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RESEARCH ARTICLE

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Young children's translanguaging as emergent in and through open-ended science pedagogies

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Abstract

Equity-focused calls for elementary education reform recognize the importance of student and teacher translanguaging, yet nuances of how this process unfolds in early childhood science is an underexplored area. This study examines young plurilingual children's participation in science investigations, with a view toward understanding how open-ended pedagogical structures supported their communication and engagement as related to science learning. We examine the work of 4- to 6-year-olds as they participated in a 3-week unit exploring worms and draw upon translanguaging theoretical perspectives to interpretively analyze their interactions in science. Situated in the multilingual national context of Luxembourg, the study examines the interactions of these plurilingual children and their teacher as they investigated worms in varied open-ended pedagogical structures. Schools are trilingual in Luxembourg, yet approximately half of the students in the country's elementary schools do not come to school with proficiency in any of the three languages of instruction. Issues of equity in schooling are thus heavily bound in languages. The robust dataset incorporating video data were examined using multimodal interaction analysis,

and three vignettes zoom in on children's actions, utterances, and materials in open-ended science learning spaces, providing rich examples of classroom structures that support meaningful translanguaging through students' agentic science communication. Young students' communication and science engagement are inseparable, and this study shows that these intertwine through translanguaging, in a process which is emergent when children are able to agentically draw upon diverse resources to make meanings.

KEYWORDS

early childhood science education; elementary science education; embodied engagement; multimodal interaction analysis, agency; structure dialectic, plurilingual students, multilingual learning contexts; translanguaging

INTRODUCTION

> Tom and Henry are sitting at a table in their Kindergarten classroom, each with a bowl in front of them containing some soil and worms. Both are digging in the soil with a plastic spoon, and occasionally Henry finds a worm and puts it in a petri dish next to his bowl, which already contains some worms. Tom says, *Oh my god!* looking at the worms in Henry's Petri dish, while Henry continues digging in the soil, responding *There, there*, pointing at the petri dish and reaching to touch Tom's arm to get his attention, *Henry, oh there there! Chk chk chk chk chk*, tracing a path with his finger from the Petri dish leading outside of it, Tom follows Henry's actions with his eyes, *Oooiiii yes, oh look, he* (...) *that there* (...), pointing at the Petri dish with his finger. Both turn their attention back to their bowls and continue digging in the soil. Henry finds a worm, carefully takes it out of the bowl with his spoon, and the worm falls off the spoon. *Eeeeeeeh!* pulling himself back, then grabbing the worm with his fingers and putting it into the petri dish. At almost the same time. Tom finds a worm and has it on his spoon. *Henry*! He says, showing his spoon to Henry. Henry looks at the spoon Tom is showing him. *Oh my god! Come, there, there*, pointing at the dish with his spoon *Come, there, there, there Tom*, pointing at Tom's dish with his spoon. Tom follows the instructions and puts his worm into his own Petri dish.

While a growing body of research supports translanguaging pedagogies as one path to support equity-focused teaching, teachers report feeling they are lacking resources to implement translanguaging practices, often facing insurmountable challenges when implementing translanguaging instructional approaches. This can prevent them from taking up translanguaging approaches with their students. To do would necessitate the need to coordinate resources and expectations across multiple stakeholders within educational systems (e.g., Ticheloven et al., 2021), and to find ways to navigate monolingual curricular demands (Conteh, 2018). These barriers can lead to the use of superficial forms of translanguaging pedagogies, as has been found in our national context (e.g., Aleksić & García, 2022). This study explores how the

use of open-ended pedagogical structures in a multilingual early childhood setting supported children's translanguaging in science. We seek to contribute to the literature base on translanguaging in science education by exploring interactions in the classroom introduced above as children engage in investigations structured by the teacher to support open-ended exploration, communication, and science sense-making. We examine the interactions taking place as the class investigates worms and vermicomposting to understand how the open-ended structures in Tom and Henry's class afforded inclusive opportunities for children to build from their observations and ideas in ways that were not bound to the language of instruction. The analysis that follows emphasizes that such learning spaces can serve as equity-oriented structures, as the children drew upon a wide range of resources to make and communicate new meanings in science emergent from their wonderings. By examining how the structures provide opportunity and access in ways that build from children's everyday experiences and full repertoires, this study contributes to research on equitable science practices with young children, a field that remains underdeveloped (National Academies of Sciences, Engineering, and Medicine (NASEM), 2022).

As evident in the above exchange, young children's science investigations are highly complex (e.g., Fragkiadaki et al., 2021) and embodied interactions (e.g., Roth et al., 2012), and in this 40-s excerpt we see Tom and Henry communicating using a wide range of resources, including sounds, materials, words, their bodies, and gestures, each entangled, intertwined, and inseparable as they look for worms in the soil. The above interaction is highly emotional, with excitement emergent in the children's discoveries, becoming visible as they show each other worms and then together work jointly to move the worms into petri dishes, a process which is embodied and vocal, with extensive bodily movement and multiple utterances, yet few identifiable words. Our research seeks to uncover, highlight, and valorize this complexity, by demonstrating the resourcefulness (Bengochea et al., 2018) and the brilliance (National Academies of Sciences, Engineering, and Medicine (NASEM), 2022) of these children as they engage in learning about worms and vermicomposting. We adopt resource-rich perspectives on what young plurilingual children do when they engage in science investigations (e.g., Siry, 2011), and in this article we draw on translanguaging perspectives to guide analysis of children's interactions in science with the goal of drawing implications for classroom structures that build from children's resources.

In our context, multilingual curricular opportunities are often implemented in surface ways, meaning opportunities to build upon students' diverse communicative resources are limited and restrict opportunities for student equity and inclusion (Aleksić & García, 2022). This drives our motivation to seek out and provide examples of meaningful translanguaging opportunities that support learning by having science sense-making emerge and build from children's resources. Our emergent analytic process led us to explore the following question:

How do open-ended science learning spaces mediate children's opportunities for translanguaging and sense making?

With this question, we were able to consider how children's agentic science engagement unfolded, which allowed us to see how the structures mediated moments of translanguaging. This led to views on how the teacher built from children's engagement in ways that fostered equitable and inclusive science learning opportunities.

1 | GUIDING FRAMEWORKS AND PERSPECTIVES

Our work is guided by cultural studies theoretical lenses (i.e., Kincheloe, 2005; Schutz, 1967; Sewell, 1992; Tobin, 2015) and we conceive of science education as cultural enactment—it is a

lived practice (Hwang & Roth, 2011) that is emergent from interactions of symbolic, social, and material resources. Science learning occurs through embodied interactions in the dynamic and dialectic relationship between learners and their contexts (e.g., Otrel-Cass, 2024; Rahm, 2024; Varelas et al., 2022). A key part of learning is about developing repertoires of cultural practices (Swidler, 1986), practices that are given value within a particular community (Lave & Wenger, 1991). As elaborated in the sections that follow, the science education praxis that we hope to encourage in our work with teachers is one that engages learners in the culture and practices of science by honoring and building from the diversity of resources that young children bring to open-ended science learning spaces. Students use emotions, reflections, and experiences from areas other than school for sense-making when provided with opportunities to engage in open-ended tasks in science (Book & Tandberg, 2024), and such classroom structures can serve as inclusive and equity-oriented approaches, as they allow for children's participation in myriad ways, and as such can be accessible to all students. On the overall, our projects are motivated by seeking to understand nuances of the relationship between these structures and young children's agentic participation as we examine what emerges in interaction to understand how open-ended pedagogical structures shape children's science learning and engagement in investigation-driven science education.

