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An orchestra of semiotic resources in a translanguaging science classroom

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ABSTRACT

The aim of this article is to explore how socially and culturally shaped resources for meaning-making are used in a translanguaging science classroom and how these interact to promote multilingual students' participation and understanding of science. The data consist of video- and audio-recorded science lessons in a Swedish compulsory school (Grades 4–6). The analysis, rooted in translanguaging and sociocultural perspectives on learning, views learning as dialogic processes within social contexts and is framed within social semiotic theory, both regarding systemic functional linguistics and social semiotic perspectives on multimodality. Multimodal interaction analysis is used to clarify the use of semiotic resources by students, the science teacher and the mother-tongue teacher, as well as their various functions in meaning-making processes. Findings show how the participants' linguistic repertoires contribute to semiotic resources in the dialogic conversations and how each expression provides a unique aspect of the subject content, which together shape a comprehensive whole. By combining and integrating different modalities, such as gestures, drawings, and objects with verbal resources, continuity is fostered in the science activities. However, the study also underlines the importance of verbal language resources for students' opportunities to develop a broader and deeper knowledge in science subjects.

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Introduction

In science education, subject-specific language is a tool for understanding and organising the subject content and the activities (Lemke, 1990). Language and subject matter are intimately intertwined, which means that the development of the subject-specific language goes hand in hand with the development of knowledge (Halliday & Martin, 2015). However, the construction of meaning occurs not only through verbal resources but also through multimodal representations, including models, graphs, symbolic languages, etc. (Lemke, 1998; Olander et al., 2018). This implies that teachers must integrate language and subject as coherent parts of science education and emphasise the central role of subject

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language with its various representations. This can pose a challenge in multilingual science classrooms, where several students simultaneously developing proficiency in the language of instruction and their content knowledge in science subjects, often without the opportunity to draw on their full range of linguistic resources to connect with prior experiences and express subject-specific knowledge. Several studies indicate that science teaching is usually adapted to the students' proficiency in the language of instruction rather than to the students' subject knowledge (Axelsson, 2023; Van Laere et al., 2014). Therefore, a central challenge lies in how science teaching can utilise the rich range of semiotic resources available in translanguaging science classrooms, to ensure that teaching is adapted to students' subject knowledge and is sufficiently cognitively demanding for all students.

One strategy to promote multilingual students' opportunities for increased participation and engagement is the use of translanguaging (Jakobsson et al., 2022). A translanguaging pedagogy involves both students and teachers consciously leveraging all of their linguistic resources to facilitate comprehension and learning. It entails fluidly alternating between different languages based on the context and needs, rather than adhering strictly to one language at a time (García & Wei, 2014). This approach promotes an integrated and dynamic use of all available linguistic resources simultaneously. This pedagogical approach has been shown to foster language development, high-order thinking and conceptual understanding (Charamba, 2022; Karlsson et al., 2019; Poza, 2018), and to help students understand more complex aspects, such as scientific argumentation (Licona & Kelly, 2022), thus contributing to more equitable learning environments for multilingual students (Buxton & Lee, 2023; Hattingh et al., 2022; Pun & Tai, 2022). Additionally, recent years have also seen a growing body of research that delves into the multimodal aspects of translanguaging in science education (Cheng et al., 2020; Danielsson & Uddling, 2022; Moro et al., 2020; Pierson et al., 2021; Siry & Gorges, 2020; Ünsal et al., 2018, 2020; Williams, 2022; Williams & Tang, 2020). These studies explore how students and teachers use multimodal resources in ways that are closely tied to their local contexts and evolve through interactive processes.

Another important aspect to consider in research on meaning-making in multilingual science classrooms is that students' communicative repertoires are related to their social and cultural background (Kress & Van Leeuwen, 2021; Otheguy et al., 2015), which means that meaning-making processes in multilingual classrooms are usually multidimensional and complex. For example, words and concepts that have developed functionally in one cultural context can be problematic to translate in another cultural context; that is, from one national language to another (Axelsson, 2023; Karlsson et al., 2019). Even gestures can have varying meanings in different contexts (Ünsal et al., 2018). Consequently, the multilingual science classroom constitutes a challenge that requires further knowledge of how teaching can integrate and use the diversity of the semiotic resources available. Harnessing these resources' meaning-making potential can expand the range of communicative tools – both verbal and non-verbal – thereby increasing *all* students' opportunities for active participation and socialisation into the discourse of science.

The aim of this study

This study addresses the critical need for a deeper understanding of how socially, culturally and disciplinarily shaped resources for meaning-making are utilised and can be

leveraged in a translanguaging science classroom. It examines the interplay of these semiotic resources, exploring how they interact, complement one another, and collectively contribute to meaning-making processes. Specifically, this research investigates the potential of these resources to enhance multilingual students' learning in science, as well as their inherent limitations. While many studies have highlighted the role of specific semiotic resources – such as gestures, visual representations, and verbal language – in supporting multilingual students, there is still a significant gap in understanding how these resources interact dynamically in translanguaging science classrooms. Addressing this gap, this study seeks to answer the following research questions:

- What semiotic resources do students and teachers employ as they engage in science?
- What do the various resources contribute to in the meaning-making processes, and what are their limitations?
- In what way do the resources interact and complement each other to promote students' understanding in science?

