European Journal of Science and Mathematics Education, 2023, **11**(2), 197-214
ISSN: 2301-251X (Online)
OPEN ACCESS
Research Article

Subject-language perspectives on multilingual students learning in science

Anders Jakobsson [1,2*]
0000-0003-1438-3607

Maria Kouns [1]
0000-0002-6630-9209

[1] Malmö University, Malmö, SWEDEN
[2] Inland Norway University of Applied Sciences, Hamar, NORWAY
[*] Corresponding author: anders.jakobsson@mau.se

Citation: Jakobsson, A., & Kouns, M. (2023). Subject-language perspectives on multilingual students learning in science. *European Journal of Science and Mathematics Education, 11*(2), 197-214. https://doi.org/10.30935/scimath/12568

ARTICLE INFO

Received: 31 Mar 2022
Accepted: 15 Oct 2022

ABSTRACT

In this study, we have explored the ways in which small-group work in science can contribute to strengthen multilingual students' subject language and conceptual development when working with language-oriented classroom activities in primary classrooms. The aim is to determine whether it is possible to identify factors in interactions in small-group work that strengthen and facilitate the students' language development. We have focused on how students orally formulate themselves when describing observations, hypotheses, and explanations of certain scientific experiments on the properties of air. An important starting point has been that students' successive development of a subject-specific language is crucial for their conceptual development and understanding. The analyses of the dialogues have made it possible to study how individual students gradually develop their way of expressing themselves by taking over others' expressions and word choices and making their own. The analysis also shows that these dialogical situations are crucial for all students to develop their language use in science, primarily through probing a more precise way of expressing themselves and putting their scientific ideas and thoughts into words. An important conclusion is that students should be offered opportunities and space to develop their subject language register in science and that this is important for all students, but crucial for those for whom the language of instruction is a second language.

Keywords: subject language, multilingual students, small-group interactions in science education

INTRODUCTION

In recent years, a relatively large number of research studies in science education have focused on the significance of students developing a subject-specific language in order to improve and strengthen their learning (e.g., Hernandez Garcia & Schleppegrell, 2021; Schleppegrell, 2016). Thus, the subject language perspectives have increasingly come into focus, both in terms of teaching strategies and in terms of understanding students' learning processes. However, when discussing subject language perspectives on teaching and learning in science, several different aspects may be emphasized. For example, such a perspective may imply a focus on the semantic patterns (e.g., Lemke, 1990, 2001) that teachers and students assume when constructing scientific sentences or the particular linguistic or lexicogrammatically structure (e.g., Fang, 2005, 2006) that participants use when engage in negotiations about the meaning of a concept. However, the construction of meaning takes place not only through verbal and linguistic resources, but also through images, graphs, diagrams, or other semiotic and multimodal representations (e.g., Kress & van Leeuwen, 2006), which also constitutes an important aspect of subject language perspectives in science. Furthermore, a number of studies (e.g., Gee, 2015) have emphasized the need to understand science education from the perspective that it constitutes a specific discourse in which specialized ways of talking, thinking, and acting often establish an apparent contrast to everyday language use and ways to communicate outside of school (Nygård Larsson & Jakobsson, 2020).

All of these aspects are interrelated and interwoven in teaching contexts, which may contribute to the fact that a relatively large proportion of students around the world experience science as difficult, abstract, incomprehensible, or as an area that is not for them (e.g., Banks & Banks, 2019; Osborne et al., 2003; Van Horne & Bell, 2017). Other studies have shown that this may be especially true for multilingual students or second-language learners who are faced with the dual task of learning a new language at the same time as they are expected to develop an understanding of concepts and theories in science with the help of this language (e.g., Banks & Banks, 2019; Probyn, 2019). This brings a further dimension of complexity into multilingual science classrooms and places high demands on the teacher's language awareness in teaching. An important issue in this context is what science classroom activities can facilitate and strengthen multilingual students' subject language development, and thus their conceptual understanding.

In a northern European research project, primary teachers participated in a continuing education course focusing on subject-language perspectives, inclusive teaching, and language scaffolding strategies in science teaching in multilingual classrooms. The present article analyses and reports the results of a sub-study in this research project. In the study, we followed multilingual students who were working with specially designed inclusive language-oriented classroom activities that their teachers have developed during their continuing course. As researchers, we focus on students' subject language usage in these situations and analyze what contributes to strengthening their subject language development and their conceptual understanding, and what obstacles may arise in these processes. Thus, the main aim of the study is to examine the students' language use in a process when working with language-oriented activities in science, and to analyze whether it is possible to identify factors in small-group work that strengthen and facilitate their language development.

Language Development Perspectives on Learning Science

Focusing on language perspectives in teaching and learning science is not a new perspective. However, ever since Lemke's (1990) book *"Talking science,"* many studies have explored science education on the basis that it constitutes a communicative and language-oriented activity. In the book, Lemke (1990) emphasized that *talking science* may be understood not only as teaching science being about talking science with the help of a scientific language, but more as "doing science through the medium of language" (p. 9). Since then, a number of research studies have highlighted similar ways of thinking, focusing mainly on teaching situations, where language is regarded more as a meaning-making tool for understanding in learning processes in science education (e.g., Mercer, 2019). A well-known example of this is Mercer and Wegerif's (1999) *explorative talk*, which constitutes situations when students in small-group settings use "social modes of thinking". This implies situations in which they use probing language to be able to formulate hypotheses and reformulate expressions and word choices in a process of developing a conceptual understanding of a specific content. Such a teaching method not only aims to strengthen students' thinking, but also offers opportunities to develop their language use in science.

Since then, several other studies have emphasized the value of this type of dialogical, explorative, and language-oriented learning situation in science education (e.g., Karlsson et al., 2016; Mortimer & Scott, 2003; Seah & Yore, 2017). However, some of these studies have had a one-sided focus on whether this type of teaching situation could have a positive impact on the development of students' conceptual understanding, which risks underestimating the relation between language and conceptual development. In recent years, however, the students' language use and the dialectic relationship (Mercer, 2019; Mercer et al., 2004) between their subject language development and conceptual understanding have become an increasingly central focus in this type of study. Some examples are Scott et al.'s (2011) study about "pedagogical link-making", which concerns how students make connections between ideas and words in ongoing meaning-making interactions of classroom teaching and learning. The idea is that students formulate explicit links between their existing understanding of a concept and the new ideas and words presented in teaching sequences, which are then discussed in small-group interactions. Another example is Haug and Ødegaard (2014), in which teachers implemented a teaching material with a focus on learning science key concepts through the development of *word knowledge*. This concept constitutes a part of a framework that aims to evaluate students' language use during their conversations and is based on the mindset that highly developed understanding of a word also consists of conceptual knowledge. According to the authors, this includes knowledge about how words are situated within a network of other words and ideas.

Further, Alvarez et al. (2022) emphasizes that dialogic, sense-making interactions are critical venues for language development and science learning, particularly for multilingual students. Designing and facilitating such learning opportunities is pedagogically complex work and often requires significant shifts in practice. Therefore, in a design study the researchers created special inquiry-based science units for linguistically diverse classrooms and let primary teachers test the material and observed the outcome. The analyses showed that teachers explicitly stated that students are capable of engaging with inquiry-based science regardless of language proficiency, that science learning and language development was supported through inquiry, and that opportunities for sense-making and discussion in small groups were crucial. Nygård Larsson (2018) acknowledged the students' everyday wordings as explorative meaning-making resources, allowing them to expand their knowledge and semiotic resources. This approach goes beyond a unilateral focus on experimental lab-work or linguistic features and invites the students to explore scientific discourse in a broader sense.