1.1 | Investigation-driven early childhood science

An important approach for supporting children in learning science is to create opportunities for engaging in science practices that includes wondering, questioning, exploring and communicating, as routes to building science understandings (NGSS Lead States, 2013; National Research Council (NRC), 2012). Investigation-driven science education at the early childhood level can support children's engagement in science activities (Lehrer & Schauble, 2015; Schwarz et al., 2017) emergent from their every-day worlds (Bang et al., 2012) and nurture critical processes of sense-making (Braaten et al., 2020). Pedagogical approaches that support students in developing and learning science through investigations have been framed as inquiry-based science education (National Research Council (NRC), 2012), providing opportunities for investigating the world through engagement in science practices (NGSS Lead States, 2013). Open-ended investigation-driven science education positions children to engage in science practices and work collectively in ways that can lead to emotions such as wonder, excitement, and joy (Wilmes, 2021). Through children's direct exploration of science phenomena, they can make sense of their everyday experiences, and are provided with opportunities to build understandings and use ideas to come to understand and engage with the world, in particular when there is time and space for wonderings and questions that are meaningful to them (e.g., Fleer, 2023; National Academies of Sciences, Engineering, and Medicine (NASEM), 2022). Such meaningful exploration leads to authentic experiences for documenting and communicating, which are central aspects of investigation-driven science education and essential to developing science understandings.

Our work begins from the position that young children can create novel understandings of the world through engagement in rich science experiences. We believe that an inclusive and equity-oriented early childhood science education creates spaces for children to engage in opportunities to pursue their interests in ways that are valorized, communicated and built upon (National Academies of Sciences, Engineering, and Medicine (NASEM), 2022). Building from children's interests in science provides a basis for relevant science content to emerge (Raven &

Wenner, 2023), and can shift the focus of learning from the teacher to the collective interests of the students, and with that in mind we collaborate with teachers to create open-ended pedagogical structures for students to engage in science exploration (e.g., Siry et al., 2016; 2024 Open-ended investigation is central to science inquiry, and children's authentic engagement in science creates a space for science learning and communication to unfold from students' interests. Children's wonderings within open-ended exploration provide a valuable resource for meaning-making in science (e.g., Monteira & Jimenez-Aleixandre, 2016; Siry & Max, 2013), and opportunities for such open-ended science investigations can position students to take agency in new ways (Arnold, 2012; Vaughn, 2019).

1.2 | Science education through the agency | structure dialectic

Herein, we turn to the agency | structure dialectic (Sewell, 1992)[1] to understand the ways in which science sense-making emerges within the open-ended structures and how this process agentically unfolds. Agency is the "socioculturally mediated capacity to act" (Ahearn, 2001, p.112), which can be viewed as "a student's desire, ability, and power to determine their own course of action (whether that means choosing a learning goal, a topic to study, an activity to pursue, or a means of pursuing it)" (Vaughn, 2018, p. 63). Dialectics allows for exploring relationships between differing social constructs that are together holistically, implying that each of these constructs is "recursively related, presupposes the existence of the other, does not exist independently of the others, and does not precede the others temporally" (Tobin, 2015, p. 7)—meaning both exist at the same time, together, and through this relationship, as one shifts so does the other. This grounding allows for exploring the ways in which a student's ability to be agentic in a particular classroom situation is dialectically related to the structures at hand. Structures consist of both schemas, which are virtual, and resources, which are actual (Sewell, 1992), and these combine and intersect in a multiplicity of ways (Sewell, 1999). "Agency arises from the actor's knowledge of schemas, which means the ability to apply them to new contexts" (Sewell, 1992, p. 20). Structures in a classroom, including, for example, teachers' expectations, classroom rules, teaching sequences, curricular guidelines, materials, time, space, and so forth—all come together to shape the ways in which a participant can be agentic in a dialectically occurring process. "A focus on the structure–agency dialectic exposes forces that may stifle access, participation, learning, and achievement, but also celebrates the agentic ways in which students, communities, institutions, and educators develop and use in particular contexts" (Varelas, Settlage, & Mensah, 2015, p. 440).

Studies have shown how structures and spaces for children to take agency lead to participating in and contributing to science processes through engagement in meaningful experiences (Varelas et al., 2022; Varelas, Tucker-Raymond, & Richards, 2015), in ways that afford them spaces to direct science explorations and meaning-making (Kane, 2015).

Children's agency is at the core of equity-focused science education (Varelas, Settlage, & Mensah, 2015; Varelas, Tucker-Raymond, & Richards, 2015) and we seek to understand the ways in which the open-ended structures position students relative to science sense-making and communication, and more specifically to consider how these mediate opportunities to communicate. In our prior work, we have shown that spaces for children's open-ended investigation mediated opportunities for children to take agency in ways that afforded learning, participation, investigation, and emotional, collective and joyful exploration (see, e.g., Siry & Gorges, 2020; Gómez Fernández & Siry, 2018; Siry et al., 2024; Siry & Brendel, 2016; Wilmes, 2021). Herein,

we examine children's agentic communication within such structures, thereby revealing that translanguaging emerges from their interactions within such open spaces, as they draw upon a diversity of resources to express and make meaning.

1.2.1 | Translanguaging as a lens on learning

Translanguaging is "the deployment of a speaker's full linguistic repertoire without regard for watchful adherence to the socially and politically defined boundaries of named (and usually national and state) languages" (Otheguy et al., 2015, p. 283). It is a communicative process through which speakers flexibly draw upon resources (e.g., García & Wei, 2014), with the trans-prefix implying going beyond named languages (García & Wei, 2014). In comparison with views on language use in social spaces which segregate and separate language use within the borders of national languages, through translanguaging, communication is a dynamic, emergent process that unfolds in contextualized ways through social interaction (Lin et al., 2020). It is a process of drawing on diverse communicative resources, through fluid use of dynamic resources with local and global connections (Moore et al. 2018). The term translanguaging is used in a range of ways in the literature, emergent from Baker's (2011) English translation of a Welsh term, *trawsieithu*, that was used by Williams (1994) in groundbreaking work describing pedagogical practices teachers were using in Welsh revitalization programs (Charamba, 2019). The term has since been widened through literature, to include the original focus on pedagogy, and extended in explorations of how students and teachers employ translanguaging practices in formal and informal school settings, and how such ways of interacting and approaching teaching and learning can support equitable and justice-oriented learning opportunities for diverse learners.

"Translanguaging is about boundaries crossing, be it the boundaries between languages, modalities or materiality, or at the symbolic level, the existing status quo and structures" (Hua & Wei, 2022, p. 2), and we draw on translanguaging theories (e.g., Wei, 2018) to make sense of what we were seeing unfold in communication as we explore how children's engagement and sense-making evolves within the open-ended learning spaces. On the overall, we seek to understand how these structures shape children's science communication, learning, and engagement, and translanguaging provides a compelling lens.

