

**HETEROGENEITY – CHALLENGE AND/OR OPPORTUNITY
IN SCIENCE EDUCATION?**

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ABSTRACT

The following paper focuses on a field of science research which has not yet been thoroughly researched in many countries: mixed languages in the science classroom. This area represents terra incognita in many areas of science education research. First, this paper will define the term heterogeneity and contrast it with the term diversity. According to the literature, one word stands for challenges, while the other highlights the opportunities arising from heterogeneity in science classrooms. The focus here will be on students' linguistic heterogeneity in science. The main part of this paper discusses a collaborative research and development project carried out by in-service science teachers, teachers of German as a Second Language (GSL), and science educators. The project was developed under the framework of Participatory Action Research in science education. It focuses on the development of teaching modules for early lower secondary science (grades 5 to 7, ages 10-13) on different topics, including matter and its properties and water. The teaching modules consequently implement learning content and language as envisioned in the Content and Language Integrated Learning (CLIL) approach. After focusing on linguistic heterogeneity and various means for dealing with it, the question of whether such heterogeneity in science classes represents a challenge and/or an opportunity will be raised and discussed.

KEY WORDS

Heterogeneity; Language; Challenges; Opportunities.



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Heterogeneity – Challenge and/or Opportunity in Science Education?

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INTRODUCTION

There is currently a high level of migration from one country to another due to worldwide economic changes («globalization»). Populations in many countries are therefore becoming increasingly diluted and heterogeneous in the ethnic, linguistic and cultural sense. These changes are noticeable in school settings around the world, since classroom heterogeneity is also on the rise. In many countries like the US and Germany, is this effect not a new one. For example, Germany has served as the crossroads of Europe for centuries and has also seen large ethnic changes in its population since the end of the Second World War. These changes have influenced the research occurring in both general and science education. However, since science education research in the US has a long tradition, this field has also affected German research efforts, especially since the publication of such international comparative studies as PISA and TIMMS. Factors covering the changes in school populations have also become much more obvious since PISA and TIMMS were published (Lynch, 2001).

There are many differences in research carried out in this field in different countries. Independent of global location, however, the special research focus almost always tends to delve into students' linguistic skills in the official language(s) of a given country. But the question remains, whether



such studies are actually comparable or not. Are the results really transferable between different countries, school systems and pupils? We can use the US and Germany as an example: 1) The English and German languages are widely different, despite their common ancestry. 2) The school systems in both countries differ broadly in their sizes, amounts of resources, school laws, curricula, educational foci, organization, etc. 3) The chances for successful entry into and learning success within such systems for students with migration backgrounds vary widely at the State and national levels. 4) The ethnic, cultural, economic, educational, etc. backgrounds of both foreigners and second- or third-generation citizens are not comparable. The US currently has large numbers of Latin and South Americans, however, immigrant groups include people from all around the world. Germany has mainly Turkish, Arabic, Polish and Russian minorities with smaller numbers from Greece, Italy and Spain. 5) The «degree» of migration differs. In the US pupils tend to be mainly from either newly-arrived or refugee families. In Germany students were to a large extent born in Germany, but have parents who immigrated coming from another country.

With all of the above differences and varying national reactions to increasing diversity, the main question should be whether such heterogeneity is something that should be viewed as a burden or rather be perceived as an opportunity when it comes to science education. Furthermore, we must also recognize that the terms used to describe such differences vary widely and are not universal in their application.

This paper presents a project by the University of Bremen in which in-service science teachers and science researchers have taken up the challenge of linguistically heterogeneous classes and used it as an opportunity for continuous professional development.

CLARIFICATION OF THE TERMS

In the research literature for science education, two terms dominate the discussion dealing with varying student requirements for successful learning: *heterogeneity* and *diversity*. The choice of the definition often depends both on the research tradition in the country where the study originates and the overall context of the study. However, the terms are used as separate constructs, which frequently overlap and then become synonyms. Studies performed in

English-speaking countries mainly use the term «diversity». As mentioned above, this field of research has a longer tradition than research efforts in Germany. The National Education Association (NEA) defines diversity

(...) as the sum of the ways that people are both alike and different. The dimensions of diversity include race, ethnicity, gender, sexual orientation, language, culture, religion, mental and physical ability, class, and immigration status. While diversity itself is not a value-laden term, the way that people react to diversity is driven by values, attitudes, beliefs, and so on. Full acceptance of diversity is a major principle of social justice (<http://diversity.dpsk12.org/definitions>).