However, developing and acquiring a scientifically functional language is complex and requires careful consideration and an explicit language focus on the part of the teacher. For example, Brown and Spang (2008) noted that the grammatical features, the significance of words, and the typical semantic patterns (Lemke, 1990, 2001) that constitute scientific languages create difficulties for most students. Apart from specific scientific concepts, there are colloquial words and expressions that may have a specific definition and use in science (such as heat, work, force, and energy). Several studies have shown that an implicit use of this kind of words tends to create confusion and conceptual misunderstanding (Fang, 2006; Jakobsson et al., 2009; Nygård Larsson & Jakobsson, 2020; Seah et al., 2011). In addition, several subject-typical words (such as reference, constant, pattern, and factor) may have different meanings or connotations in different scientific disciplines, which further increases complexity (Nygård Larsson & Jakobsson, 2020). However, Halliday and Martin (1993) emphasize that the difficulties of understanding scientific languages exist not only at the word level. Technical and scientific language use goes beyond the use of individual words and defined technical conditions. The scientific words derive their meaning and value from being taxonomically organized, which means that semantic relations become central for understanding scientific ideas and concepts (Lemke, 1990). In this way, technical terms and abstract units are important parts of academic knowledge production, and an essential way of constructing scientific terms and words is to use grammatical metaphors such as nominalizations (such as evolve–evolution and exit–excitation).

Science Education as a Hybrid of Languages

As mentioned, the disciplinary discourse of science education constitutes a special educational situation for students in general, with high demands on their literacy abilities when it comes to speaking, writing, reading, thinking, understanding, and doing science (e.g., Halliday & Martin, 1993; Norris & Phillips, 2003). This implies that science education may be described as a *secondary discourse* (Gee, 1999) that can be seen as a substantive opposite to the everyday discourses most students encounter outside school. In this classroom, meaning in language is situated, but also strongly related to the actual discourse in which the participants use their language within. In this sense, scientific literacy may be defined as the specific ability to participate, understand, communicate, and ultimately master the use of language, concepts, and theories in this discourse. This implies that the language in science education comprises aspects of both fundamental and derived scientific literacy or literacies (Hand et al., 2016; Norris & Phillips, 2003).

When it comes to teaching in science, Yore and Treagust (2006) describe science instruction as a "three-language problem", as students move between home, school, and scientific discourses and are expected to understand that words and expressions have different meanings or connotations in different contexts. According to Gee (1999), this does not imply that words and their meanings are totally separable or mutually exclusive; instead, they are related and interwoven and operate at different levels of students' lives. Thus, language usage in science and science education becomes specific choices of words, grammar, idioms, and metaphors and ways of excluding or including common elements of everyday life. Several researchers argue that in order to successfully create commitment and understanding in science teaching, it is necessary to facilitate the discovery of the relationship between everyday experiences, on one hand, and the subject content, on the other. For example, Tan et al. (2012) assert that teaching language-oriented science includes professional knowledge about how to empower students to connect the science content and language usage with their life outside of school. However, this process can be relatively complex, as the language in these situations tends to move in a continuum between an everyday and a *scientific language register* (Halliday, 2014). This continuum constitutes a *hybrid space* between the two different ways of using language and may be described as an *interlanguage* (Olander & Ingerman, 2011) or a *hybrid language* (Lemke, 2004, Nygård Larsson & Jakobsson, 2020). Brown and Spang (2008) showed that one way of concretizing these theoretical concepts to a practical educational strategy is to use the term *double talk* in order make the process of making every day and academic discourses and language use explicit to students. It will also be a way to clarify to the students when and why it is appropriate and functional to use a scientific language and word choice and when more everyday words are more suitable. Thus, the aim is not really for the students to use a scientific language on every occasion, but rather to create a relationship between different language use and an understanding of when it is relevant and productive to use them.

Second-Language Learners and Science Education

As previously noted, the appropriation of the scientific languages is a long and ongoing process for all students but entails an increased complexity for students who have the language of instruction as their second language (cf. Lee et al., 2019; Oliveira et al., 2019). This implies offering all students rich opportunities to gradually develop a highly specialized subject-specific language in science simultaneously as they develop their language register in different languages. (Hajer & Meestringa, 2014; Kouns, 2014; Schleppegrell, 2016, 2020). From this perspective, students develop language and literacy skills through participation in activities with more knowledgeable “others” (Vygotsky, 1980, 1997) who guide them into more scientific and academic ways of talking, writing, and thinking (Jakobsson & Davidsson, 2012; Säljö, 2010). In this sense, literacy, language, and content learning become intertwined and inseparable. Further, science teachers’ awareness of power relations between national languages in the classroom plays a crucial role since this affects the students’ confidence and motivation (Blackledge & Creese, 2017). However, several studies (e.g., Buxton & Lee, 2014) indicate that that science teachers often display a lack of experience and professional knowledge about how science instruction could be organized to support multilingual students’ needs when it comes to developing their language and conceptual knowledge. An obvious risk is that is that teachers who work in schools with linguistically diverse student populations tend to lower their expectations regarding the students’ skills related to the content of instruction (Van Laere et al., 2014). This can lead to a unilateral alignment on student reading and writing skills, rather than focusing on their knowledge development in science. In these contexts, Hajer and Meestringa (2014) assert that the subject content and the subject-specific language risk becoming too simplified, which further disadvantages this student group. Instead, a language-oriented science education is primarily about making the use of scientific language explicit for the students.

The Classroom Study and Research Questions

As mentioned in the introduction, this study focuses mainly on students’ conversations in multilingual school contexts when working with specially designed language-oriented classroom activities in science. The aim is to examine the students’ language use during the process of working with the language-oriented activities and to analyze whether it is possible to identify factors that strengthen their language and conceptual development during this process. Thus, the research question in this study is, as follows:

What factors in small-group work can contribute to strengthen multilingual students’ language and conceptual development when working with language-oriented classroom activities in science?

THE CONTEXT OF THE NORDFORSK RESEARCH PROJECT

The research project *Inclusive science education–A design study* aimed to explore and to contribute to a development of inclusive science education (ISE) through studying teachers’ classroom work when they were provided with educational tools to test language-oriented approaches and integrate them in their planning. The challenge of creating inclusive science classrooms has been approached from the perspective that

Table 1. Summary of teachers' perceptions of schools' contexts

	School S (city school)	School K (suburb school)
Students with a first language other than the language of instruction	90-99%, e.g., Arabic, Bosnian, Albanian, Somali, & Turkish	15-25%, e.g., Arabic, Danish, Ukrainian, & Bosnian
Newly arrived students	Several	Few
In class study guidance in the students' first language	A few lessons each week (mostly in Arabic)	None
Students' perceived need of language support	70%	10-30%
Description of school	Multilingual students with low socioeconomic family background	Many multilingual students with higher socioeconomic family background

mastering the subject-specific language is crucial for students' participation and thereby to their learning in science. In the research project, the inclusive practices were operationalized as the integration of three influential educational perspectives:

1. using multilingualism as a resource,
2. second-language scaffolding, and
3. interactive discourse science practices.

These constitute a summary and consensus description of important results of educational science research in the field of inclusion and language scaffolding over the past decade (e.g., Cummins, 2021; Gee, 2015; Hajer & Meestringa, 2014; Mercer, 2019; Schleppegrell, 2016). The main ideas in these perspectives were integrated into three different primary science units on "sound", "technology", and "grow plants" by subject experts in different fields and were used as training material for the participating teachers. Twenty-one teachers participated voluntarily in the project, which lasted for one school year and followed a professional development sessions program, at the same time as adapting and further developing the units into their own classrooms and reflecting on their experiences. The teachers came almost exclusively from school districts that had a relatively high proportion of students with an immigrant background and with linguistically heterogeneous classrooms, which means that a range of "national" languages were used in some classrooms. However, the students' use of different national languages and translanguaging in teaching and learning situations has been reported in other studies and is not in focus in the present study (Jakobsson et al., 2022).