Bridging everyday and subject-specific discourse in science classrooms using various semiotic resources

In science education, students' active participation based on their background, prior experiences, language, and knowledge is crucial for their socialisation into the discourse of science (Buxton & Lee, 2023; Piliouras & Evangelou, 2012; Tan et al., 2012). Nygård Larsson and Jakobsson (2020) show that successful students have, to a greater degree than other students, developed the ability to productively relate the scientific subject content to prior experiences by moving discursively between expressing the subject content in an everyday way and a more scientific way. The authors argue that science teaching needs to create rich opportunities for all students to express both everyday and more subject-specific experiences and knowledge, thus developing their ability to move between discourses and language use. This can be related to the concept of *register*, which describes how language varies depending on the context (Halliday & Matthiessen, 2004). Two main types of registers can be identified: everyday register and subject-specific register. According to Halliday and Matthiessen (2004), the ability to switch between these registers is crucial for effective communication in various contexts. In multilingual science classroom, this can be facilitated by using translanguaging as a pedagogical strategy (Karlsson et al., 2019, p. 2022). In a Swedish study of bilingual (Swedish-Arabic) teaching, the authors show that multilingual students often use their first language (Arabic) when moving towards an everyday discourse and their second language (Swedish) when moving towards the more subject-specific discourse. This type of *multilingual discursive loops* is particularly common in situations where students negotiate and relate the science subject content to everyday and practical experiences (Karlsson et al., 2022). In another study, Knain et al. (2021) demonstrate the evolution of students' illustrations during a class activity on the workings of the greenhouse effect. These drawings transition from representing everyday features in a typical manner to progressively portraying elements of a scientific elucidation of the greenhouse effect in an increasingly scientific manner. In another study, which focused on the use of

gestures in a multilingual classroom, Ünsal et al. (2018) show how students and teachers both draw on the use of gestures to talk about the science content, and how this creates continuity in the science activities. The students use gestures to express scientific knowledge and the teachers use gestures to direct the communication toward the goal of the lessons, which is learning how to *talk science*.

Meaning-making resources in translanguaging science classrooms

In negotiation processes about science content, the students gradually appropriate the subject-specific language while their knowledge of the subject is deepened and broadened (Jakobsson & Kouns, 2023). In these processes, students develop knowledge about the specific meaning and character of subject words and concepts, as well as when and how they should be used and how they are related to each other to create meaning (Lemke, 1990; Seah et al., 2014). In translanguaging science classrooms, it is common for students to use both their first and second languages to develop understanding of subject-specific words and concepts. For instance, in a Swedish study, students semantically relate subject-specific concepts (expressed in their second language) to each other using descriptive, explanatory, and linking words and expressions (in their first language), while also employing gestures to clarify meaning (Karlsson et al., 2019). The students' use of both first and second languages and gestures shows that a complementation of mode is essential because the capacities of each mode might have limitations (Kress & Van Leeuwen, 2021).

Theories of social semiotics describe each mode as having unique affordances and commitments (Kress & Van Leeuwen, 2021). For instance, speech and visual are two modes that can sometimes be used individually, but also together to complement each other. In this way, meaning-making in science largely comprises learning to move between, integrate and produce meaning through a variety of ways of representing ideas that are often abstract or technical (Jakobson & Axelsson, 2017). Cheng et al. (2020) show that the learning and teaching of the particle model can be facilitated by utilising a variety of modes. With multimodal scaffolding, Grade 3 students were able to demonstrate aspects of the particle model related to the expansion of gases in a warmer environment. The students described and explained the phenomenon by exploiting the affordances of image and speech and by orchestrating these resources in ways that highlight central aspects of the particle model.

When everyday knowledge is expressed, verbal language is often supported by affordances in the environment, such as gestures, demonstrations and physical objects (Kress & Van Leeuwen, 2021). This means that, for example, physical artefacts can play a crucial role in science learning and constitute mediational means that become integrated into the meaning-making processes (Moro et al., 2020; Tang et al., 2022). In a translanguaging science classroom, Ünsal et al. (2020) conducted a study to understand how the use of physical artefacts can aid in the learning process of emergent bilingual students in a science class. Their research reveals that teachers employ physical artefacts in two distinct manners. Initially, the artefacts are used to make the subject matter more tangible for the students. This approach encourages students to begin discussing their observations in their everyday language, which, with the guidance of the teachers, is gradually transformed into a more scientific mode of expression. Furthermore, when the students'

proficiency in the instructional language hinders their ability to comprehend, the use of physical artefacts allows them to associate unfamiliar words with the scientific content, thereby facilitating their understanding.

By embracing and using students' entire communicative repertoires, translanguaging pedagogy has the potential to scaffold students in recognising and utilising a wider range of semiotic resources for meaning-making and expression (Moro et al., 2020). Research in translanguaging has often focused on linguistic resources and multilingual classrooms. However, in recent years, the multimodal resources have been increasingly emphasised (Pierson et al., 2021). An example is the concept of *transmodaling*, which is used to show that language is just one of a multitude of modes that students fluidly move between as they engage in doing science (Siry et al., 2022). Another example is the concept of *trans-semiotizing* (He & Lin, 2022), which defines communication as ensembles of modalities that are used fluidly and without boundaries in dynamic, dialogical and meaning-making processes.