1.2.2 | Translanguaging in science education

Turning to science learning contexts specifically, there is a rapidly expanding body of research exploring translanguaging in science education (e.g.; Jakobsson et al., 2022; Suárez & Otero, 2024; this JRST special issue), with studies examining the ways in which teachers and students' use of translanguaging mediates their science learning in different learning settings and linguistic contexts. For example, Espinosa et al. (2016) examined a dual language bilingual classroom in the United States, illustrating the ways in which a teacher used both her own, as well as her students', linguistic repertoires in ways that supported science learning and thinking while maximizing their interactions. Through this examination, they demonstrate the complex way in which translanguaging mediated both the students' science and language learning. Charamba (2019) explored how translanguaging practices in a secondary General Science classroom in rural Zimbabwe mediated students' science learning, with his study indicating that

instructional materials prepared in students' home languages created a comfortable learning environment while positively affecting students' performance in science tests. Charamba's study reveals how the students' home language provided a scaffold to learning science, which mediated their engagement and positioned their home language as a resource to science learning.

Relative to translanguaging in elementary contexts, the focus on languages as resources to learning science is also key to Jakobsson et al.'s (2022) work, whereby they demonstrate how a translanguaging science classroom serves as a resource for negotiating the content and language of science, while also supporting students' relations and connections to the content. Lemmi et al. (2022) examine translanguaging acts between a student and teacher in an elementary context in the United States. Through an analytical process grounded in conversation analysis, they show how student's translanguaging helped in ways that furthered academic purposes, but also and as equally important, for social purposes. Drawing on Spanish and English communicative resources afforded opportunities for students to be humorous. In this way translanguaging in this classroom supported developing science understandings, and relationships with fellow students. Their work positions translanguaging as a pedagogical approach that works to undo English-dominant spaces and to center marginalized students' ways of communicating in formal classroom settings. With a lens on informal science learning contexts, Suárez (2020) focused on elementary-aged emergent bilingual students participating in an out-of-school program to explore how students engaged in different kinds of translanguaging practices when problematizing electrical phenomena and co-constructing knowledge. His work demonstrates the nuanced ways in which students leveraged multiple linguistic and nonlinguistic semiotic resources, resources that became both tools for communicating as well for making new meanings. These studies offer important insights into the value of translanguaging as a pedagogical foundation for science across a range of age levels and provide important perspectives on students' and teachers' use of translanguaging in a diversity of contexts. Our work hopes to add a layer to the field's understandings by considering the ways in which early childhood aged plurilingual children communicate while doing science and the wide range of resources they draw upon within open-ended learning spaces.

Research into young children's practices in school settings illustrates the complexities of communication and interaction in different contexts, emphasizing the multiplicity of ways in which young learners weave together semiotic resources—including linguistic resources; paralinguistic resources, meaning the aspects of spoken communication that are not words; and extralinguistic, including gestures and facial expressions—in interaction to make meanings and to better understand their reality (e.g., Bengochea et al., 2018; Jewitt et al., 2001; Kress & van Leeuwen, 2006). A case study of a newcomer to Luxembourg revealed how he coordinated and attuned a range of semiotic resources in science, demonstrating how assemblages of linguistic, visual, and gestural resources came together to further his communication, as he translanguaged across modes and modalities (Degano and Kirsch, 2020). The complexities of children's communication is also highlighted in a study by Bengochea et al. (2018), through a detailed analysis of a bilingual child's communication with his peers and teachers during play, as he describes, persuades and collaborates through a range of transmodal (including translingual) practices, illustrating how the child employs features from his translanguaging repertoire including his nonverbal modes. Relatedly, in our own work, we have extended our view of the ways in which translanguaging spaces support science learning to take a broad view on students' engagement (Siry et al., 2022), which allows for understanding the fluid, flexible and creative ways students use their communicative repertoires and diverse resources to express and make meaning in science (Siry & Gorges, 2020). This layers with translanguaging perspectives that work to push against separating, dividing and marginalizing in educational contexts,

thereby considering wide ranges of communicative resource use, and transcending boundaries between semiotic resources that are essential for sense-making (Wei, 2022). Our work on the overall seeks to be contextually responsive (Siry & Wilmes, 2020) and we use emergent approaches to allow for research designs that highlight the diversity of resources that young children draw on. As such, our focus on the embodied and material ways in which plurilingual children engage in science emerged in response to our highly diverse context, introduced in the sections that follow, although we contend that this focus is an inclusive orientation that is relevant to all contexts in working toward an equity-oriented science education practice.

2 | STUDY CONTEXT

Luxembourg is a small country in Europe with approximately 660,000 inhabitants (STATEC, 2023). Nestled between its three neighboring countries—France, Germany, and Belgium. Luxembourg's linguistic context is under strong influence of German and French, which are two of the three national languages, with Luxembourgish being only the third national language since 1984. In this multilingual context, the schools have a multilingual curricular policy, meaning that the language of instruction can vary between Luxembourgish, German, and French, depending on the school level and subject. Hence, the three languages are not only the *subjects* of instruction, but also the *means* of instruction. The multilingual school system dates from a time when most children in primary school had Luxembourgish as their first language, and thus the language of instruction for the two years of kindergarten is Luxembourgish. In the first grade, the alphabetization is in German and the general language of instruction switches from Luxembourgish to German. French is added as a third language in second grade and becomes a language of instruction in some branches of secondary school.

2.1 | A super-diverse national context

Until the early 21st century, more than 60% of the children had Luxembourgish as their first language and these students were typically quite successful in this school system, first learning to read and write in a language that is familiar to them and finishing school speaking three to four languages fluently. However, over the past 20 years, the Luxembourgish context has changed rapidly. Today the population is highly diverse, with 47.4% (STATEC, 2023) being foreigners. In today's super-diverse (Vertovec, 2007) context, approximately 32.5% of children enrolled in primary school speak Luxembourgish at home, fewer than in past years (MENJE, 2023). Additionally, many families identify as speaking more than one language at home. Within this context, inequalities between Luxembourgish or German-speaking students and students with other language resources are increasing (MENJE, 2023). Accordingly, the school system has become outdated by our rapidly changing population, and issues of equity and justice in this context are heavily bound in languages, as the trilingual system can create language barriers for newcomers (e.g., Degano & Kirsch, 2020).

2.2 | Plurilingual students in multilingual contexts

We purposefully use the term plurilingual to describe the linguistic capabilities of the participants with whom we work, as also suggested by the Council of Europe (2001, 2018).

Plurilingualism is defined by the Common European Framework of Reference for Languages (CeFR) as "the dynamic and developing linguistic repertoire of an individual user/learner" (Council of Europe, 2020, p. 28) and the concept implies a holistic view, "which considers the languages of an individual as composing a single dynamic language *repertoire* ...thus shifting the focus from the languages themselves to the agency of the individual in the interaction of languages" (Kharkhurin, 2021, p. 229) and as such, "plurilingualism calls for a broader and more dynamic view of linguistic plurality than classic bi-/multilingualism" (Kharkhurin, 2021, p. 230).