The Sub-Study and School Contexts

The empirical material for this sub-study was gathered in grades 4-6 grades (10-12-year-old students) in two public primary schools in an urban area in Southern Sweden. The teachers who teach science at these two schools were also participants in the research project described in the previous section. Both schools serve the local community, one in the central part of the city (S school) and the other one in a suburb area just outside the city limits (K school). S school consists almost exclusively of students who have a mother tongue other than the language of instruction, and there was an influx of newly arrived students during the data collection period. The teachers estimated that more than two-thirds of the students needed language support, which was usually lacking in resources, and they described their students' family backgrounds as being at a relatively low socioeconomic and educational level. The context for the suburban school (K) was somewhat different as there were, on average, only four or five students with a first language other than the instructional language in every class. The teachers estimated that up to one-third of their students required some kind of language support. A summary of the teachers' descriptions of the schools' context can be found in **Table 1**.

Small-Group Language-Oriented Activities in the Science Classrooms

As mentioned, this study aims to investigate the classroom practices in some of the schools participating in the research project entitled *Inclusive science teaching in multilingual classrooms–A design study*. This means that we have investigated how the material that the teachers have provided and further developed works in classroom environments. We have chosen to focus on the activity *meet in the middle* in order to explore how this activity may have an effect on the students' language and conceptual development when jointly discussing

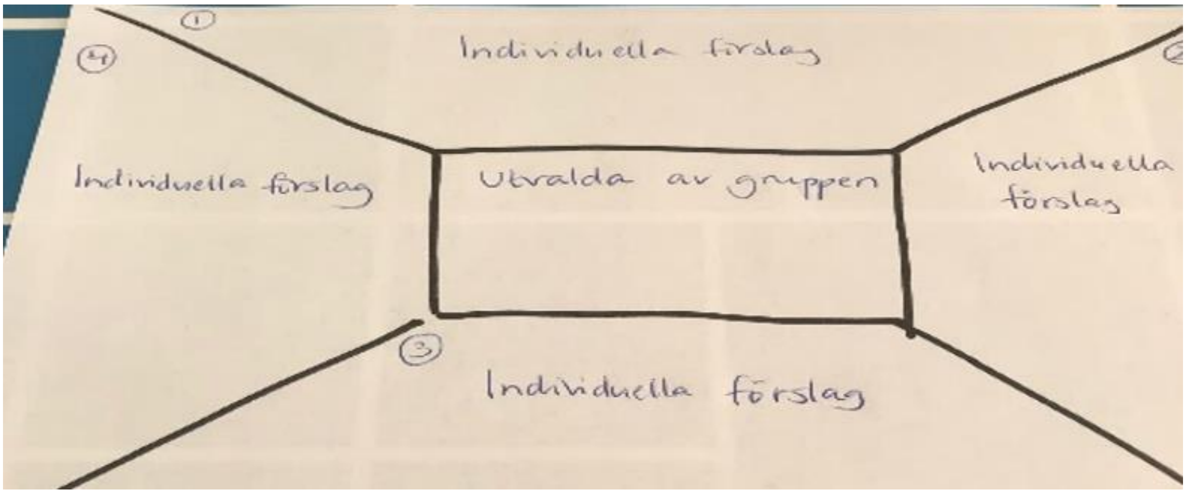

Figure 1. The activity *meet in the middle* aims to structure and scaffold students' language and conceptual development (Source: Authors' own elaboration)

observations and explanations of some experiments. The activity was chosen because it aims to promote all students' participation and inclusion in small-group work, to make their ideas and language use explicit, and to help structure their discussion. This implies organizing the students into groups of four and providing each group with a sheet of paper divided into five areas (**Figure 1**). There is one writing space for each student and one area in the middle where they will later write what they have agreed on as a group. The students have a statement or a question as a starting point; for example, what they observed in the experiments or what conclusions they might draw based on their observations. The final step is to let all the groups present their answers or suggestions and to comment on them in the whole class.

METHODOLOGICAL CONSIDERATIONS, DATA COLLECTION, AND ANALYSES

An important starting point in the method selection and data collection phase is choosing methods that can capture the students' conversations and practical actions during the work with the language-oriented activities (*meet in the middle*). This means that we have striven to capture the authentic interaction and dialogues between the students and the student/teacher interactions as carefully as possible. In these situations, the participants' meaning-making processes, their utterances, hypotheses, and interpretations, together with their written production, have been important focal points in the data collection (Linell, 2009; Solli et al., 2017). In this respect, it is possible to emphasize that the study has received inspiration from a typical ethnographic data collection and research design (e.g., Willis & Trondman, 2002). However, our focus has been primarily related to the research question of what factors may help strengthen multilingual students' language and conceptual development in science during the activities. In order to successfully obtain the best possible quality in the data collection of students' interactions and statements, we have chosen to use two parallel methods: video recording and separate audio recording (Banks & Banks, 2004). The total data material comprises approximately 32 hours of recordings from several video cameras and audio recorders, the researchers' field notes, and photographs of students' written texts and other teaching materials. According to Mondada (2006), this type of data collection and the recordings of everyday situations in classrooms aims to increase the credibility and validly of the analyses of students' language use and to minimize researchers' possible bias and impartiality. The data collection has addressed the ethical considerations and the permissions required to record students in classroom situations (Swedish Research Council, 2011). This means that, before the data collection, we carefully considered the possible risks that may arise in research of students in school environments and applied for the permissions required to document students in classroom situations. The teacher, the students and their parents/ guardians were all informed about the study and about participation being voluntary.

The analytic procedure in the study consists of three separable but interrelated phases. In the first phase of the analysis, all of the data material was carefully reviewed, and content-related situations in which

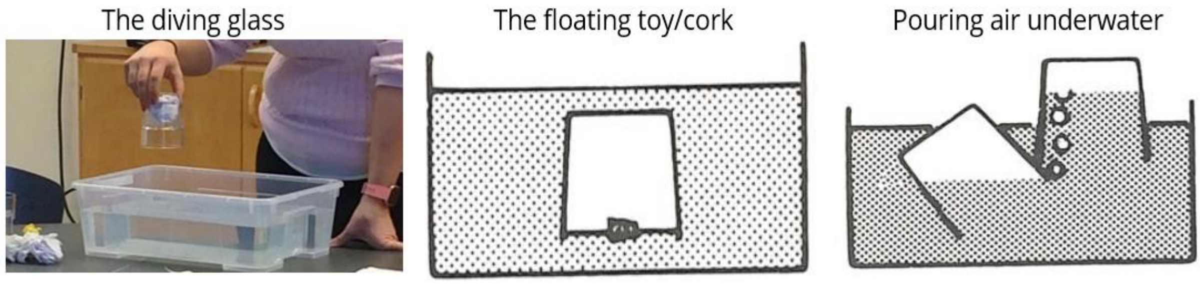

Figure 2. Three experiments (Source: Authors' own elaboration)

students clearly expressed perceptions, hypotheses, interpretations, observations, or explanations of how they understood the experiments were selected (e.g., Jakobsson et al., 2009; Karlsson et al., 2016). This means that, in this phase, we focused on the students' linguistic expressions, their word choices, and the semantic structure of their oral wordings. In this regard, it was especially interesting when some students expressed different hypotheses, made different observations in the experiments, or clearly expressed contrasting explanations. This also applies to situations when the students jointly tried to find common agreement about what they would present to the class. All of this material was carefully transcribed for further analysis. In this part, we identified several thematic patterns (Lemke, 1990, 2001) in students' group discussions, characterized by the semantic relationships, which participants drew upon, followed up through their joint sense-making process, and thereby became observable through participants' use of language. The excerpts presented in the results section are only a few examples of this.