Meaning-making resources in relation to situational, social, and cultural aspects

Language and other semiotic resources are developed for meaning-making in social and cultural contexts (Halliday & Matthiessen, 2004; Kress & Van Leeuwen, 2021). They can be disciplinary resources used in specific subject areas, such as science, or more general, such as everyday language, gestures and body language, which often gain their meaning in the context in which they are performed, influenced by individual and cultural factors. This means that language and actions used in the situation must be interpreted in a rich context, understood as an ecology of the materiality of the situation, the present and the non-present, and what has been and what comes next, as inferred from participants' utterances (Linell, 2009). Bakhtin (1981) uses the concept of *social languages* to mean that languages are the carriers of ideologies and different worldviews; this means that a word not only constitutes an object or a phenomenon but also includes socially constructed values, opinions, and worldviews. Consequently, each statement in a dialogue between speakers has not only one semantic meaning but also a background of other social and cultural experiences of the same thing. Thus a translanguaging practice, where each student uses their entire *linguistic repertoire* (Otheguy et al., 2015), creates 'a social space for multilingual user by bringing together different dimensions of their personal history, experience and environment, their attitude, belief and ideology, their cognitive and physical capacity into one coordinated and meaningful performance' (Wei, 2011, p. 1223). In this way, students' and teachers' utterances and actions will interact with the already spoken words and actions while presenting their semantic meaning in the situation.

Context, method, and analysis

Contextual description

The data for this article were collected at a multicultural compulsory school in Sweden, where science lessons were observed in a single class over a period of 3 years (Grades 4–

6). All the students in the class were native Arabic speakers; some were born in Sweden, while others were newly arrived. The instruction was provided by a science teacher (Maria) and an Arabic mother-tongue teacher (Hoda). Hoda offered the students multilingual study guidance during one science lesson each week. This multilingual study guidance is a form of support for newly arrived students in Swedish educational settings, enabling them to fully utilise their linguistic repertoire (Reath Warren, 2017). Moreover, the classroom setting encouraged all participants to employ various semiotic tools, such as their first and second languages, gestures, and visual aids, to enhance their understanding of the subject matter and the different classroom activities. This teaching strategy characterises the classroom as a space for *translanguaging practices* (García & Wei, 2014).

Method and data collection

The data comprise audio and video recordings, field notes, photographs, and student texts. The video captures alone account for 117 hours of science teaching and learning within the educational setting. As per Heath and Hindmarsh (2002), such a method of data gathering enhances the reliability of the subsequent analyses. By repeatedly scrutinising the captures, employing slow motion and other techniques, these video recordings offer a deep dive into the participants' employment of semiotic resources in their dialogues that create meaning, both verbal and bodily. These recordings also enable to identify the focus of individuals' attention and their subjects of interest, as well as to understand how they interact with objects and artefacts.

The analysis is based on sociocultural and translanguaging perspectives on learning, where learning is considered as dialogic meaning-making processes in social contexts (Bakhtin, 1981) and is framed within social semiotic theory, both with regard to systemic functional linguistics (Halliday & Matthiessen, 2004) and to social semiotic perspectives on multimodality (Kress & Van Leeuwen, 2021). In the data collection, the authentic everyday interaction and communication between the students themselves and the teacher–student interactions have been in focus. In these situations, the wide range of resources that the participants drew on in the interaction were important focal points. To apprehend the students' process of creating meaning, a research design and data collection method rooted in ethnography was employed (Denscombe, 2017). The approach involved non-participant observation, aiming to minimise disruption to the actions of students and teachers.

The analytic procedure

This study aims to deepen the understanding of how socially shaped and culturally and disciplinary given resources are used for meaning-making in multilingual science classrooms. It reanalyses data previously used to explore multilingual students' authentic use of their first and second languages in a translanguaging science classroom (Karlsson et al., 2019; 2020). Employing multimodal interaction analysis (MIA) (Wilmes & Siry, 2021), this study highlights multimodal resources rather than treating them solely as supplementary to linguistic resources. This approach opens new avenues for elucidating the potential meanings of the semiotic resources used in interactive learning processes

within translanguaging science classrooms, encompassing both verbal and non-verbal modalities, and how these resources can support learning for multilingual students.

In the initial phase of analysis, all collected data were carefully reviewed, with a focus on interactions where students and teachers utilised a variety of semiotic resources – both verbal and non-verbal. From this review, approximately 10 hours of content-related interactions were selected for in-depth analysis.

The second phase specifically analysed visual modes and embodied interaction resources. To foreground non-verbal resources, video recordings were observed with the sound muted. This methodological shift deliberately moved away from a verbal language-centric perspective, focusing on visual and embodied interactions.

This analysis revealed that students and teachers employ a variety of meaning-making resources beyond spoken language, such as gestures, body language, drawings, artefacts, and facial expressions. These findings are consistent with current research in the field (Cheng et al., 2020; Siry & Gorges, 2020; Tang et al., 2022; Ünsal et al., 2018; 2020; Williams, 2022). The complexity of these interactions was evident, as visual and embodied resources were often integrated with verbal communication. This necessitated an analytical approach that considered the interplay of all semiotic resources.

In the final phase of the analysis, typical situations were identified where diverse meaning-making resources were employed. These resources included gestures, visual aids, artefacts, first and second languages, as well as everyday and subject-specific language. The analysis focused on understanding how these resources function within specific contexts, exploring their roles in meaning-making processes, discursive shifts, and their contribution to deepening subject-specific understanding. In the results chapter, the concept *multilingual discursive loops* (Karlsson et al., 2022) is used to describe these processes. Key questions guiding the analysis included: What resources are employed to facilitate understanding of activities and subject matter, to articulate and convey knowledge, and to deepen subject-specific understanding? How do these resources contribute to the learning process, and what are their limitations? Furthermore, how do these resources interact and complement each other in this context? By addressing these questions, the study illuminates the complex interplay of semiotic resources in translanguaging science classrooms.