Through a plurilingualism lens, a speaker does not keep "languages and cultures in strictly separated mental compartments, but rather builds up a communicative competence to which all knowledge and experience of language contributes and in which languages interrelate and interact" (Council of Europe, 2001, p. 4). This perspective on plurilingualism highlights *both* the interconnections of language competences of an individual as well as importance of accepting various levels of mastery of languages (Jeoffrion et al., 2014) as it presents a paradigm for languages, "based on a plurilingual and asymmetric model where not all language competence needs to be the same" (King, 2018, p. 31). Through this positioning, people are referred to as plurilingual, while contexts are framed as multilingual, a term which typically implies the coexistence of multiple languages, as in a national context, a classroom, or a curriculum document, for example. The terms we use to describe students with whom we work matter (González-Howard & Suárez, 2021), and our purposeful use of the term plurilingual valorizes the abilities and strengths of those with diverse communicative repertoires (Wei & García, 2022). Through this view, we honor the full semiotic repertoires that each person possesses and is able to draw upon when communicating (Suárez, 2020). For a more detailed discussion of reflections on the use of a plurilingual theoretical position see Piccardo (2017), and in relation to our research specifically see Wilmes, Siry, Gómez Fernández, and Gorges (2018).

2.3 | Co-design and co-teaching with in-service teachers

Tom and Henry's kindergarten class is an example of the high diversity of today's early childhood classrooms in Luxembourg (MENJE, 2023). All 15 students in the class speak at least one language other than Luxembourgish at home, including Arabic, Creole, Italian, Mandarin, Portuguese, Urdu, French, and/or English. This reflects the demographics in our country, wherein more than half of the students speak at least one language *other than* the school languages of instruction (MENJE, 2023). With Luxembourgish being the language of instruction at this level, verbal communication can be challenging for the students as well as for the teachers, thus one of our main commitments is to collaborate with teachers to work toward resolving some of the related challenges. To do so, we created a teacher resource center in 2016[2], the SciTeach Center, to support the teaching and learning of science through open-ended, inquiry-oriented, investigation-driven approaches. Building from the particular linguistic and cultural complexities of our context, we draw from inclusive and equity-centered pedagogies that provide time and space for children's interactions in our work with teachers, while hoping to highlight children's resourcefulness, engagement and sense-making. We provide teachers with strategies that offer possibilities to engage in open-ended investigation and emphasize how these allow for children to draw upon a wide range of modalities in science investigations, including linguistic, embodied, and material resources.

In support of equity-oriented instruction, we collaborate and co-teach with in-service teachers through an ongoing collaboration with the Ministry of Education in partnership through the SciTeach Center, through which several teachers are released from their teaching-duties 1 day each week during the school year to work as team members in the Center. Co-teaching is central to our collaborations, as it is a key structure we draw on to support professional development (PD; Gallo-Fox & Scantlebury, 2016). Therese, the teacher in this research, began working with us as a collaborating teacher-leader in 2015, and through our collaboration with the Ministry of Education, she was detached (on special assignment) 1 day per week to work with our team to co-develop and co-teach PD initiatives for other teachers. The collaboration with the teacher-leaders emphasizes a student-driven inquiry-based learning approach, which she also worked to incorporate into her own classroom practice. In the frame of the presented research, Therese co-taught a 3-week Worms and Vermicomposting unit, described next, with Sara and Chris, which aimed to engage students in integrated science explorations grounded in their questions about worms and vermicomposting in various open-ended settings. Sara and Chris co-developed and co-taught the unit and participated in reflective conversations with Therese. Throughout the collaborative co-teaching processes, together they reflected on the classroom happenings, and this was a key step into the analysis detailed here. Doriana is a PhD researcher in our team that has been involved with multiple phases of this study over several years and she also collaborates with Therese through our collective work at the SciTeach Center. Being plurilingual language-learners in multilingual spaces ourselves shapes our perspectives and insights into the children's translanguaging and sense-making and provides methodological sensitivities.

2.4 | Investigating worms and vermicomposting unit

The unit was designed to introduce students to vermicomposting through open-ended inquiry experiences allowing for exploration of the role of worms as decomposers. The overarching aim of five focal investigations emerged from the students' questions as Therese built from their emergent wonderings (e.g., Siry & Max, 2013) through class discussions following on their shared experiences setting up and observing the vermicomposter. Students explored worm diversity, essential components worms need to survive with opportunities to openly investigate how worms react to light, worm body structures and movement using tools including digital microscopes and hand lenses.

The overarching integrated unit goals supported students' development of science,[3] language, math, and art competencies in ways that afforded them opportunities to draw upon their full communicative repertoires while in multimodal learning spaces (Table 1).

Opportunities for the children to build arguments from experiences and evidence followed each of the five focal investigations. Over the 3 weeks students worked through several cycles of discussing experiences and working with emerging questions, by investigating, documenting and communicating findings and developing understandings (Table 2). Students were provided with opportunities to document using drawings and digital recordings and subsequently to communicate their findings with drawings and explanations. Overall, the unit was framed by starting, and returning to the question, "What do we know about worms?" A class-poster on which Therese recorded students' claims was displayed. Photos, microscopic digital images from students' explorations, drawings, and a 3D scientific worm model were displayed in the classroom for the duration of the unit. An overview of the instructional approach emergent from students' questions and wonderings is shown in Table 2.

TABLE 1 Integrated unit competencies.

Science: Discovery of the world	To observe and explore environments and living phenomena To formulate questions building from observations To explore interrelationships between living organism and the environment To document investigations
Luxembourgish	To talk in interaction with others To communicate using nonverbal resources To comprehend conversations To mobilize and execute listening strategies
Math	To represent and communicate numbers and operations To describe and compare quantities To use magnitudes to describe everyday situations

TABLE 2 Investigating worms and vermicomposting unit overview.

Session	Instructional overview
1	**Group discussion: How big are the worms?** Student exploration stations: • Investigating worms • Digital microscope observation • Children's literature for exploration and drawing • Worm puzzles and games
2	**Group discussion: What do we know about worms?** Student exploration stations: • Investigating worms • Digital microscope observation • Children's literature for exploration and drawing
3	**Group discussion: Do worms like dark or light?** • Whole-class discussion about 3D worm model Student exploration stations: • Investigating worms • Digital microscope observation • Children's literature for exploration and drawing • Worm puzzles and games
4	**Group discussion: Do worms prefer wet or dry surfaces?** • Group discussion about worm farm that travels home with students Student exploration stations: • Investigating worms • Digital microscope observation • Children's literature for exploration and drawing
5	**Group discussion: What do worms eat?** Student exploration stations: • Providing food for the worms in the vermicomposter • Children's literature for exploration and drawing

3 | RESEARCH DESIGN

We conducted a multilayered critical ethnography of Therese's class as they investigated worms during the 2018/2019 school year, and over the 3-week period interrelated sources of data were collected, including classroom videos of each instructional period, photos of classroom teaching artifacts such as posters, scans of student documentations, and researcher reflective field notes constructed following each instructional session. Further, reflective interviews with Therese were recorded at the culmination of the vermicomposting unit. All lessons were recorded, capturing a total of 30 h of video across two classroom cameras and two table-top close-up cameras. All linguistic aspects of data were analyzed in their original versions and excerpts key to presenting the findings from analysis were translated into English by the authors for publication. These layered data sources allowed us to reflexively look back at instruction, and focus on the opportunities created throughout the unit for children's communication within the lessons through the analytical processes detailed in the next sections.