In the second and third phases, we returned to all excerpts in the entire data material in order to follow individuals and their statements in more detail throughout the work theme. Even in these phases, students' meaning-making processes, their utterances, hypotheses, and interpretations were in focus. This gave us the opportunity to analyze changes in how the students expressed themselves and altered their word choices throughout the process. The conclusions from this analysis concern statements related to the experiments "the diving glass" and "the floating toy/cork", which are described later. For example, this could mean that a student would explain "the diving glass" experiment by first expressing that *the air went away* and then later in the process change the word choice to *air take up space*. We describe a similar procedure based on the "pouring air underwater" experiment. Thus, we present individual statements from the total data material at various times during group discussions and aim to describe how some of the students gradually develop and refine their word choice when it comes to explaining the experiments. In the third phase of the analysis, we returned to the transcripts to derive the changes in word choices during the meaning-making processes. These situations are described in more detail in the following section.

RESULTS

The context of the first excerpt is that the teacher demonstrated some experiments with the purpose of showing the students that "air takes up space and consists of matter". The experiment is a pre-exercise in a section on the concept of sound, where students need to understand the properties of air and that air consists of matter where sound can be transported to the ear for us to hear. The exercise consists of three experiments (**Figure 2**):

1. The "diving glass" in which a crumpled paper is attached to the bottom of a glass and then turned upside-down and lowered into the water.
2. A small toy or cork floating on the water surface is pushed under the surface of the water by an upside-down glass.
3. Two upside-down glasses, filled with air and water, respectively, are brought down below the water surface.

The glass with air is then held under the water-filled glass and tilted so that the air is transferred to the water-filled glass. In this way, the air is transferred from one glass to the other. In other words, the air is "poured over" into the other glass.

Reem	What happened to the toy?
T	What did you see? Did you see any difference? Did you see anything different when you pushed the glass down … or?
Reem	It fleet [sic]… a little [inaudible] It was so heavily loaded that the toy… the air went away…
Reem	Ahh … I know what happened. The air went away. Yes, I wrote that.
Sandra	I just wrote that.
Max	Should I write because the air…
Sandra	…you should just write what you saw.
Sandra	Write what you want… Then it proves like, that air takes up space in water. Even in water, then.
Hadi	Like when you push like, the air just then… more and more
Sandra	Imagine how cool it is, and then when you do like this… it's the same thing that happened in the glass to the toy. It was as if there was a bit of air in it.
Hadi	It's like it takes away the water in it.
Sandra	Yes, it just disappears. That's cool.
Hadi	Yes.
Sandra	Yes, but the paper was still in place … So, I'll just write what I saw.

T	Yes, then you get to start with number one. Start telling what you have written. Then number two, three, four. Then you try to come up with something that you want to put in the middle … that you can tell to the whole class. So, get on with it.
Reem	I'll start with number one … When we tested the experiment, there was one thing that happened. We tested to put paper in a cup… Then we put in the water … Then we pickded [sic] it up. It was not wet like it should've been … like I thought it would have been … like the experiment went
T	mm … and then what happened to the duck … the toy?
Reem	Then, experiment two first. Then we put into when we were going to close it in and then we threw it into the water … and it started to float … and when we put the cup in, it stopped floating because air got away … ahh from the water. 09.16

Figure 3. Excerpt A (Reprinted with permission of the participants)

In excerpt A (**Figure 3**), four students and the teacher are involved in a discussion about what happened and how to explain the toy-experiment. Just before the situation in excerpt A, the teacher expressed that the students should first formulate their observations on the experiments individually and later jointly formulate an agreed view on the experiments (*meet in the middle*). The instruction created some confusion as the students expressed uncertainty about what to do and what experiment to describe.

Excerpt A: "What Happened to the Toy?" (School S)

Reem initiates the discussion by formulating the question, what happened to the toy? (1). The teacher has probably noted the uncertainty in the group and tried to get the students work started by asking some scaffolding questions, such as, did you see anything different when you pushed the glass down? (2). By doing so, she focuses the students on writing down their observations and what they noted during the experiments. The teacher's questions stimulate Reem to try to explain the toy experiment by emphasizing that It fleet [sic]… a little … It was so heavily loaded that the toy … (4) to later in the same statement conclude the explanation that the air went away … (4-5). It is unclear what Reem actually means when she points out that it is the air that disappears when the toy is pushed down. However, this view seems to be strong and important for Reem and she returns to this explanation no fewer than three times during this brief excerpt (4, 6, 30). The sequence ends with Reem writing down the statement in the protocol simultaneously, expressing uncertainty about whether she did right by saying, should I write because the air … (8).

Sandra captures the question and interrupts Reem's reasoning by stating that … you should just write what you saw (9). It is clear that, by this point, Sandra wants to highlight another explanation for the experiments. This is reinforced when she expresses that, then it proves like, that air takes up space in water. Even in water, then (9-10). Hadi seems to support this line of reasoning, which influences Sandra to further clarify her idea when she expresses, … it's the same thing that happened in the glass to the toy. It was as if there was a bit of air in it. (12-13). Both statements clearly indicate that she is trying to emphasize that it is the air in the glass that presses the toy down and pushes away the water so that the paper does not get wet. Even Hadi seems to assume a similar line of reasoning and supports Sandra's statement by saying, It's like it takes away the water in it (14).

We argue that the excerpt constitutes an example of how students are searching and probing for more and more accurate ways of expressing what they observed in the experiments and that the dialogues with others seem to facilitate this work. We will return to this issue. After a while, the teacher returns to the group to emphasize that the students must now come up with a common answer regarding how to understand what is happening in the experiments. Reem immediately perceives the challenge and begins to describe how she views "the diving glass experiment" by stating, it was not wet like it should've been … like I thought it would have been … (24-25). This is an important statement because Reem herself emphasizes that her idea was that the paper would get wet in the water and that she therefore had an incorrect understanding of what would happen. This is, of course, an important prerequisite for considering reassessing the understanding of the experiment. The teacher does not really pick up that thread with Reem, but instead asks what happened to the toy in the other experiment. The question leads to Reem again presenting her description of the experiment by saying that we threw it into the water … and it started to float … and when we put the cup in, it stopped floating because air got away … ahh from the water (27-29). As mentioned earlier, this statement confirms that Reem has not really changed her understanding or choice of words so far in the conversation.

Excerpt B (**Figure 4**) is a continuation of excerpt A, where the same group of students try to agree about what should be in the middle of the protocol.

Excerpt B: "It Proves That … That Air Actually Takes Up Space" (School S)

The teacher discusses with the group and tries to get them to agree about what to write when Sandra summarizes her own understanding of the experiments. As before, she points out that the teacher put a big paper in a glass, and she took it upside down and pushed the glass down in the water (1-5) and notes that the paper was dry afterwards. Sandra also emphasizes that the same principle applies with the toy when she then says that the teacher put the glass over it [toy] and pushed it down (3-5). It is possible to discover that Sandra's way of expressing herself and choice of words have a great impact on how the group later summarizes what they have understood from the experiments. The word choice "to push the glass" into the water is an example of ways she expresses, which several students "pick up" and make their own during the discussion. Another example is when Reem expresses … I only wrote … it proves (9), which indicates that she has probably taken over from Sandra. However, this situation leads to Sandra again attempting to insert the phrase "it proves" in a relevant way in relation to the experiments when she says, that proves that … that air actually takes up space even in the water then … (12). She then continues on the same theme with the toy experiment when she expresses that the teacher … pushed in with the glass, then … it went down … like to the bottom … and then that proves that the water [air] takes up space … (13-15). Reem captures this way of expressing oneself and says that the teacher turned the cup upside down and [the paper] got stuck in the cup because that the water [air] takes up space in the water … (16-17). She returns to this new way of expressing herself after a while when she then says, … could not we write [in the middle] that the air takes up space in the water (20-21). This statement clearly indicates that Reem has made the expression "air takes up space" her own and she does not return to the earlier expression ("the air goes away"). However, Hadi returns to the phrase "the air goes away" one more time, but now in a new way in which he tries to connect the two sentences by expressing The ar [air] can take up space … like when you in lock the air … so the air goes away … in the water (22-23). Here it becomes clear that Hadi uses the term "the air goes away" to describe how the enclosed air in the glass "goes away" into the water.

