, there is a need for further research about how teachers can make students' minority language continuous with the language of science.

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