3.1 | Critical ethnography and co-teaching

Our research is guided by critical ethnography, which has been described as "conventional ethnography with a political purpose" (Thomas, 1993, p. 4) as it works to illuminate power differences, agency, and resistance (Castagno, 2012). Critical ethnographers strive toward research that is "sensitive to the dialectical relationship between the social structural constraints on human actors and the relative autonomy of human agency" (Anderson, 1989, p. 249), and critical ethnography supports dialogue across differences. We layer critical ethnography with co-teaching as one way to work toward such dialogue together with teachers, like Therese. We have developed a structure in our team that allows for an emergent process of collaboration, one which is closely tied to context through co-teaching and co-developing the science education PD workshops of the Center together with teachers. Co-teaching provides the space for us to critically analyze the teaching and learning that occurs together, and it helps us to develop shared, critical understandings of learning, teaching, and learning to teach science as we engage in a shared praxis of teaching at the same time (e.g., Wilmes & Siry, 2018; Wilmes, Siry, Gómez Fernández, & Gorges, 2018; Wilmes, Siry, te Heesen, et al., 2018). Aligned with our commitment to the value of co-teaching, we also co-teach together with teachers in their classrooms, connected to the topics guiding the PD initiatives. Co-teaching through the perspectives that we bring to our work is grounded in a dialogic and iterative process, providing a reflexive space for participants to learn about teaching "at the elbow of the other" (Roth & Tobin, 2004).

3.2 | Multimodal interaction analysis

Multi-layered multimodal interaction analysis (MIA) provides a lens for exploring how students and teachers utilize resources in ways that are locally contextualized and that unfold through interactions (Wilmes & Siry, 2024). Modes are semiotic resources mobilized for the purpose of meaning making (Givry & Roth, 2006; Kress, 2010), and MIA highlights the nuances of how these are mobilized in interaction. The MIA approach that we have developed and use across projects with our research team is a relational way to explore the embodied and material ways that children engage with science (e.g., Wilmes & Siry, 2021), as multilayered MIA starts with

our participation as co-teachers, in this case with Therese in her classroom, also document classroom interactions through videorecording.

MIA afforded us views on teaching and instruction through which we contextualized translanguaging within the structures setup in Therese's classroom. The analytical approach involved first, constructing instructional maps detailing the teaching approach, teaching and learning sequences, structures, and forms of interactions supported for each session in the 3-week unit. This highlighted the structures provided for embodied and material interaction and exploration. Second, video analysis was conducted for all videos. In an initial step of video analysis, videos were viewed with the sound off, which foregroundedwhat was being done, rather than initially focusing on what was being said. Through this initial analysis with the sound off, we were able to reflect upon experiences in ways that shifts focus from what was spoken to what was enacted, and through this process open up analytic views on communication beyond the spoken. This purposeful move to *seeing without hearing* serves to de-center our predilection toward framing classroom interactions via utterances, which is often normed toward dominant classroom languages, and rather allows us to see how embodied and material interactions unfold through classroom structures.

We moved between analyzing video with sound off/video with sound on, in an iterative and recursive process, which allowed us to view classroom enactments and engagement, and then to layer upon this moments of translanguaging through sound on for identification of communicative resources employed by children and teachers. Building from the instructional logs, notes were constructed about the structures available for each lesson sequence, student and teacher interactions within these structures, and then notations were made in the logs to indicate the national languages students used. The multimodal transcripts built through this process centered on the structures across each lesson, and layered communication upon these sequences, a dialogic process that allowed us to identify moments of translanguaging across the Vermicomposting unit. We then used a process of MIA to tease apart the moment-to-moment embodied, material, and communicative interactions within these moments, to produce detailed multimodal transcripts of verbalizations and use of communicative resources (Erickson, 2017). Analysis afforded us views on the ways children agentically employed communicative resources in interactions relative to the structures available for engaging in science. Three vignettes were selected using theory-driven selection (Patton, 2015) specifically as they allowed for zooming in on how students engaged in science learning and for viewing their agentic moves within the structures used over the course of the unit. This led to selecting three vignettes - two small-group structures, and a whole-class discussion structure. Overall, this multilayered analytical process allowed us to examine how these young plurilingual children participated and communicated while engaged in open-ended science learning structures with the goal of examining the roles that translanguaging plays for children's communication and sense making. It additionally allowed us to focus on how the teacher, Therese, built from children's engagement as a way to engage all of her students in science.

4 | FINDINGS: YOUNG CHILDREN'S COMPLEX COMMUNICATION

We next present analytical findings that detail three key events that took place as children investigated worms and vermicomposting within the open classroom structures. These events are presented as vignettes that will be interpretively layered together in the discussion to address the research question introduced earlier, *How do open-ended science learning spaces*

TABLE 3 Transcript conventions (Adapted from Hwang and Roth (2011)).

[and]	square brackets in consecutive lines show an overlap of speech with body movements
((draws))	words within double parentheses comment on visible body movements
NOW	capitalization marks speech that is louder than the normal speech intensity
?,;.	punctuation marks are used to indicate characteristics of speech production rather than grammatical units
it's-	Dash indicates sudden stop of talk

mediate children's opportunities for translanguaging and sense making? The three vignettes are unpacked through a combination of transcript excerpts and narrative description to highlight the resources children mobilized. We utilize transcript conventions adapted from Hwang and Roth (2011) and as detailed in Table 3. The national languages used in the vignettes are identified in the transcripts as follows: normal font for Luxembourgish; *italic font* for French, and underlined font for Italian. Note that while analysis began with views on interaction without the sound turned on and built up to identify moments of translanguaging and science learning, what we present are three episodes which represent key structures used throughout the unit—small-group investigations and whole-class discussions, and we highlight the utterances made in order to make claims about the role of students' agentic communication and translanguaging relative to these structures.

4.1 | Vignette 1—Observing a worm hotel with a magnifying glass and a flashlight

In this vignette, three students, Maria, Diana and Frank are sitting around a table on which there is a worm hotel. A worm hotel consists of a container with clear sides that allows the students to see the worms burrowing in soil. Therese constructed the worm hotel by removing a sample of dirt and worms from the vermicomposter and packing it into the worm hotel.

FIGURE 1 Students explore a worm farm.

This would allow the children to observe how the worms burrow and move within the soil, a perspective they had not seen when observing the soil in petri dishes (Figure 1). At one point, Maria, Diana, and Frank are sitting around the worm hotel and holding magnifying glasses and flashlights that they are using to look at the worm hotel. Maria knocks on the worm hotel with her magnifying glass, and the following interaction unfolded.

4.2 | Vignette 1—Observing a worm hotel with a magnifying glass and a flashlight

		Original*	English translation*
01:00	Maria	Toc, toc. Non c'é niente.	Knock, knock. There is nothing.
01:03	Diana	((knocks on the worm hotel with her magnifying glass))	((knocks on the worm hotel with her magnifying glass))
01:05	Maria	No, tu quando hai fatto cosi ((making her hand into a fist as if to knock on the worm hotel)) cosi fatto, toc toc, e sono morti.	No, when you did like this ((making her hand into a fist as if to knock on the worm hotel)) like this, knock knock, they all died.
01:09	Diana	No! ((pulling together the eyebrows))	No! ((pulling together the eyebrows))
01:10	Maria	Joffer! ((turning to Therese who is standing next to them, speaking with Sara)) [Diana hat]	Teacher! ((turning to Therese who is standing next to them, speaking with Sara)) [Diana, she]
01:14	Diana	[Ma che dici?!]	[What are you saying?!]