At the end of the conversation, the students focus increasingly on what to write "in the middle" of the protocol and report to the others. In this sequence, as Sandra points out on several occasions, it is the air inside the glass that "pushes" the toy under the water surface. An example of this is when she expresses … then the toy floated … but afterwards when she [the teacher] took the cup … and put it over and pushed it down … then it was the air that pushed it down … then the toy floated (28-30). In this statement, however, there is an important addition indicating that Sandra has made another important observation. Namely, she both starts and ends the statement by stating that the toy is floating at different times and in different places. We have interpreted this situation, as her first finding is that the toy floats on the water surface in the large beaker, while at the end of the sentence she emphasizes that the toy floats on the water surface inside the glass at the bottom of the breaker. Finally, the students agree that the group's reporting for the whole class should be:

Sandra	The way I see it, like Nensi [the teacher] put a big paper in a glass and she took it upside-down and pushed the glass down in the water and when she pulled it up, then was, then the paper was dry and the other experiment with the toy, then … like when you put the plastic toy in the water and pushed the glass down … like it didn't float, but instead ended up on the bottom.
T	Have you written why you think that it ended up like this?
Hadi	If you don't, you know or think that the toy got wet but not the paper.
Sandra	Would you write?
Reem	I didn't write, because I only wrote … it proves, I didn't write because…
Hadi	But, like air, then. Like when you pushed the paper in and took it out again, then it was not wet.
Sandra	Yes, and then that proves that … that air actually takes up space even in the water then … and the other experiment, like the toy and the glass, like saying, but then when Nensi pushed in with the glass, then … it went down … like to the bottom … and then that proves that the water [air] takes up space…
Reem	Like, pushed the paper down … in a cup and … turned the cup upside down and got stuck in the cup because that the air takes up space in the water … When Nensi takes down toy in the water and you turn the cup and the cup went down in…[inaudible]

Reem	Like, we know what happened … couldn't we write [in the middle] that the air takes up space in the water
Hadi	The ar [air] can take up space … like when you in lock the air … so the air goes away … in the water.

Sandra	Write … air takes up space in the water … write … write what first happened [is writing] When Nensi put a … toy in the water
Hadi	Yes.
Sandra	[Writing] then floated … then the toy floated … but afterwards when she took the cup … and put it over and pushed it down … then it was the air that pushed it down … then the toy floated
	---
Sandra	She put a glass over the toy.
Hadi	And then the toy sunk … carefully down into the water.
Sandra	She said something the furthest down [reads everything again]
Hadi	[Adds to the reading] then it sunk. How is sunk spelled? [Swedish: sjönk]…
Sandra	It was the air that pushed the toy down.
Hadi	Write because things cannot float in the air.

Figure 4. Excerpt B (Reprinted with permission of the participants)

> Reem: The teacher put a toy in the water and when she put a glass over it and pushed it down into the water, then the toy sank … It was the air that pushed the toy down … because things cannot float in water … ehh in air … It proves that air actually takes up space, even in water.

The next example (excerpt C) is from school K (**Figure 5**). The students in this conversation work with the same experiments as in the previous excerpt and with the *meet in the middle* task, where the students are expected to come up with a common description and hypothesis.

The excerpt starts with Jelena expressing her view on why the paper in the glass does not get wet: … it stays dry, because there is some sort of pressure that makes it that it stays dry (1-2). She does not develop this reasoning further but seems to express some initial understanding of what is happening by pointing out that the air in the glass creates some sort of pressure (1), which helps prevent the paper from getting wet. None of the other students in the group respond immediately to the statement; rather, they seem to be concerned with the order in which to present their view of the experiment. The conversation continues when Alexa, at the request of the teacher, reports her observation by stating that when the paper is in the glass, then it stays dry (5). Antonio tries to bring the discussion closer to an explanation when he states … what do you call it, like, the water only gets in because the water only gets in out there (7-8). However, it is obvious that

Jelena	When the paper is in the glass, then it stays dry, because there is some sort of pressure that makes it… that it stays dry.
Jelena	Is number four after number three?
T	Number four tells what number four has written.
Alexa	When the paper is in the glass, then it stays dry.
T	Number one tells.
Antonio	Okay, when you, when you have the paper in the glass, so, when you dip it in, then what do you call it, like, the water won't get in because the water only gets in out there.
…	
T	Then. Now you're going to agree on something to write in the middle, that you, that you as a group agreed on. What you thought and why. Talk to each other. Is there something that you can agree on that, yes, but, this is what we think.
Antonio	But better than so, like. It's good at so. Are you good at writing?
Jelena	Eeeh, but we were supposed to decide together on something to write in the middle.
Antonio	Wait. One person writes and a few three say
Jelena	I can write, then you can like say what it should say.
Antonio	No, but
T	One more minute.
Jelena	Just because that you are number one doesn't mean that have to write.
Jelena	Mmm. What should we write? When you put the paper in the glass…
Antonio	No, no. Maybe, maybe the air takes up space in the glass…
Jelena	… And therefore it doesn't get dry [wet]…
Antonio	Yes … Yes, therefore it get, when the pap…
Jelena	… Just like when the paper is in the glass, air takes up space.
Antonio	Yes.
Jelena	Then the paper, then stays the paper dry.
Antonio	Yes, and the water goes only outside, not inside.
Antonio	Only two different things…
T	Have you agreed?
Jelena	Yes … wait. When the paper is in the glass, so there is air in the glass and that is why the paper stays dry completely.
Antonio	Yes, but, like, the air takes up space.

Figure 5. Excerpt C (Reprinted with permission of the participants)

Antonio is looking for the right words or probing for a correct way to express himself. He seems to express that the water does not enter the glass but is only on the outside. It is unclear if he is trying to get closer to an explanation or if he lacks the words to describe what he really wants to express. Later in the conversation, however, he returns to the experiment and then expresses … maybe the air takes up space in the glass (21), which indicates a development and provides a more accurate way of describing the experiment. Before that, the teacher encouraged the students to try to agree on a common understanding and the students discuss who should do the writing.

The students start discussing what to write in the middle of the protocol when Jelena states that when you put the paper in the glass … (20). She does not get the opportunity to finish her reasoning before Antonio interrupts by filling in the unfinished sentence, claiming that it may be the air that takes up space in the glass. This, in turn, leads to Jelena filling in his statement by claiming that … and therefore it does not get dry [wet] (22). (Considering her earlier and subsequent statements, it is likely that the use of the word "dry" here is a slip of the tongue and that she means "wet".) The dialogue between Antonio and Jelena seems to lead the two students to trigger each other to jointly find as adequate words as possible to describe and explain the experiment and, at the same time, unite the ideas that air takes up space and that the paper does not get wet. The dialogue between the two students continues as Antonio further tries to complement the previous statement but is interrupted by Jelena when she claims … when the paper is in the glass, air takes up space (24). Here, Jelena has suddenly taken over Antonio's expression that "air takes up space" and integrated it with the idea that the paper does not get wet. This statement seems to be crucial in finding an explanation, as it leads to Antonio affirming the claim and Jelena again concluding that this is what makes the paper stay dry (30-31). Finally, Antonio also emphasizes that this is why … water goes only outside, not inside [the glass] (27).