Since educational research in this field in Germany is not that old, the terms heterogeneity and diversity are often understood to be synonyms of each other. Many different perspectives can be labelled as «heterogeneity» and «diversity». However, differences in understanding these two terms and the paradigms hidden behind them are slowly beginning to emerge in Germany's educational world. School systems are also being influenced by the decision to move schools more firmly in the direction of «inclusion». «Whereas the paradigm of heterogeneity perceives difference as a challenge to be dealt with actively, diversity as a systemic paradigm perceives difference as an asset» and a resource for learning (Sliwka, 2010, p. 213, Figure 1).

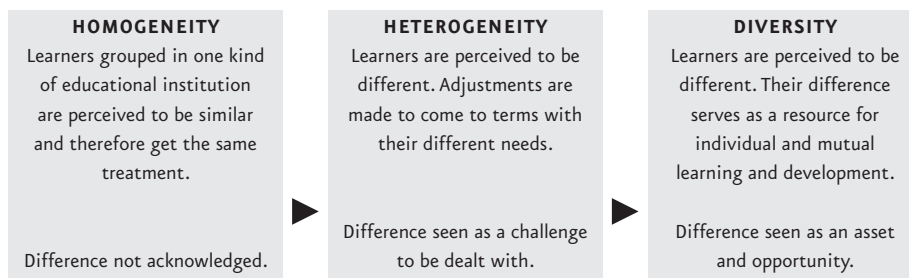


FIGURE 1 – PARADIGM SHIFT FROM HOMOGENEITY TO HETEROGENEITY TO DIVERSITY (SLIWKA, 2010, P. 214).

Looking at the possible differences which students in the classroom may bring with them, we quickly recognize a broad spectrum. Students possess many different, often highly individual prerequisites in the classroom and an ideal

teacher is supposed cope with each and every one. These differences are multifarious among the student body, but they also overlap in many areas. In the American literature these differences are summarized in eight main dimensions which are represented as «The Big Eight». Krell, Riedmüller, Sieben and Vinz (2007) listed the following eight dimensions as important: age, gender, ethnicity, religion, race, sexual orientation, functional role, and mental/physical ability. Another representation commonly employed is the diversity wheel, which is mostly used for diversity management in large organizations. It distinguishes between internal and external dimensions (see Figure 2).

The different dimensions of diversity and the concepts presented by Sliwka (2010) give us one possible starting point. We might suggest that since we are concerned with the language and science classes, we should positively focus on linguistic heterogeneity instead of linguistic diversity. Language in the science classroom represents much more of a challenge than is commonly perceived, since science teachers can't use pupils' poor linguistic skills as an asset so that other students can learn more. (This is definitely not true for language classes.) However, other dimensions such as culture can be viewed as opportunities in teaching and learning. They can serve as a resource for the individual while also supporting mutual learning and development processes.



FIGURE 2 – DIVERSITY WHEEL (RETRIEVED JANUARY 1, 2014, FROM [HTTP://WEB.JHU.EDU/DLC/RESOURCES/DIVERSITY _ WHEEL/](http://web.jhu.edu/dlc/resources/diversity_wheel/))

DESCRIPTION OF THE PROJECT

About four years ago, a group of in-service teachers combined with education researchers from the University of Bremen to look at the issue of heterogeneity in the classroom. They used the difficulties faced by students with poor linguistic skills and the subsequent problems confronted by teachers when teaching in linguistically heterogeneous classes as a starting point for their study. The research and development project aims to develop both new teaching methods and learning materials for linguistically sensitive science classes. The effort includes research on the effects of such products on teaching and learning. There are different goals that newly-developed lesson plans that should attain:

1. The lesson plans should develop teaching methods and learning materials for linguistically heterogeneous classes.
2. These lesson plans should help students to develop a linguistic basis for learning and correctly employing scientific language without making linguistic mistakes.
3. The lesson plans should aid teachers in supporting communication between students by helping pupils express themselves in both proper German and scientific language terminology, for example, «mass» instead of «weight».
4. The new lesson approach and learning materials developed should combine both content and language using Content and Language Integrated Learning (CLIL) along with cooperative and autonomous learning.