The process of verbal transcription was carried out in collaboration with a translator fluent in Arabic and was subsequently reviewed by a university associate who is a native Arabic speaker. To enhance the readability of the transcriptions, the rules of written language is adhered. The recordings were initially transcribed in the spoken language (Swedish and Arabic), and this transcription was subsequently translated into English. The original utterances of the speakers in Swedish or Arabic can be found in Appendix. Utterances that incorporate both Swedish and Arabic are presented twice (first in Arabic and English, then in English alone), and the multimodal utterances are represented by still images from the video recording. A contextual description of the situation is provided in the final column.

Results

The results section presents the utilisation and interplay of various semiotic resources in meaning-making processes within a translanguaging science classroom. To illustrate these processes, four representative conversation sequences from Grade 5 (Excerpts 1–4) have been selected.

What is a tornado?

The class has been working on various weather phenomena during some lessons, exploring how they arise and the consequences that severe storms can have on communities. During this lesson, the students are asked to collectively reflect and write down their thoughts on the subject. Maha, Fatme, and Ahmed work together and Fatme suggests they can write about tornadoes. First, Maha is annoyed and turns to the teacher to ask why they always must explain everything, but after a while, when it is time for the students to present their reflections to the teacher and the other students in the class, Maha explains to Fatme what a tornado is (Figure 1).

The excerpt demonstrates that Maha employs various semiotic resources when explaining to Fatme what a tornado is. Maha uses gestures to illustrate how the air currents in a tornado move. She moves her hand in a circular motion while saying ‘a kind of air’ (1) and then moves her hand in a circular motion up and down, saying ‘whirl’ (2). After this, she begins drawing circular lines around a centre on a paper and says, ‘it spins like this on the floor’ (3). In the class, it is common for students to use the word ‘floor’ instead of the ‘ground’. Then she lifts the pencil and moves it in a circular motion upward, saying ‘and like this’ (4), and then she continues to draw with the circular lines on the paper (5). After a short while, Maha stops drawing and explains to Fatme what to write: ‘some countries are affected/for example/like China or write the Philippines/they are also affected’ (6).

The movements in the powerful vortex winds of a tornado are primarily mediated through gestures and drawings. Gestures in the form of circular motions depict the tornado’s swirling storm (2), and the drawings illustrate how the tornado initially moves in a ground-level vortex (3) before forming an almost vertically rising air vortex (4). The subsequent consequences of tornadoes – that they can destroy everything in their path – are expressed in verbal language, first in speech and then written on paper (1, 6), and the reasons for the formation of tornadoes are expressed through both gestures and verbal language (1).

The excerpt shows how each modality contributes to the formation of a comprehensive understanding of what a tornado is, based on Maha’s prior experience and knowledge: how they occur, how air currents move, the consequences of tornado, and where they can occur. The excerpt is a typical example from the data material and shows how the movements of various phenomena are usually mediated through gestures in combination with objects, drawing, or verbal language. The locations (the floor, China, and the Philippines) and consequences of events (it kills people) are mainly mediated through verbal language. In this way, the semiotic resources complement each other, and creating ensembles of modalities that are used fluidly and without boundaries, which He and Lin (2022) call trans-semiotising. The next excerpts show how drawn picture on the whiteboard, gestures (Figure 2), and students’ first language (Figure 3) interact in the meaning-making process.

A whole-class discussion about the different parts of the plant

The second example shows a whole-class situation in which the class together read a text about the structure of trees and their growth. The mother-tongue teacher (Hoda) is a






Turn	Person	Transcription (Appendix 1)	Image	Contextual description
1.	Maha:	Tornado I know / write tornado affects many countries / tornado / tornado / it kills people / it is a kind of air / and it comes when it is very cold		Maha moves her hand in a circular motion while saying a kind of air.
2.	Maha:	Whirl		Maha moves her hand in a circular motion up and down while saying whirl.
3.	Maha:	It spins like this on the floor		Maha draws with a circular motion on the paper while saying that it spins like that on the floor.
4.	Maha:	And like this		Maha moves the pen in an upward circular motion.
5.	Maha:			Maha continues to draw with a circular motion on the paper.
6.	Maha:	Some countries are affected / for example / like China or write the Philippines / they are also affected		Maha stops drawing and tells Fatme what to write.

Figure 1. Excerpt 1: 140113K1 [46:24–47:08]; Maha, Fatme and Ahmed.

resource in the classroom and supports Kamal, a newly arrived student. Hoda sits next to Kamal and explains to him in both Swedish and Arabic. The text is displayed digitally on the board and the teacher follows in the text with a pencil, sentence by sentence. In the text, trees are compared to flowers, and when the teacher comes to the sentence ‘Both trees and flowers have roots, tree trunk (on the flower, we say stalk), leaves, and flowers’ the teacher asks the students, ‘What does this sentence mean?’ None of the students respond. The teacher then says that they are welcome to draw, if they think it is easier. Then Musa raises his hand and the teacher asks him to draw on the board (Figure 2).