Table 2. Individual statements from students at various times during group discussions regarding *diving glass* and *floating toy/cork* experiments, as well as examples of how students take over expression from others

	Student	Utterance A→	Utterance B	Taking over expressions↓
1	Reem (S)	"The air went away."	"Air takes up space."	From Sandra
2	Sandra	"Pushed the glass down."	"The air pushed the toy down."	
3	Hadi	"The air gets stuck."	"The air blocks [the water]."	
4	Sandra	"A special substance takes away the water."	"Maybe it also has something to do with the air."	From Reem (?)
5	Antonio (K)	"The water will not get in."	"Air takes up space."	
6	Antonio	"The water only goes on the outside [of the glass]."	"Air takes up space."	
7	Jelena	"Some sorts of pressure that makes it [the paper] stays dry."	"There is air in the glass and air takes up space."	From Antonio
8	Antonio	"It was air around the paper."	"The paper was covered by air."	
9	Jelena	"There is air all around the paper."	"Air covered the paper."	From Antonio
10	Alexa	"There is air in the glass."	"The glass takes air with it [under the water]."	
11	Vera	"It was air around the paper."	"Because it was covered by air."	From S3
12	Kim	"So, you cannot wet it because there is also air all around."	"Because it was covered by air … Air covered."	
13	Isaac	"It [the glass] was pushed down."	"[Write] that it was with the air."	

Analysis of Students' Individual Statements at Various Times During Group Discussions

In this part of the analysis, we examine the students' individual statements about the experiments on various occasions during the group discussions in the *meet in the middle* activity. The main purpose is to interpret the ways in which the students' choice of words changes over time when describing and explaining the experiments and to focus on what expressions they have "picked up" from others and made their own. In this context, taking over someone else's words and making it their own implies that they can use the new words in a relevant, coherent, and consistent way to create meaning. The examples presented in **Table 2** are statements made by students in the previously presented excerpts, as well as examples from the total data material.

In the analysis, it becomes clear that most of the students gradually change their way of describing and explaining the experiments and that their word choice tends to become increasingly precise and accurate during the discussions. It is also possible to claim that this development seems to be largely related to discussions about the observations and a consequence of a more detailed description of what has been observed. In these contexts, there are several examples of conversations about the observation itself and what has actually been observed that seems to make it easier for the students to put words into what they have seen or to choose more appropriate and accurate words to describe it. **Table 2** constitutes examples of this type of language change in students' word choices during the discussions about the "diving glass" and "the floating toy/cork" experiments.

In the first example, as we mentioned earlier (excerpt A), it is not clear why Reem uses the expression the air went away on three occasions before she finally takes over the expression air take up space and makes her own. In the analysis of the excerpt, however, it become clear that she takes over this expression from Sandra and that she can use this new expression in a relevant and consistent way. In the second example in the same group, Sandra also changes the way she expresses herself, from focusing on how the teacher pushed the glass down to more fully describing that it was the air [that] pushed the toy down. In the analysis of excerpt (A), it becomes clear that the conversation in the group is contributing to this change. It is possible to discover a similar refinement of the language usage and focus in the third example. During the discussion, Hadi changes modes of expression from the air gets stuck [in the glass] to the air blocks [the water], which may be described as a change from a descriptive to an explanatory way of expression. It is clear that this shift between a descriptive and an explanatory orientation (which is also in the task itself) changes and develops the students' language use and their word choices. Examples 5-7 in **Table 2** represent similar situations, where students change their language use and orientation as they move from a descriptive discourse to an explanatory one. In example 7, the conversation (excerpt C) shows that Jelena describes the experiment by pointing out that some kind of pressure … makes it [the paper] stays dry while the explanation focuses on the

Table 3. Individual statements from students at various times during group discussions regarding the experiment *pouring air underwater*, as well as examples of how students take expression from others

	Student	Utterance A→	Utterance B	Taking over expressions↓
13	Jasmina	"The bubbles in the water, like change places."	"The air bubbles went over to the other glass."	
14	Noah	"But when she turned this glass with air, then water came in, like and then the other one, there like air."	"That water came into the air glasses and then, air bubbles came, yes, air bubbles to the other glass."	From Anna
15	Anna	"Then water came in and then there came bubbles with air up and then, so it was the other glass and then there came into the other one."	"Water came … in that air glass … But first air bubbles came out … there came air bubbles … to the other glass."	
16	Adi	"Then there were bubbles going up and in the other glass … so that it was empty."	"That air bubbles went into the other glass."	From Anna

fact that there is air in the glass and that it actually takes up space. The analysis of excerpt C showed that the addition air takes up space is an expression that Jelena has taken over from Antonio and managed to insert in a relevant and meaningful way in order to formulate an explanation. **Table 2** provides examples of individual statements from the total data material at various times during group discussions and aims to describe how some of the students gradually develop and refine their word choice when it comes to explaining the experiments. The table also provides examples of how, during the discussion, students "take over" expressions from others and make them their own where this process is obvious and possible to derive.

Regarding examples 8-9, Antonio first expresses that it was air around the paper that explained why the paper did not get wet, but he later changed his word choice by stating that the paper was covered by air. This is another example of how the students in the discussion explore different ways of expressing themselves and thus increase their language repertoire. We argue that this represents a development of the ability to communicate science. The same applies to Jelena (example 9), who takes over the expression from Antonio and even expresses that she understands the experiment in the same way as Antonio. Examples 11-12 from another group and another class are almost identical. However, it is possible to understand example 10 as an expansion of how the student expresses herself about her observation. This means that she first notes that there is air in the glass and then more fully describes the glass takes air with it [under the water], which may also be understood as an extension of her language repertoire.

Table 3 concerns students' utterances and statements regarding the "pouring air underwater" experiment. All four examples in the table clearly constitute situations where students search for words and expressions to be able to describe what happens in the experiment in a more detailed way.

In example 14, Noah refines the observation through first focusing on the fact that the water came into the air-filled glass and then the fact that air bubbles leave the air-filled glass to the water-filled glass. In the first stage, most of the students largely lack words and structure to describe what they have observed, but they gradually master a functional language and words to do so. In this context, it is possible to emphasize that the small-group discussions form an important support structure for several of the students in this situation. As for Anna (example 15), her initial description is somewhat incoherent and lacks an overall structure, which may imply that some necessary words and expressions seem to be missing. However, in the second description, Anna focuses on the fact that it is an exchange between the glasses by expressing water came… in that air glass and that there came air bubbles … to the other glass.

DISCUSSION AND CONCLUSIONS

In this study, we have explored the ways in which small-group work can contribute to strengthen multilingual students' language and conceptual development when working with language-oriented classroom activities in a primary science classroom. The main aim was to examine the students' subject language use in these processes and to analyze whether it is possible to identify factors that contribute to strengthen and facilitate their language development. This implies that we have focused on how students orally formulate themselves when describing observations, hypotheses, and explanations of some scientific experiments on the properties of air. The analyses have also made it possible to follow how individual students gradually develop their way of expressing themselves by taking over others' expressions and word choices and making them their own. An important starting point in the study has been the hypothesis that students' successive development of a subject-specific language in science may be crucial for their conceptual development and understanding of the subject content. Several researchers (e.g., Lemke, 2001; Mercer, 2019) have emphasized this dialectical relationship between the students' subject language development and their conceptual understanding, and that the subject language and the conceptual understanding drive and accelerate each other. Our results confirm that small-group work creates conditions for students to further develop and deepen their language use in science and indicate that these contexts also facilitate and drive their conceptual understanding. The analyses further indicate that these situations seem to benefit all students regardless of language background (cf. Lee et al., 2019; Nygård Larsson, 2018).