From this initial starting point the main research question emerges:

To what extent it is possible to simultaneously learn scientific methods, terminology, content matter and the German language as the students work in a cooperative, autonomous learning environment?

This project is based on the Participatory Action Research (PAR) method of science education (Figure 3) (Eilks & Ralle, 2002). PAR is a joint effort between teachers and science educators for curriculum development, educational research, and classroom innovation. This allows different competencies to meld together into new developments of teaching practices.



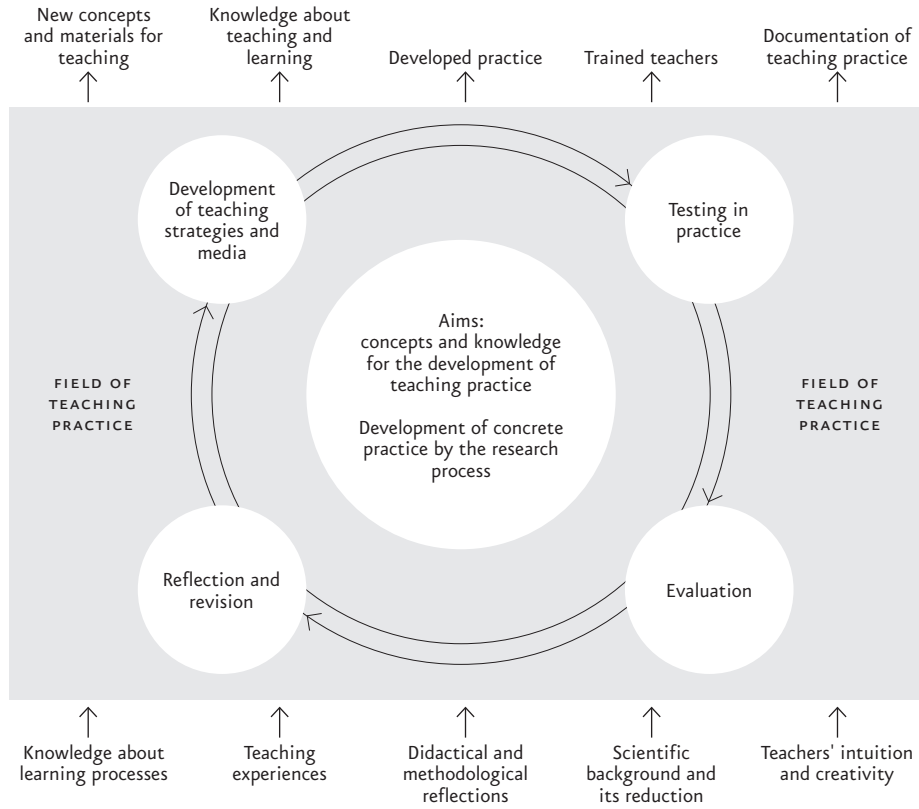


FIGURE 3 – PAR IN SCIENCE EDUCATION

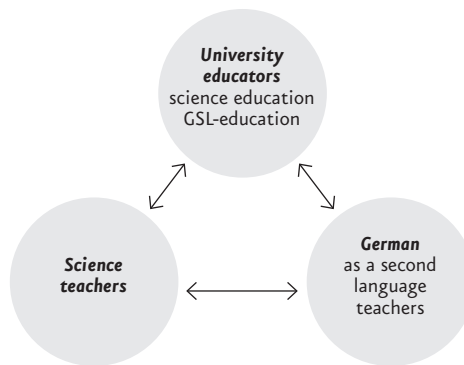


FIGURE 4 – PAR GROUP IN THE PRESENT PROJECT

Time	Activity
May 2010	analysis of relevant literature; collecting ideas for methods and experiments; first provisional structuring
End of June 2010 (Meeting of the group)	presentation of the provisional lesson plan; negotiating and restructuring the first part of the lesson plan; collecting ideas for structuring the second half
July to August 2010	revising the lesson plan
September to October 2010	testing of the lesson plan in two learning groups; observation of the lessons by one university researcher and teacher self-reflection after each lesson
Mid of November 2010 (Meeting of the group)	reflection on first experiences with the whole group of teachers; negotiating the test and students questionnaires
November to December 2010	testing occurs in another learning group; test and student questionnaires
Mid of December 2010 (Meeting of the group)	reflection in the whole group
January to June 2010	testing in another three learning groups occurs; test and student questionnaires

TABLE I – DEVELOPMENT AND EVALUATION

This paper describes the results of a group of eight Chemistry teachers and three German as Second Language (GSL) teachers from different schools, who collaborated with a university researcher (Figure 4). The group meets regularly every four to five weeks and has been developing lesson plans concerning CLIL for roughly four years. At the group meetings, changes in teaching practices are proposed, negotiated, and refined so that the resulting structures can be tested and applied in classroom situations before being reflected upon and improved.