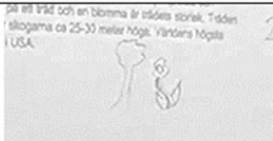


Turn	Person	Transcription (Appendix 1)	Image	Contextual description
8.	Musa:	What should I draw?		Musa asks the teacher what he should draw.
9.	Maria:	You are to draw a tree trunk on a tree and a stalk on a flower		The teacher tells Musa to draw a tree with a tree trunk and a flower with a stalk.
10.	Musa:	Where should I draw / Here?		Musa wonders where on the board he should draw.
11.	Maria:	Yes / you can do that for so long / just so we will see / so everyone understands what tree trunk...		The teacher says that it is not so important where he draws, the important thing is that everyone understands.
12.	Zein:	... who does not know what a tree trunk is		Zein questions, saying that everyone knows what a tree trunk is.
13.	Maria:	But only so you have / so everyone really knows / I want to know that everyone knows		The teacher replies that it is important that everyone understands.
14.	Musa:			Musa draws a tree and a flower on the board.
15.	Musa:	It is very big		Musa points to the flower.
16.	Maria:	Yes / it does not matter / it does not matter		
17.	Maria:	Here we have the tree trunk		Maria points to the tree trunk and says, 'here we have the tree trunk'.
18.	Maria:	...And here we have the stalk		The she points to the stalk and says, 'and here we have the stalk'.
19.	Maria:	Is there any word in Arabic for tree trunk / on tree?		The teacher asks the class what tree trunk is in Arabic.

Figure 2. Excerpt 2: 140513K5a [11.35–12:17]; A whole-class conversation.

After Musa has drawn a tree and a flower and the teacher has pointed to the tree trunk and stalk, the teacher asks the students what the words for tree trunk and stalk are in Arabic. Maria often asks the students how words and concepts are expressed in Arabic. When none of the students respond, Hoda prompts the class to respond. Then

Turn	Person	Transcription (Appendix 1)	Image	Contextual description
20.	Hoda:	It is called the same / Zay maqolt / gid[^] chagara wa gid[^] elwarde It is called the same / as I said / the tree trunk to the tree and the tree trunk to the flower		Then, the mother-tongue teacher explains for the class that ‘tree trunk’ and ‘stalk’ corresponds to the same Arabic word ‘gid [^] ’.
21.	Nabaa:	Do they have the same name?		Nabaa asks, ‘Do they [“tree trunk” and “stalk”] have the same name [gid [^] in Arabic]?’
22.	Hoda:	Yes gid[^] cha... Yes the trunk to the thr...		The mother-tongue teacher confirms Nabaa’s question.
23.	Maria:	...Does it have the same name on a flower as on...?		But is interrupted by the Swedish-speaking teacher, who seems surprised.
24.	Hoda:	...Yes it has the same name / gid[^] chagara wa gid[^] elwarde ...Yes it has the same name / the tree trunk to the tree and the tree trunk to the flower		Again, the mother-tongue teacher confirms.
25.	Nabaa:	Then you just add tree and flower		Nabaa states that the words ‘tree’ and ‘flower’ are just added to the word ‘trunk’.

Figure 3. Excerpt 3: 140513K5a [13.00–13:13]; A whole-class conversation.

Ali replies ‘gid[^]’ (tree trunk) in Arabic. After this, Maria asks what ‘stalk’ is in Arabic, but none of the students answer this question, so Hoda explains (Figure 3).

In Excerpt 2 (Figure 2), the meaning of the words ‘tree trunk’ and ‘stalk’ are clarified as Musa draws a tree and a flower on the board (14), and the teacher points first to the tree trunk (17) and then to the stalk (18) while saying, ‘here we have the tree trunk’ (17) and ‘and here we have the stalk’ (18). Zein questions why a tree trunk should be drawn on the board and argues that everyone surely knows what a tree trunk is (12). The teacher explains that she wants to make sure that everyone really knows what a tree trunk and a stalk are (13). After the teacher has pointed out the tree trunk and the stalk, she asks the students, ‘Is there any word in Arabic for tree trunk/on trees’ (19). Encouraged by Hoda, Ali answers, ‘gid[^]’ (tree trunk) in Arabic. The teacher then asks what the word ‘stalk’ is in Arabic, but none of the students respond. Then Hoda explains (Figure 3) that in Arabic it is called the same, ‘gid[^] chagara wa gid[^] elwarde’ (the tree trunk to the tree and the tree trunk to the flower) (20). Nabaa (21) and the teacher Maria (22) ask if it is called the same and Hoda confirms that it is (24). Nabaa notes that, in Arabic, the words tree and flower are just added to the Arabic word ‘gid[^]’ depending on whether it is a tree trunk or a stalk (25).

The words ‘tree trunk’ and ‘stalk’ are first clarified for the students through drawn pictures on the board. Then the concepts are further clarified as the teacher first points to the tree trunk and verbally expresses the word ‘tree trunk’ and then the stalk in the same manner. After this, the teacher introduces another semiotic resource, Arabic, which is the students’ first language, and through a metalinguistic comparison between Swedish and Arabic, the students are given another semiotic resource in this process of meaning-making. The mother-tongue teacher clarifies the meaning of the words by using the everyday expression: ‘gid[^] chagara wa gid[^] elwarde’ (the tree trunk to the

tree and the tree trunk to the flower) (20, 24), to facilitate the students' comprehension of the distinctions between the languages and advance their grasp of the subject matter.