However, many studies have highlighted the complexity involved in mastering the language in science education, and the fact that this applies to most students regardless of their language background (e.g., Karlsson et al., 2019, 2020; Mortimer & Scott, 2003; Seah & Yore, 2017). Subject language perspectives on teaching and learning in science imply that several different language aspects are given attention, such as semantic, discursive, formal linguistic, or multimodal perspectives (Fang, 2005, 2006; Gee, 2015; Kress & van Leeuwen, 2006). Over 20 years ago, Lemke (2001) emphasized that "talking science" may be primarily understood as an educational focus on science instruction as a subject-language-focused activity, where students are offered opportunities to develop their abilities to communicate science. This means that students are offered meaningful teaching situations where they receive support in the process of constructing the logical and semantic structures that build scientific sentences and ways of reasoning. In this process, students also need to be given space to explicitly compare and negotiate the meaning of everyday and scientific expressions in order to acquire and develop a functional language and to be able to develop new knowledge (e.g., Alvarez et al., 2022; Gee, 2015). However, all these aspects of language in science teaching are often intertwined in an implicit and un-reflected teaching context, which risks leading students to experience science as abstract, difficult, and sometimes incomprehensible (Osborne et al., 2003; Van Horne & Bell, 2017). As mentioned, this may apply to all students, but entails an extra dimension of complexity for multilingual students or second-language learners who face the dual task of simultaneously learning a new language and developing an understanding of concepts and theories through this language (e.g., Banks & Banks, 2019; Cummins, 2008; Probyn, 2019).

In the empirical part of the article, we have interpreted several of the dialogues as typical examples of how students successively create a common subject language and choice of words in order to be able to orally explain and describe the experiments. We also argue that these dialogical situations are crucial for all students to develop their language use in science, primarily through probing a more precise way of expressing themselves and putting their scientific ideas and thoughts into words. The dialogues also offers opportunities to explore different ways of expressing themselves and reformulating and arguing their views (cf. Mercer, 2019). This kind of situation compels students to develop and refine their language repertoire related to science, which may facilitate and allow the development of their conceptual understanding. We also emphasize the importance of students developing their skills in describing their observations in order to be able to reason, understand, and explain, all of which constitute important components in literacy development in science. We further argue that these types of situations are significant for all students, but crucial for those students who do not have the language of instruction as their first language. In relation to this, our results conform to Mercer (2019) and demonstrate the importance of this type of "exploratory talk" and hypothetical reasoning as a significant opportunity to develop second-language students' language use and knowledge in science.

However, we cannot unilaterally claim that a more detailed and precise way of expressing oneself automatically means that the student in question has further developed his or her conceptual understanding. Although it is likely in this way, it is not possible to display this development, as these internal processes are usually invisible. We also see this relationship as far more complex and more difficult to describe. There is also the possibility that some students started from an initial understanding of what is happening in the experiment even before the dialogues, but that they lacked the language or specific words to express that understanding. Thus, for the majority of students in this study, the language of instruction is their second language, and they are largely engaged in developing science knowledge with the help of this language. Therefore, we argue, this type of group discussion and language-oriented activities becomes crucial as all students are offered opportunities to take part of the specific language expressions and word choices of others, to probe and negotiate the word meanings, which in itself may lead to increased participation and an ISE for these students (cf. Schleppegrell, 2020).

Although students' individual conceptual development and their understanding are mainly invisible to an observer, we argue that a change in the active language use and a more precise way of expressing oneself indicates a possible transformation of the conceptual understanding. Similar results were confirmed in Haug and Ødegaard (2014). This also becomes especially clear in the second part of the analysis, where individual statements from students, at various times during the group discussions, are analyzed throughout the process. The analysis shows that students' choice of words changes over time when describing and explaining the experiments and that they have successively picked up expressions from others and made them their own (cf. Mercer, 2019). As previously mentioned, taking over someone else's choice of words and making it their own, in this study, implies that they can use the new words in a relevant, coherent, and consistent way to create meaning. Some examples of this are students who first express that "the air went away" and later express, more precisely, that "air take up space" or that "some kind of pressure makes the paper stay dry" to "there is air in the glass and the air takes up space". A similar development of language use occurs when a student first expresses that "there is air in the glass" and later develops the description to "the glass takes air under the water". This constitutes one of many examples of where students gradually become increasingly accurate when it comes to putting their observations into words. A further illustration of this is a student who describes the "pouring air underwater" experiment as it is "the bubbles in the water, like, change places" and later emphasizes "the air bubbles went over to the other glass".

An important conclusion from this study is that the students' knowledge development is largely comprised of their gradually increased ability to describe and explain more exactly what they have observed and how to explain the experiments. Thus, the results of this study clearly indicate that the language-oriented activities presented to the teachers in the research project help to gradually deepen and expand students' scientific language register. It seems that the teachers' participation in continuing education on subject-language perspectives on teaching science actually influences their activities in the classroom and shows that relatively few effort is needed to have an effect in the classroom. An essential implication is that all students should be offered opportunities and space to develop their subject language register in science classroom activities and that this is important for all students, but crucial for students who have the language of instruction as a second language.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approve final version of the article.

Funding: This article was supported by NordForsk (86052) and Malmö University.

Ethical declarations: The authors state that all participants in the study were informed about how and why the research was conducted, that their anonymity was ensured and that their answers were stored securely on Malmö University's hard drives. Participation in the study was voluntary. Furthermore, all ethical regulations according to the Swedish Research Council have been followed.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Alvarez, L., Capitelli, S., Valdés, G., & De Loney, M. (2022). Toward an integrated practice: Facilitating peer interactions to support language development in science. *The New Educator, 18*(1-2), 110-131. https://doi.org/10.1080/1547688X.2022.2035473

Banks, J. A., & Banks, C. A. M. (Eds.) (2004). *Handbook of research on multicultural education*. Macmillan. https://doi.org/10.1080/00131720408984645

Banks, J. A., & Banks, C. A. M. (Eds.) (2019). *Multicultural education: Issues and perspectives.* John Wiley & Sons.

Blackledge, A., & Creese, A. (2017). *Translanguaging in mobility. The Routledge handbook of migration and language*. Routledge. https://doi.org/10.4324/9781315754512-2

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing every day and science language in the classroom. *Science Education, 92*(4), 708-732. https://doi.org/10.1002/sce.20251

Buxton, C. A., & Lee, O. (2014). English learners in science education. In N. Lederman, & S. Abell, (Eds.), *Handbook of research on science education* (pp. 204-222). Routledge.

Cummins, J. (2021). *Rethinking the education of multilingual learners: A critical analysis of theoretical concepts*. Springer. https://doi.org/10.21832/9781800413597

Fang, Z. (2005). Scientific literacy: A systemic functional linguistics perspective. *Science Education, 89*(2), 335-347. https://doi.org/10.1002/sce.20050

Fang, Z. (2006). The language demands of science reading in middle school. *International Journal of Science Education, 28*(5), 491-520. https://doi.org/10.1080/09500690500339092

Gee, J. P. (1999). *An introduction to discourse analysis: Theory and method*. Routledge.

Gee, J. P. (2015). *Social linguistics and literacies: Ideology in discourses.* Routledge. https://doi.org/10.4324/9781315722511

Hajer, M., & Meestringa, T. (2014). *Språkutvecklande undervisning–En handbok* [*Language development education–A handbook*]. Hallgren & Fallgren.

Halliday, M. A. K. (2014). Language as social semiotic. In J. Benjamins (Ed.), *The discourse studies reader* (pp. 263-272). John Benjamins Publishing Company.

Halliday, M. A. K., & Martin, J. R. (1993). *Writing science. Literacy and discursive power.* University of Pittsburgh Press.