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

As Diana interrupts Maria with What are you saying?!, she puts on an angry face and comes closer to Maria. Diana then turns back to the worm hotel immediately and looks at it through the magnifying glass she is holding. The teacher does not come into their conversation at this point, and both children return their focus to observing the worm hotel with the flashlight and their magnifying glasses, and Maria starts to sing a melody. At that point, Frank turns to Diana, reaching for her flashlight.

		Original*	English translation*
01:20	Frank	Däerf ech eng Kéier, eng Minutt? ((reaching for the flashlight)) Eng Minutt, ok?	May I once, one minute? ((reaching for the flashlight)) One minute, ok?
01:24	Diana	Ja, ja. ((letting go of the flashlight))	Yes, yes. ((letting go of the flashlight))

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

As Diana lets go of the flashlight, Frank returns to where he was sitting, and all three children then direct their focus to observing the worm hotel. Maria continues singing, and then Diana suddenly makes a surprised face:

		Original*	English translation*
01:29	Diana	Ey, ey! Ech hu gesinn, ech hu gesinn ((standing up and looking at the worm hotel from the top now))	Hey, hey! I saw, I saw! ((standing up and looking at the worm hotel from the top now))
01:32	Maria	((interrupting her singing and putting her flashlight toward the worm hotel.)) Ech gesinn eppes. ((turning toward a teacher standing next to them.)) Wees de Joffer, ech gesinn eppes. Ee Wuerm. ((turning back to the worm hotel and pointing her flashlight on it.)) E Wuerm ech gesinn ech. E Wuerm. ((Frank comes to her side of the table)) Guarda qua, ech hunn gesin virdrun. Guarda, guarda. E andato qua, ha fatto la striscia, guarda. ((tracing a path in the soil of the worm hotel with her flashlight)) Ha fatto una cosa e adesso [inaudible] è andata qua. ((retracing a path into the soil with her flashlight, while Diana seems to listen carefully to what Maria says))	((interrupting her singing and putting her flashlight toward the worm hotel.)) I see something. ((turning toward a teacher standing next to them.)) You know teacher, I see something. A worm. ((turning back to the worm hotel and pointing her flashlight on it.)) A worm I saw I. A worm. ((Frank comes to her side of the table)) Look here, I saw it before. Look look. He went here, he made a line, look. ((tracing a path in the soil of the worm hotel with her flashlight)) He did one thing and now [inaudible] he went here. ((retracing a path into the soil with her flashlight, while Diana seems to listen carefully to what Maria says))
02:02	Frank	((handing the flashlight back to Diana))	((handing the flashlight back to Diana))
02:08	Maria	Con questa vedi bene, quella è più facile. Poi gira un pò. ((making a hand gesture as if to set the focus on the digital microscope. Diana goes back to her side of the table and starts looking at the worm hotel with her torch and her magnifying glass)) No, vedi qua. ((stands up and bends over to a corner of the worm hotel)) Sono tutti qui. ((pointing to that corner with the flashlight and the magnifying glass, Diana comes over to see what Maria is pointing at))	With this you see well, that is more easy. Then spin a bit. ((making a hand gesture as if to set the focus on the digital microscope. Diana goes back to her side of the table and starts looking at the worm hotel with her torch and her magnifying glass)) No, see here. ((stands up and bends over to a corner of the worm hotel)) They are all here. ((pointing to that corner with the flashlight and the magnifying glass, Diana comes over to see what Maria is pointing at))
02:23	Diana	Non c'è! ((starts looking at the corner Maria was pointing at))	It's not here! ((starts looking at the corner Maria was pointing at))

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

This vignette illustrates some of the ways in which the children draw on a wide range of communicative resources in interaction around their worm observations and wonderings, emergent from investigations grounded in the materials and resources the space afforded to them in the classroom. They communicate by drawing on resources from their linguistic

repertoires including Italian, which they also speak with their families, and the classroom language Luxembourgish. Regarding the use of languages in this interaction, Maria uses Italian to speak with Diana, as Diana is not yet proficient in Luxembourgish, while Maria uses Luxembourgish to speak with Frank, who is not an Italian speaker. Interesting to note is that when Therese is with the children, Maria speaks in the school language of Luxembourgish to Therese, while to Diana she then draws upon Italian for communicating similar observations, although Therese also understands Italian and the children are aware of this.

The children engage in focused observation around worm movement mediated by the materials and the structure set up by Therese. Children could choose to move and interact with these materials, to view the worms in the hotel, and then communicate by drawing upon Italian and Luxembourgish as resources, layered together with their bodies, including gestures, intonations, and movements. The flashlight and the magnifying glasses are key tools in the children's interaction and sense-making, as they serve both as tools for observing the worms as well as for communicating their observations about the worms. They use these as resources to clarify what they are trying to communicate, as they build from each other's actions and comments.

4.3 | Vignette 2—Le bebe et la maman: The baby and the mama

In this vignette, a preschool class of 3-year olds has joined the 4 and 5-year-old class for a weekly science investigation, in which the older children share their observations from prior science explorations with the younger children and together they investigate the worms and how they move (Figure 2). We have presented a different excerpt from this lesson in prior work (Siry et al., 2022), in which we introduce the ways in which these young children seamlessly move between languages in interaction, depending on the speakers, illustrating how the children communicate their worm-related wonderings and understandings across modalities, moving in and out of languages while drawing on facial expressions, materials, gestures, and vocal intonations. The vignette introduced next follows from an one presented in an earlier publication (Wilmes & Siry, 2024), as three children (Karan, Eric, and Matthieu) are standing around a table looking at a bowl with dirt and worms, and Eric and Matthieu are digging in the dirt with plastic spoons. The three children hold magnifying glasses, which they use to point at the bowl and occasionally look through. Karan invites Felix, who is also holding a magnifying glass, to look at what they found, by looking at Felix and then back to the bowl. At the same time, Felix takes Karan's magnifying glass, then he leans over to observe the bowl (Figure 2).

		Original*	English translation*
8:09	Felix	Do sinn, do sinn! ((Felix points at the bowl with the magnifying glass. Eric pushes them both slightly to the side as they block his way))	There are, there are! ((Felix points at the bowl with the magnifying glass. Eric pushes them both slightly to the side as they block his way))
8:12	Eric	Jo kuck, do ass ee groussen, do ass ee klengen.	Yes look, there is a big one, there is a small one.

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

FIGURE 2 Children investigate worms from the vermicomposter.