This example illustrates how the students are given the opportunity to create understanding of the subject content through multiple semiotic resources, both visually and verbally. Employing both Swedish and Arabic facilitates a meta-linguistic comparison between national languages, serving as a resource for creating meaning. This acts as a supportive structure, bolstering students' linguistic development in both languages and thereby enhancing their understanding of scientific content. Nonetheless, the students did not come across the Arabic term 'Saq', an academic word for 'stalk', which is seldom utilised in daily situations or within the context of primary education. Hence, this conversation remained in everyday discourse and did not move towards the more scientific discourse. Furthermore, the example illustrates a well-known language phenomenon whereby words in one language does not always have a simple corresponding word in another language, which can pose challenges for multilingual students in science. For instance, the Arabic word 'gid^' has evolved within the Arabic-speaking part of the world and gained its meaning potential in this context, while the Swedish word 'stam' (tree trunk) has developed in Sweden in a different contextual setting, where over 70 percent of the land area is covered by forests. Consequently, the words 'gid^' and 'stam' do not quite carry the same meaning; instead, their meaning potentials overlap, creating a more nuanced understanding of the concept of tree trunk. The next excerpt illustrates the use of object, national and discursive languages, and how this can create a broader and deeper understanding of the subject content.

The trees topple over in the storm

The class continues to read the text about the structure and growth of trees. The teacher (Maria) reads: 'The tree needs a good root system to hold the tree in place. If there is a storm and the tree does not have a good root system, the tree will topple over in the storm'. After this sentence, Maria tells the students about how the last storm had toppled over several trees, so that the trees' root systems had become visible. Encouraged by Hoda, Kamal, the newly arrived student, raises his hand and ask what 'topple over' means. Maria goes back to the sentence on the board and reads it once more. After that she asks the class, 'what does topple over mean/what do you think?' Many students raise their hands and want to answer the question (Figure 4).

To explain what 'topple over' means, Maria first puts the word into its context by reading the sentence once again. After that, she asks the students to explain what the word means. Salam replies 'that it falls' (27). Maria then asks if there is 'a word for topple over in Arabic' (28). Ali answers 'taqaa al shagara' (the tree lies) (30) in standard Arabic. In Arabic, 'taqaa' is usually used to express that something is located in a place, that the trees are located on the ground. The more correct expression for 'the tree falls' in standard Arabic is 'tasqutu al shagara'. Hoda hears Ahmed, sitting at the next table, use another word for 'fall' in Arabic and asks him to repeat it (31). Ahmed then says 'toqaa' (fall) (32), which is an everyday expression in dialect. Hoda confirms by repeating both the Arabic words 'toqaa, taqaa wla toqaa' (falls, lies or falls) (33). Zein, who is sitting across from Kamal and Hoda, then claps his hands and says 'tahaar' (gone) (34), which is standard Arabic and is usually used in the expression 'gone with the wind'. Maria




Turn	Person	Transcription (Appendix 1)	Image	Contextual description
26.	Maria:	What do you think Salam?		The teacher lets Salam speak.
27.	Salam:	That it falls		Nabaa answers 'that it falls'.
28.	Maria:	That it falls / do we have a word for topple over in Arabic?		The teacher asks the class for the Arabic word for fall.
29.	Maria:	Ali		The teacher gives the floor to Ali.
30.	Ali:	Taqaa al shagara The tree lies		Ali replies 'taqaa al shagara' in standard Arabic.
31.	Hoda:	Taqaa wla you also said something / just say it a little bit louder Lie or you also said something / just say it a little bit louder		The mother-tongue teacher hears Ahmed, sitting at the next table, say another word for 'fall' in Arabic and asks him to repeat it.
32.	Ahmed:	Toqaa Fall		Ahmed then says 'toqaa', which is a more everyday expression for fall in Arabic.
33.	Hoda:	Toqaa / taqaa wla toqaa Falls / lies or falls		Hoda repeats the words 'toqaa' and 'taqaa'.
34.	Zein:	Tahar Gone		Zein, sitting across from Kamal and Hoda, clasps his hands together and says 'tahar', which is standard Arabic and means that something disappears.
35.	Maria:	Did you get wiser Kamal? You did understand that it is falls?		The teacher asks Kamal if he understands what falling means.
36.	Zein:			Zein shows with his whole body how something falls over to the side.
37.	Kamal:			Kamal says nothing.
38.	Nabaa:			Nabaa who is sitting next to Kamal raises her hand.
39.	Maria:	Nabaa		The teacher gives Nabaa the floor.
40.	Nabaa:	I topple over now		Nabaa takes a pencil and stands it upright and dropping it aside as she is saying, 'I topple over now'. At the same time, Zein knocks over his eraser.
41.	Maria:	Yes / now Nabaa shows how to topple something over		

Figure 4. Excerpt 4: 140513K2 [21:25-21:55]; A whole-class conversation.

asks Kamal if he understands (35), while Zein continues to explain to Kamal what ‘topple over’ means by using his whole body to show how something falls to the side (36). But Kamal does not answer (37). Nabaa, sitting next to Kamal, then takes a pencil, stands it upright and then drops it to the side, saying, ‘I topple over now’ (40), at the same time Zein knocks over his eraser to the side. Maria then exclaims ‘Yes/now Nabaa shows how to topple something over’ (41).