Up to now six different lesson plans have been developed using this model. The development and evaluation of two lesson plans called «Matter and Its Properties» and «Water» will be presented in this paper as examples. Table I offers an overview of the development and evaluation process for the lesson plan «Matter and Its Properties».

Multidimensional triangulation was performed to arrive at an answer to our research question. All of the groups that implemented the lesson plans were continuously accompanied by and observed by university researchers, who were actively developing the lesson plan. Furthermore, after each lesson a self-reflection exercise (an interview by an observer from the university) was completed by the teachers and recorded. These experiences were regularly discussed by the entire PAR group. Finally, students were asked to write a short text based on their personal knowledge. This exercise was developed



by the teacher group, based on the teachers' own experiences and knowledge. Additionally, a student feedback tool was collected, which combined an open and a Likert questionnaire.

LESSON PLAN EXAMPLES

MATTER AND ITS PROPERTIES

The lesson plan «Matter and its Properties» occurs in two phases: (I) experimentation and (II) exchange. In the first phase students are divided into two groups: chemists and physicists. Both groups must work at stations and conduct experiments on the properties of matter. The chemists focus on the chemical properties of matter and the physicists concentrate on physical properties. Both groups are structured around a research folder containing helpful materials. The folder is very similar in both cases. The first page lists all of the materials needed to carry out the experiments. As a language aid, German vocabulary and definitions are provided in the appendix, including pictures of the laboratory equipment with the definite (der/die/das) and indefinite (einer/eine/ein) articles for German masculine, feminine and neuter nouns in both the singular and plural forms. This is important, since many German words undergo both spelling and pronunciation changes and/or receive new word endings in the plural form. Every worksheet begins with a sentence describing the aim of that particular station. Linguistic aids are offered for topics which the teachers in the group viewed as necessary.

In the second phase, the original groups from the first phase are mixed to form new groups. In this phase, two chemists and two physicists must work together. Their job is to exchange the relevant knowledge which they individually discovered in their original role. They must also work cooperatively to fill in an exercise book covering both topics.

The entire lesson plan is also supported by laminated «Help Cards» (different levels) and «Solution Cards», both of which are available on the teacher's desk in case students reach an impasse.

WATER

This lesson plan is also divided into experimentation and exchange parts. In the first phase students must work on a research folder which has been



constructed to cover the different properties of water. Similar to the previous lesson, the first page lists all the materials needed to carry out the experiments. German vocabulary and definitions are also provided, as well as the definite and indefinite articles for German masculine, feminine and neuter nouns in both the singular and plural forms. Students must work in groups of two in the learning at stations method. Every station is based on a single experiment and contains exercises on the station topic. However, each exercise aims at both repeating and building upon knowledge, while simultaneously improving students' German language proficiency. This is why every exercise includes a short problem requiring practice in the German language. The experiments are mainly presented as a drawings or a sequence of pictures. To acquire the necessary skills in writing a protocol, pupils are aided by «Help Cards» at nearly every station. This allows students to actively decide whether or not they need help and what learning level the help should take place.

In the second phase of the lesson plan, content matter from chemistry and biology is combined. Students must work on their research folders again, but now the method consists of «think – pair – share». First, students are required work on the characteristics of four different animals. Information concerning important details for each animal is provided. The information is specifically based on the properties of water, e.g. water striders using water's surface tension to keep themselves afloat. After working out the details, the learners must work on exercises inquiring into the characteristics of the different animals, and then combine this knowledge with the information on the properties of water. These exercises are strongly linked to exercises in the German language. In this phase students can rely on the «Solution Cards» that are offered. It is important that the learners know that they can receive aid, but that they are not forced to do so.