As Eric explains to Karan and Felix what he and Matthieu found, Felix turns away again and looks through both of the magnifying glasses he is holding. Matthieu is looking into the room and says something inaudible while Karan and Eric continue to dig in the dirt and to observe. Sara passes by the boys carrying a tripod, as Eric turns to her, calling out:

		Original*	**English translation***
8:30	Eric	Kuck mir hunn ee méi groussen!	Look we have a more big one!
	Matthieu	((briefly points his finger at the bowl and also turns in Sara's direction))	((briefly points his finger at the bowl and also turns in Sara's direction))
8:33	Sara	Ah jo? Wou? ((comes back from behind the camera to the table and also bends over the bowl, looking at where Matthieu is pointing))	Oh yes? Where? ((comes back from behind the camera to the table and also bends over the bowl, looking at where Matthieu is pointing))
08:34	Eric	Dee, dee, deen do, do. ((points with a spoon at the worm))	The, the, that one there, there. ((points with a spoon at the worm))
08:35	Sara	((looking at where Eric is pointing)) Ooooh! [inaudible]	((looking at where Eric is pointing)) Ooooh! [inaudible]
8:37	Matthieu	((bends over the bowl, pointing into the bowl with his index finger while searching for something)) *Après le... Après le bébé, il est là.* ((turns to look at Sara, who has looked up at him when he started speaking))	((bends over the bowl, pointing into the bowl with his index finger while searching for something)) *After the...after the baby, it is there.* ((turns to look at Sara, who has looked up at him when he started speaking))
8:41	Sara	((Looks down to the worms)) *Là? Wow! Le bébé il est où? Là? There?* ((points with a finger at a worm))	((Looks down to the worms)) *There? Wow! The baby it is where? There?* ((points with a finger at a worm))
8:46	Matthieu	((bends over the bowl again, uses the magnifying glass for a moment, then points into the bowl with his index finger, while Eric continues to poke at the bowl with the spoon)) *Et après la mam...* ((turning back toward Sara who kneels down and looks back at Matthieu)) *et après il y a le papa!*	((bends over the bowl again, uses the magnifying glass for a moment, then points into the bowl with his index finger, while Eric continues to poke at the bowl with the spoon)) *And after the mam...* ((turning back toward Sara who kneels down and looks back at Matthieu)) *and after it is the papa!*

		Original*	English translation*
8:48	Sara	*Aaaaah! Oú est le papa?* ((looks back at the bowl))	*Ahhhhh! Where is the papa?* ((looks back at the bowl))
8:50	Eric	*Là* ((points with a spoon to the worm))	*There* ((points with a spoon to the worm))
8:51	Matthieu	*It est ici*. ((points his finger at another worm))	*It is here*. ((points his finger at another worm))
8:52	Eric	*Là, il est là, il est là! Là, là*. ((points to a worm with the spoon, while Matthieu looks closely))	*There, it is there, it is there! There, there*. ((points to a worm with the spoon, while Matthieu looks closely))
8:55	Sara	((gaze remains on bowl)) *Aaaah!*	((gaze remains on bowl)) *Aaaah!*

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

Sara leaves the group to finish installing the tripod she was carrying, and Eric asks her about what she is doing, while another child approaches the bowl. Eric turns back to the bowl to explain their findings to the newly arrived student, while Karan and Matthieu observe what Sara is doing with the camera.

The exchanges in this interaction are highly emotional and occurring rapidly, with excitement evident in body positioning, facial expressions, and combined French and Luxembourgish utterances. While the Kindergarten children have had experience with the worms, this is the first time that the preschool children are freely observing the worms in the dirt from the compost, and this lesson is focused on open exploration and engagement. The children have different magnifying glasses they can use to observe, and they are also aware of the digital microscope at the end of the working table, thus different options for viewing the worms are possible. Eric seems to express freely using both Luxembourgish and French. On the other hand, Karan and Felix do not seem to understand French, while Matthieu does not speak Luxembourgish. Eric therefore alternates between Luxembourgish and French, depending on who he is addressing, working to integrate all the children present equally into the interaction, as we also found in a related episode (Siry et al., 2022). Herein, we build from the focus on the children's fluid use of transmodal resources to highlight Sara's role in structuring the interaction as it unfolds. The children call her over to share their discovery, and throughout most of the interaction, she moves her eye gaze from the speaker to the worms, repeating what they say in the language they say it in, following with a prompting question. In doing so, she expresses excitement over their discoveries, leaning in her body aligned with theirs, and then kneeling down to be at the children's level. In doing so, she is recognizing and respecting their discoveries while valorizing their ways of communicating and building from these with prompting questions to further their exploration and sense-making (Figure 3).

4.4 | Vignette 3—Is it big, is it small, how is it?

In this third vignette, we present a moment from analyses representative of a common practice Therese employed with her class during circle time. Therese used circle time at several points during instruction, to start lessons, to culminate lessons, and as a transition space. During this

time, the children would sit on benches in a circle, with the board behind Therese as she sat on the same level and benches with them. In this next vignette, Therese was exploring children's ideas about the sizes of the worms in the compost, and engaged them in an embodied conversation:

		Original*	English translation*
08:52	Therese	So, ass ee Wuerm dann, ass dee grouss, ass dee kleng, wéi ass deen? ((raises her shoulders while making a questioning facial expression))	So, is a worm then, is it big, is it small, how is it? ((raises her shoulders while making a questioning facial expression))
08:53	Children	Kleng! Kleng! Bessi kleng! ((children each showing with their hands their ideas to the worm size, some staying in their seats, while others stand up while gesturing))	Small! Small! A little small! ((children each showing with their hands their ideas to the worm size, some staying in their seats, while others stand up while gesturing))
08:59	Therese	Mengs du sou? ((turning to Matteo, holding her hands approximately the same distance apart as Matteo is holding his hands apart))	You think like this? ((turning to Matteo, holding her hands approximately the same distance apart as Matteo is holding his hands apart))
09:00	Maria	Nee sou! ((showing a smaller distance with her hands))	No, like this! ((showing a smaller distance with her hands))
	Frank	Esou. ((brings his hands closer together to show a smaller size))	Like this. ((brings his hands closer together to show a smaller size))
09:01	Therese	Weist mol mat den Hänn. ((holds her hands out in front of her, moving them closer and further apart from each other while speaking)) Wat mengt der wéi grouss meng Wierm sinn?	Show me with your hands. ((holds her hands out in front of her, moving them closer and further apart from each other while speaking)) How big do you think my worms are?

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

FIGURE 3 The class discusses the size of the worms in the vermicomposter.

In response to Therese's question, multiple children in the circle call out Sou! (Like this!), with children all extending their arms with their hands at different distances apart, most keeping their hands relatively stable in distance. Therese responds to children individually, either by referring to them by name directly, or showing her recognition with eye contact, and each time taking over their hand gestures with her own hands. The discussion about the length of worms continues until 00:09:50, and then the conversation returns to the worm movements.

		Original*	English translation*
11:44	Therese	Jo hei de Nico-Wuerm, wéi mëscht de Nico-Wuerm?	Yes, here the Nico-worm, how does the Nico-worm do it?
11:45	Nico	((stands up)) De den Frank huet esou gemaach ((makes a wave-form movement with both his arms)) an also sou mëscht eigentlech eng RAUP ((while lifting up one of his pointer fingers))	((stands up)) Frank did like this ((makes a wave-form movement with both his arms)) and so that is actually how a CATERPILLAR does it. ((while lifting up one of his pointer fingers))
11:51	Therese	Sou mëscht eng Raup. ((points with her finger to Nico))	The caterpillar does that. ((points with her finger to Nico))
11:52	Nico	Also sou. ((mimics Nico's wavelike motions with both arms))	So, like this. ((mimics Nico's wavelike motions with both arms))
11:54	Therese	Sou mëscht eng Raup. ((mimics the movement that Nico made)) Jo. ((Nico nods)) A wi mëscht de Wuerm dann? Wat mengs du dann?	A caterpillar does like that. ((mimics the movement that Nico made)) Yes. ((Nico nods)) And how does the worm then? What do you think then?
	Nico	((lies down on the floor and pulls himself forward crawling with his arms))	((lies down on the floor and pulls himself forward crawling with his arms))
12:00	Claude	Ech, ech meng...	I, I think...
	Therese	Schht!	Shhh!
12:02	Therese	Okeee. ((nodding, to Nico)) So eh Nico, mëscht de Wuerm dann, d'selwecht wéi de Raup?	Okayy.((nodding, to Nico)) So, eh Nico, does the worm do the same as the caterpillar then?
12:07	Nico	Neee!	Nooo!
12:08	Therese	Ma wat mëscht en dann anescht? ((several children stand up from their seats))	What does he do differently then? ((several children stand up from their seats))
12:09	Nico	Well de Raup geet esou. ((repeats the wave-like movement with his hands)) Sou.	Because the caterpillar goes like this. ((repeats the wave-like movement with his hands)) Like this.
12:13	Therese	Aah de geet sou! ((mimics Nico's movements with her hands as Nico nods))	Aah he goes like this! ((mimics Nico's movements with her hands as Nico nods))