The teacher starts explaining the word by placing the verb in a contextual context, in a subject-specific school discourse; then the conversation moves towards an everyday discourse through Nabaa’s everyday expression for falling in Swedish (27). After this, Maria asks for the Arabic expression for falling, and Ali answers that ‘the tree lies’ in standard Arabic (30); in this way, Ali’s linguistic repertoire helps move the meaning-making process towards a more subject-specific discourse. Ahmed’s more everyday expression of falling in Arabic brings the conversation back towards an everyday discourse again (32). Then, Zein brings in another aspect of the subject matter, that the trees are disappearing; he expresses this by clapping his hands together while saying ‘gone’ in standard Arabic (34). In this way, the meaning-making process is moving in multilingual discursive loops and gives the students both everyday and subject-specific verbal expressions for ‘topple over’, in both Swedish and Arabic. Despite this, Kamal does not seem to understand what the verb means. Zein tries to visually explain by putting his hands together (34); he also uses his whole body to show how something falls to the side (36). Finally, Nabaa intervenes and explains by placing a pencil vertically and tipping it to the side, while saying, ‘I topple over now’. Maria seems grateful for Nabaa’s help and then continues reading the text, which can be interpreted as her being convinced that Kamal understands what ‘topple over’ means.

This excerpt (Figure 4) is typical example of how teachers and students together use a diversity of semiotic resources to explain subject-specific words and concepts as well as subject content to each other in a translanguaging science classroom. The communication involves multiple modes, with each mode playing distinct roles in shaping a comprehensive whole (Kress & Van Leeuwen, 2021). The conversations move in discursive loops between both national and discursive languages together with multimodal resources. All available resources are used in the negotiations about the science subject content. For instance, the example shows how multimodal resources are often used to create continuity in meaning-making processes when the verbal language resources are limited (34, 36, 40). The verb ‘topple over’ is first explained with a synonym in Swedish, which translates into Arabic, but it is only when Nabaa uses a pencil to visually illustrate how a tree falls that Kamal seems to understand what ‘topple over’ means and the teacher can continue reading the text. This use of object and artefacts for meaning-making is repeated throughout the data material. Furthermore, the example shows how students and teachers move in discursive loops between an everyday way of expression (such as *toqaa*) and a more scientific way (e.g. *taqaat*, *tahar*), and how this creates a diversity of semiotic resources in the meaning-making processes. The text and the conversation are about the root systems of trees and how trees can topple when there is a storm; through the students’ use of a variety of semiotic resources, a comprehensive understanding of the subject content is created. The verbal synonym in Swedish (27), the everyday expression for falling in Arabic (32) and the visually expressions for how something topples over (34, 36, 40) contribute to the understanding of that trees are falling when

there is a storm. Ali's contribution in Standard Arabic 'taqaa al shagara' (the tree lies) (30) expands the understanding by suggesting that trees that fall in the storm are placed on the ground, while Zein's expression 'tahaar' (gone) (34) explains that the trees will eventually disappear. In this way, an orchestra of all available semiotic resources is created, which together shapes a comprehensive whole and becomes an asset for developing a broader and deeper understanding of the science subject content.

Discussion

The results indicate that in a translanguaging science classroom, there are multiple pathways to active participation and socialisation into the discourse of science. These pathways can be continuously developed based on students' prior experiences, knowledge, and needs. Throughout these developmental processes, a diversity of communicative repertoires offers a rich array of meaning-making resources that should be fully utilised to enhance students' opportunities to develop their understanding of scientific content. This article contributes to a deeper understanding of the specific functions of various semiotic resources in a translanguaging science classroom and explores how these resources interact and complement one another in the meaning-making process.

The results show that multimodal modes of expression, such as gestures, drawing and the use of objects and artefacts, often facilitate communication and contribute to continuity in the science activities, which is consistent with current research in the field (Cheng et al., 2020; Knain et al., 2021). The multimodal resources are usually related to verbal language, in such a way that they both interact with and complement verbal language resources (Ünsal et al., 2018; 2020). In certain meaning-making situations, multimodal resources are mainly used to clarify and visualise what is being expressed verbally, such as when Nabaa uses a pencil to illustrate how a tree topples over (40). In other situations, the resources are used to mediate the scientific subject content through gestures, drawing or handling of objects, and the verbal language becomes a resource for verbally naming the phenomena that are mediated, such as when teacher Maria points to the tree trunk and the stalk on the whiteboard and verbally expresses 'tree trunk' and 'stalk' (17, 18). Another example is when Maha mediates the air currents in a tornado through gestures and drawing, and verbal language is used to name these air currents, but also to urge classmates to focus on her gestures 'like this' (4). Both students and teachers often use such gestures and drawing to express movement and change of position (moving, swinging, rotating, twisting, shaking, etc.).

Moreover, the non-verbal resources are often closely tied to their local context and are usually developed in interactive processes, for example a pencil can symbolise a tree falling over (40) or a circling gesture can show how the wind in a vortex moves (2). In other words, the verbal language is often supported by opportunities in the environment, such as gestures, demonstrations and physical objects, in the construction of knowledge in practical contexts (Kress & Van Leeuwen, 2021). In this way, non-verbal resources or various semiotic modes can be especially valuable in multilingual settings as they can ease communication by substituting for missing words in monolingual interactions or reinforcing the significance of words from diverse languages in a science classroom that employs translanguaging (Ünsal et al., 2018; 2020).