Haug, B. S., & Ødegaard, M. (2014). From words to concepts: Focusing on word knowledge when teaching for conceptual understanding within an inquiry-based science setting. *Research in Science Education, 44*(5), 777-800. https://doi.org/10.1007/s11165-014-9402-5

Hernandez Garcia, M., & Schleppegrell, M. J. (2021). Culturally sustaining disciplinary literacy for bi/multilingual learners: Creating a translanguaging social studies classroom. *Journal of Adolescent & Adult Literacy, 64*(4), 449-454. https://doi.org/10.1002/jaal.1129

Jakobsson, A., & Davidsson, E. (2012). Using sociocultural frameworks to understand the significance of interactions at science and technology centers and museums. In E. Davidssons, & A. Jakobssons (Eds.), *Understanding interactions at science centers and museums* (pp. 3-21). Sense Publishers. https://doi.org/10.1007/978-94-6091-725-7_2

Jakobsson, A., Mäkitalo, Å., & Säljö, R. (2009). Conceptions of knowledge in research on students' understanding of the greenhouse effect: Methodological positions and their consequences for representations of knowing. *Science Education, 93*(6), 978-995. https://doi.org/10.1002/sce.20341

Jakobsson, A., Nygård Larsson, P., & Karlsson, A. (Eds.) (2022). *Translanguaging in science education. Sociocultural explorations of science education*. Springer. https://doi.org/10.1007/978-3-030-82973-5

Karlsson, A., Larsson, P. N., & Jakobsson, A. (2016). Flerspråkighet som en resurs i NO-klassrummet [Multilingualism as a resource in the science classroom]. *Pedagogisk Forskning i Sverige* [*Educational Research in Sweden*]*, 21*(1-2), 30-55.

Karlsson, A., Nygård Larsson, P., & Jakobsson, A. (2019). Multilingual students' use of translanguaging in science classrooms. *International Journal of Science Education, 41*(15), 2049-2069. https://doi.org/10.1080/09500693.2018.1477261

Karlsson, A., Nygård Larsson, P., & Jakobsson, A. (2020). The continuity of learning in a translanguaging science classroom. *Cultural Studies of Science Education, 15*(1), 1-25. https://doi.org/10.1007/s11422-019-09933-y

Kouns, M. (2014). *Beskriv med ord: Fysiklärare utvecklar språkinriktad undervisning på gymnasiet* [*Describe with words: Physics teacher develops language-based education in high school*] [PhD dissertation, Malmö University].

Kress, G. & van Leeuwen, T. (2006). *Reading images. The grammar of visual design.* Routledge. https://doi.org/10.4324/9780203619728

Lee, O., Llosa, L., Grapin, S., Haas, A., & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education, 103*(2), 317-337. https://doi.org/10.1002/sce.21498

Lemke, J. L. (1990). *Talking science: Language, learning, and values.* Ablex Publishing Company.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*(3), 296-316. https://doi.org/10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.0.CO;2-R

Linell, P. (2009). *Rethinking language, mind, and world dialogically.* Information Age Publishing.

Mercer, N. (2019). *Language and the joint creation of knowledge: The selected works of Neil Mercer.* Routledge. https://doi.org/10.4324/9780429400759

Mercer, N., & Wegerif, R. (1999). Is 'exploratory talk' productive talk? In K. Littleton, & P. Light (Eds.), *Learning with computers: Analyzing productive interaction* (pp. 79-101). Routledge.

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359. https://doi.org/10.1080/01411920410001689689

Mondada, L. (2006). Video recording as the reflexive preservation and configuration of phenomenal features for analysis. In H. Knoblauch, J. Raab, H. G. Soeffner, & B. Schnettler (Eds.), *Video analysis* (pp. 51-68). Peter Lang.

Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms*. McGraw-Hill Education.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*, 224-240. https://doi.org/10.1002/sce.10066

Nygård Larsson, P. (2018). We're talking about mobility: Discourse strategies for promoting disciplinary knowledge and language in educational contexts. *Linguistics and Education, 48*, 61-75. https://doi.org/10.1016/j.linged.2018.10.001

Nygård Larsson, P., & Jakobsson, A. (2020). Meaning-making in science from the perspective of students' hybrid language use. *International Journal of Science and Mathematics Education, 18*(5), 811-830. https://doi.org/10.1007/s10763-019-09994-z

Olander, C., & Ingerman, Å. (2011). Towards an inter-language of talking science: Exploring students' argumentation in relation to authentic language. *Journal of Biological Education, 45*(3), 158-164. https://doi.org/10.1080/00219266.2011.591414

Oliveira, A. W., Weinburgh, M., McBride, E., Bobowski, T., & Shea, R. (2019). Teaching science to English language learners: Current research and practices in the field of science education. In L. C. de Oliveira (Ed.), *The handbook of TESOL in K-12* (pp. 277-290). Wiley. https://doi.org/10.1002/9781119421702.ch18

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079. https://doi.org/10.1080/0950069032000032199

Probyn, M. (2019). Pedagogical translanguaging and the construction of science knowledge in a multilingual South African classroom: Challenging monoglossic/post-colonial orthodoxies. *Classroom Discourse, 10*(3-4), 216-236. https://doi.org/10.1080/19463014.2019.1628792

Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: Technologies, social memory, and the performative nature of learning. *Journal of Computer Assisted Learning, 26*(1), 53-64. https://doi.org/10.1111/j.1365-2729.2009.00341.x

Schleppegrell, M. J. (2016). Content-based language teaching with functional grammar in the elementary school. *Language Teaching, 49*(1), 116-128. https://doi.org/10.1017/S0261444814000093

Schleppegrell, M. J. (2020). The knowledge base for language teaching: What is the English to be taught as content? *Language Teaching Research, 24*(1), 17-27. https://doi.org/10.1177/1362168818777519

Scott, P., Mortimer, E., & Ametller, J. (2011). Pedagogical link-making: A fundamental aspect of teaching and learning scientific conceptual knowledge. *Studies in Science Education, 47*(1), 3-36. https://doi.org/10.1080/03057267.2011.549619

Seah, L. H., & Yore, L. D. (2017). The roles of teachers' science talk in revealing language demands within diverse elementary school classrooms: A study of teaching heat and temperature in Singapore. *International Journal of Science Education, 39*(2), 135-157. https://doi.org/10.1080/09500693.2016.1270477

Seah, L. H., Clarke, D. J., & Hart, C. E. (2011). Understanding students' language use about expansion through analyzing their lexicogrammatical resources. *Science Education, 95*(5), 852-876. https://doi.org/10.1002/sce.20448

Solli, A., Hillman, T., & Mäkitalo, Å. (2017). Navigating the complexity of socio-scientific controversies—How students make multiple voices present in discourse. *Research in Science Education, 49*, 1595-1623. https://doi.org/10.1007/s11165-017-9668-5

Swedish Research Council. (2011). Good research practice. *Swedish Research Council*. https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf

Van Horne, K., & Bell, P. (2017). Youth disciplinary identification during participation in contemporary project-based science investigations in school. *Journal of the Learning Sciences, 26*(3), 437-476. https://doi.org/10.1080/10508406.2017.1330689

Van Laere, E., Aesaert, K., & van Braak, J. (2014). The role of students' home language in science achievement: A multilevel approach. *International Journal of Science Education, 36*(16), 2772-2794. https://doi.org/10.1080/09500693.2014.936327

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Vygotsky, L. S. (1997). *The collected works of LS Vygotsky: Problems of the theory and history of psychology*. Springer Science & Business Media.

Willis, P., & Trondman, M. (2002). Manifesto for ethnography. *Cultural Studies↔Critical Methodologies, 2*(3), 394-402. https://doi.org/10.1177/153270860200200309

◆❖◆