Different methods borrowed from German as a Second Language lessons were employed in the lesson plans. From the vast available repertoire some examples are (see for more in Markic, Broggy & Childs, 2013):

- Simple phrasing (1-sentence constructions);
- List of Vocabulary (with article, plural);
- Words for helping to write observations and discussions;
- Beginnings of sentences provided;
- Connecting the parts of sentences;



- Example sentences as thought provokers;
- Drawings as explanations instead of words;
- Cloze-sentences.

SAMPLE

The testing and evaluation phases were carried out using six learning groups (grade 5; age range 10-11) with a total of 119 students for «Matter and Its Properties». The lesson plan «Water» was tested in four classes (grade 5; age range 10-11) in different schools in the city-state of Bremen, Germany. All of the schools who took part in the study are located in the suburbs of Bremen. This is significant, since the residents in these areas tend to have both a lower than average educational background and social class and generally include a large percentage of people with migration backgrounds. Table 2 presents some of the characteristics taken from the sample.

Table 2 makes it clear that many students come predominantly from migration backgrounds and that a very high percentage of students do not speak the German language at home. Unfortunately, further information about students with a German background cannot be given. Some information about the pupils' competency in the German language could be provided by the science teachers in cooperation with their German language colleagues. The German students taking part in our study generally show poor German language proficiency, particularly when it comes to expressing their own knowledge in writing and creating proper sentences. They tend to come from families with low levels of education.

Characteristic		Matter and its properties (N=119)	Water (N=93)
Sex	Female	72 (60.5%)	35 (38%)
	Male	47 (39.5%)	58 (62%)
Students with a migration background		67 (56.8%)	63 (67%)
German not spoken as the home language		45 (37.8%)	56 (60%)

TABLE 2 – SAMPLE CHARACTERISTICS



RESULTS

The final knowledge test was pre-structured by the teachers according to their personal teaching experiences. Scoring was based on the pre-structured pattern for evaluating the test. The majority of students passed the test successfully, thereby achieving scores higher than 50% of the total available points. A high percentage of all student groups had scores of «good» or «very good». A total of 84% of the participants achieved more than 80% of the total points possible. Such achievement was considered to be a quite remarkable factor by the teachers.

When starting to develop the lesson plans, the teachers were very reluctant to use autonomous teaching strategies for students with language shortfalls. The teachers also expressed considerable fears about leaving pupils alone in a cooperative learning environment, particularly because of the linguistic issues faced by many students. This was not merely due to the specific scientific topics, but also because their learners would simultaneously have to deal with difficulties arising from their deficient German language skills. Nevertheless, the teachers were open to experimentation when it came to applying the scheme. After teaching and reflecting upon the lessons, the teachers' attitudes towards teaching linguistically heterogeneous classes in cooperative, autonomous lessons changed quite considerably. They were happy with the end-product, with the openness of the lessons, and with the overall motivation of their students. This reaction consistently fits in with the feedback given by the students. The learners judged the lessons to be remarkably good, especially concerning aspects such as: help in verbalizing of their own ideas and knowledge, the autonomy of learning, and structured cooperation and communication. In particular, they mentioned that the materials had helped them to better understand the topic both by themselves and within their peer-group. During the lesson plan it was easy to observe that students were proud of themselves and of their own work. They also agreed that their ability to express their own ideas and results in proper German had grown commensurately.

During the development process of the lesson plans, it was easy to observe how the teachers directly influenced the learning process. They considered the potential difficulties which they would encounter in the overall approach and suggested appropriate corrective changes. Furthermore, the differing competencies and experiences combined by teachers of science and GSL dur-



ing the process complemented one another. The teachers did not focus solely on developing materials which increased the students' scientific knowledge. Instead, they allowed the researchers to sufficiently address and undergird additional factors. These included the simultaneous enhancement of the learners' German and scientific language skills while the pupils were actively engaged in assimilating specific, scientific content knowledge. More details about the studies are to be found in Markic (2011, 2012).

CONCLUSIONS AND IMPLICATIONS

Although the knowledge test in the present study is limited in its scope in terms of judging long-term learning effects, the short-term results provided a good baseline for measuring whether students can understand topics on their own. Students' comprehension of topics includes their ability to express themselves more easily and correctly in the German language. The initial data seems very promising for implementation of further lesson plans and units which combine the learning of scientific knowledge, German language skills and cooperative learning methods.