Furthermore, the analysis shows how the multilingual participants' linguistic repertoires in a translanguaging science classroom help to broaden and deepen their understanding of the subject content. This becomes especially clear in the last excerpt (Figure 4), in the meaning-making process about trees that topple over in the storm. The linguistic repertoires of multilingual students generate a wealth of semiotic resources, including everyday and subject-specific languages in both Swedish and Arabic, gestures, and objects. Together in dialogue, these resources contribute to creating enhanced conditions for a comprehensive understanding of the subject content, such as the fact that trees that topple over in a storm fall to the ground and eventually decay or are used as timber. The question is whether such a comprehensive understanding would have been possible if the students had only used their second language (Swedish), or if the conversation had been limited to a simple translation of the term 'topple over'. This example illustrates how the use of multiple languages and multimodal resources in a translanguaging science classroom can enrich students' understanding. Additionally, this approach provides the opportunity to understand the subject from different cultural perspectives and creates an inclusive learning environment in which students can build bridges between their different knowledge and experiences, thus creating deeper connections and understanding.

Another result is the importance of the multilingual study guidance for the students' opportunities to clarify the scientific content through the first language, and to relate and see connections between Arabic and Swedish terms at a meta-linguistic level. An example of this is when the mother-tongue teacher, Hoda, explains the meaning of the terms 'tree trunk' and 'stalk' by connecting them to everyday expressions in Arabic (Figure 3). In explanations of the subject content, Hoda usually moves the conversation towards everyday discourse by translating and explaining subject-specific words and concepts in Swedish into everyday expressions in Arabic. This explanatory strategy is consistent throughout the data material; it also corresponds with other current research in the area (Axelsson, 2023; Cheng et al., 2020). Mother-tongue teachers' explanations of the scientific subject content by linking it to everyday expressions in Arabic often help create continuity in the science activities. However, the method can be problematic because the meaning-making conversation moves towards an everyday discourse, which risks limiting the multilingual students' opportunity to use their entire linguistic repertoire. By restricting the use of subject-specific terms in standard Arabic, there may be a risk that students, especially those with previous school backgrounds in their home countries, do not have access to all the meaning-making resources available and required for a deeper understanding of the subject content.

In summary, the findings underscore the pivotal role of multimodal expressions – such as gestures, illustrations, and the use of objects – in facilitating communication and ensuring continuity in science activities. These multimodal resources complement verbal language, providing students with diverse and enriched pathways to express and comprehend scientific content. Furthermore, the study reveals that employing multilingual linguistic repertoires can significantly broaden and deepen students' understanding of the subject matter. Integrating multiple languages along with multimodal resources not only increases students' opportunities to achieve a more comprehensive grasp of the scientific content but also bridge different cultural perspectives, thereby promoting an inclusive learning environment. These insights suggest practical strategies for

educators, including the intentional integration of multimodal and multilingual resources to enhance comprehension and inclusion in science education, and acknowledge 'the value of the host of resources students bring to science learning by working towards flexible classroom structures that provide space for students to fluidly engage and further develop the semiotic resources they already have at hand' (Siry & Gorges, 2020, p. 2365).

This raises important questions about how teaching and learning in translanguaging science classrooms can be enhanced. Future research should explore how socially, culturally, and disciplinarily shaped resources for meaning-making can be utilised in a dialogic practice to promote all students' comprehension, interpretation, and application of scientific concepts, methods, and approaches. Addressing these challenges is crucial for developing a science education that responds to the needs of diverse learners in an increasingly globalised educational landscape.

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Ethical statement

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Appendix

The speakers' origin utterances in Swedish or Arabic

- (1) Tornado jag vet/skriv tornado drabbar många länder/tornado/tornadon den dödar människor/det är en sorts luft och det kommer när det är jättekallt
- (2) Virvel
- (3) Den snurrar så på golvet
- (4) Och så
- (5) –
- (6) Vissa länder drabbas till exempel som Kina eller skriv Filipinerna de drabbas också
- (7) –
- (8) Vad ska jag rita?
- (9) Du ska rita en stam på ett träd och en stjälk på en blomma
- (10) Var ska jag rita/här?
- (11) Ja/det kan du göra så länge/bara så får vi se/så alla förstår vad stam ...
- (12) ... vem vet inte vad stam är?
- (13) Men bara så man har/så alla vet verkligen/jag vill veta att alla vet
- (14) –
- (15) Den är jättstor
- (16) Ja/det spelar ingen roll/det spelar ingen roll
- (17) Här har vi stammen
- (18) Och där har vi stjälken
- (19) Finns det något ord på arabiska för stam/på träd
- (20) Det heter samma/**zay maqolt/gid[^] chagara wa gid[^] elwarde**
- (21) Heter det samma sak?
- (22) Ja **gid[^] cha ...**
- (23) ... heter det samma sak på blomma som på ...
- (24) ... ja det heter samma/**gid[^] chagara wa gid[^] elwarde**
- (25) då lägger man bara till träd och blomma
- (26) Vad tror du Salam?
- (27) Att det trillar

- (28) Att det trillar/har vi något ord för välter på arabiska?
- (29) Ali
- (30) **Taqaa al shagara**
- (31) **Taqaa wla** du sa också någonting lite högre bara
- (32) **Toqaa**
- (33) **Toqaa/taqaa wla toqaa**
- (34) **Tahar**
- (35) Blev du klokare Kamal? Du förstod att det är trillar?
- (36) –
- (37) –
- (38) –
- (39) Nabaa
- (40) Jag välter nu
- (41) Ja/nu visar Nabaa hur man välter någonting