Despite the process of collaborative development being new for both teachers and students, each group dealt with it in an autonomous fashion, aided by the newly-created teaching materials and aids. This also held true for the aspects focusing on teaching the German language and the teaching methods selected. The students were able to cooperatively manage the lesson plan, despite initial doubts expressed by some of the teachers. The expectations of the teachers, which had been recorded in a pre-structured test, were exceeded by the pupils, most of whom achieved unexpectedly positive cognitive results.

Cooperative efforts between science and GSL teachers appear to provide attractive possibilities for developing new teaching materials which support linguistic heterogeneity in Chemistry lessons. Researchers also had a chance to exchange their personal experiences with linguistic difficulties, their knowledge of their students, and any pertinent interdisciplinary information, including methodologies. Furthermore, cooperation between experts stemming from multiple disciplines offers a promising path for creating motivating, highly attractive learning environments. This can bolster science teachers as they attempt to aid their students in simultaneously mastering both scientific content knowledge and German language skills.

After summing up the ideas above, our question still remains: If heterogeneity is viewed solely as an overwhelming challenge for science education, can we ever move forward from the negatively-focused paradigm surrounding such a viewpoint? This becomes especially relevant in light of the fact that classroom heterogeneity will only become more pronounced in a globalizing world, whether we recognize the problem or not, whether we like it or not, and whether we adequately address the issue or not. In Germany, for example, one person in five is either a foreigner or is a German national from a family with a migration background. This fact will not simply go away. The modern cultural and linguistic complexity in our schools will continue to increase, regardless of which country you live in.

The above question is also of paramount importance, because the general goal of education in many countries has been shifting increasingly towards «inclusion», which starts from the idea of diversity. Inclusion programs add such factors as physical, emotional and mental disability, often severe psychological and behavioural problems, general learning difficulties such as dyslexia, ADD, etc. to the mix. These factors will further combine with background linguistic issues to make the teaching and learning landscape in our schools even more complex and un navigable.

It is our belief that heterogeneity should not be ignored as a possible challenge to current teaching methods and practices. However, such heterogeneity can also serve as an opportunity and a catalyst to spur on educational decisions and more effective classroom practices for the future. The project described here shows that it is possible to view linguistic heterogeneity as a negative challenge, if the definition in the opening paragraphs is selected. However, the project also reveals that linguistic heterogeneity in science classes can also serve as a door of opportunity in different ways. First of all, poor linguistic skills can help science teachers to redefine the aim of their science lessons and to rethink their teaching materials. Furthermore, it offers science teachers an opportunity to reflect on their own teaching behaviour when it comes to teaching in a language-sensitive manner. This is very important for most teachers, since they (especially in the German context) tend to be mainly monolingual. Different studies have focused on this point. In her study, Moore (2007) interviewed three teachers. She came to the conclusion that the teachers she interviewed were sensitive to the influence of language on students' language. However, this was the case because interviewees were all Native Americans who had experienced exactly the same thing during



their own time at school. The teachers in Moore's study see language as a barrier for students to learn and understand science. Studies from Cho and Mc Donough (2009) also support this. However, the science teachers in their study were specially trained to teach English Language Learners (ELL).

The project also shows that the issues addressed by linguistic heterogeneity in the science classroom can (or to put it more provocatively *should*) be seen as an opportunity to «look past our own noses» and see what is happening in other teaching domains like linguistic science. The tools and methods which are used in the above-mentioned lesson plans are not new for GSL teachers, but they do represent largely uncharted territory for science teachers. This paper shows that cooperation between science and language teaching provides us with an opportunity to see what is happening in other teaching domains and to adapt this knowledge for our own classrooms (compare also Verplaetse, 1998).

Finally, this project also reveals that dealing with linguistic heterogeneity in science classrooms can be an opportunity for continuous professional development (CPD). As Mamlok-Naaman and Eilks (2012) have shown, the Participatory Action Research method is good for promoting continuous professional development. The current study presented here supports this idea and shows that collaboration between teaching colleagues is a good way for science teachers to develop more sensitivity to their students' poor linguistic skills, while simultaneously developing their own competencies for dealing with this issue in their classes. On the other hand, the exchange cuts both ways. This is also an opportunity for GSL teachers to gain insights into science lessons and to use this knowledge in language lessons by focusing on the language of science.

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