(Continues)

		Original*	English translation*
		Joo. An de Wuerm?	Yes. And the worm?
12:17	Nico	Deen ((sits back down on the floor as if to lie down, then showing instead a creeping movement with his hands)) deen zitt sech.	It ((sits back down on the floor as if to lie down, then showing instead a creeping movement with his hands)) it pulls itself.
12:19	Therese	[inaudible] dir wësst jo scho richteg ((momentarily interrupted by children calling out)) Sou hei wart den, d'Lena streckt ganz brav aus, ech huelen emmer déi di ganz roueg do sëtzen an de Fanger ausstrecken. Lena, wéi mëscht de Wuerm?*	[inaudible] you already know it ((momentarily interrupted by children calling out)) So now wait, Lena is holding up very patiently, I call on those that sit quietly and raise their fingers. Lena, what does the worm do?

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

Lena then shows her thoughts on the worm's movement by extending her arms and holding them apart a given distance, followed by several more children who excitedly, when Therese calls on them, show how they think the worms move. For many of them, this includes standing up from their seat and either moving their body, or lying on the floor, as one student, Claude does:

		Original*	English translation*
13:19	Claude	((Lies on the floor and makes a wriggling movement with his body))	((Lies on the floor and makes a wriggling movement with his body))
13:24	Therese	Ah jo den Claude hat, kuckt hee mengt e bëssen su, su no riets an no lénks he, su hin an hier ((shows a wriggling movement with her hands)) mengs du, ok, mir kucken dat alles herno. Frank?	Ah yes, Claude has, look he thinks a little like, like to the right and to the left, like back and forth ((shows a wriggling movement with her hands)) that is what you think, ok, we will look at all of this later. Frank?
13:33	Frank	Eng Schlang mëscht esou. ((makes a wriggling movement with his hands))	A snake does like this. ((makes a wriggling movement with his hands))
13:44	Therese	Eng Schlang? Jo, eng Schlang mëscht esou, jo. ((makes a wriggling movement with her hands))	A snake? Yes, a snake does like that, yes. ((makes a wriggling movement with her hands))
	Frank	((lies own his stomach and pulls himself slowly forward with his arms))	((lies own his stomach and pulls himself slowly forward with his arms))
13:39	Therese	Mëscht de Wuerm dann och esou? ((looking at Frank))	Does the worm also do that then? ((looking at Frank))
13:40	Children	Neee!	Nooo!

	Original*	English translation*
Therese	((Shrugs))	((Shrugs))
Claude	[DACH!	[YES!
Therese	Mer kucken, mer kucken dat herno, der dierft alles kucken herno.	We will look, we will look later, you can see everything later.
Frank	((sits down again))	((sits down again))
Children	((multiple children discussing simultaneously if the worm also makes a wriggling movement))	((multiple children discussing simultaneously if the worm also makes a wriggling movement))

*Normal font for Luxembourgish, *italic font* for *French*, underlined font for Italian.

There is an entanglement in these excerpts between *what* and *how* the children are communicating, and the ways Therese picks up and builds from the children's ways of communicating. She imitates their gestures, physically responding to the children's transmodal movements while modeling these to the other children. There is space for children's embodied understandings to emerge, and room to mimic hand gestures to indicate children's thoughts about the worm sizes, as some children stood up while others stayed in their chairs, some called out while others had wide-eyed facial expressions as they stuck out their arms to represented the length they had in mind. The conversation moved from worm sizes to worm movements, building from children's contributions, as the children used their bodies to demonstrate their ideas and understandings about how worms, snakes, and caterpillars move. Body movements, gestures, and utterances intertwined to represent children's ideas on animal movements. The open-endedness afforded by the circle-time space provided room for children to express their ideas fluidly across modes and languages in ways that were visible to Therese and that she could build from with the children.

5 | DISCUSSION

Returning to the question that guides this article, *How do open-ended science learning spaces mediate children's opportunities for translanguaging and sense-making?* we interpretively reflect upon the three vignettes to draw the claim that opportunities for translanguaging emerged in and through the open-ended pedagogical spaces, supporting children's communication and science sense-making across a wide range of semiotic resources. Young students' communication and science engagement are inseparable, and these intertwine ***through*** translanguaging and ***as*** science learning when children are able to agentically draw upon diverse resources to communicate and learn together. Therese structured opportunities that enabled students to draw upon resources in fluid and flexible ways that incorporated translanguaging. This translanguaging was grounded in transmodal processes that supported children in drawing upon a diverse array of modes in addition to those that were (verbalized) and incorporating these into interaction and communication as they engaged in science.

Positioning science learning as cultural enactment implies that science sense-making happens in interaction with others, and the open structure allows for children to be together and find ways for interacting with each other around their discoveries and wonderings. As students are positioned to draw upon a range of diverse resources fluidly and flexibly in interaction, new

meaning can be made through supported communication. In the opening vignette, a conversation unfolds with few spoken words, and in vignettes 1 and 2 the children are choosing different languages for different communication partners as a free choice, a process which serves to actively include different people. These choices are being made by 3–6 year olds, which demonstrates to us a sense of inclusion of peers through languages. In vignette 3, the children and Therese share their ideas on worm, snake and animal movements by weaving together body movements, gestures, and utterances, as some children offered their replies by lying on the ground and using their bodies—a process which Therese noticed and valorized. The spaces set up by Therese afford agency, socioemotional engagement, and translanguaging, and across all three vignettes, the children use numerous resources in interaction to participate fully in observing, communicating about, and building understandings and experiences about the worms and the vermicomposting.

We note that in this process, the science-related materials provided by Therese are used in two ways by the children: as intended and for a new means. For example, the magnifying glass is used both to look through and also to point, while the flashlight is used to shine a light on something and also to point. Through their translanguaging in the open spaces they take agency, engage in science practices, and build science meanings, in a complex process emergent from the agency | structure dialectic. The research presented through the vignettes above illustrates the relationship between the teachers' and students' interactions in such open-ended spaces as an embodied and socioemotional one, which supports the production of new experiences and new meanings in an inclusive manner (Smith, 2023) in an early-childhood science classroom.

Therese provided structures that support students' agentic engagement through the way she sets up classroom experiences, and also through the ways she interacted with students within these spaces. Both Therese and Sara, as co-teacher in vignette 2, respect children's ways of communicating by imitating their body language in conversations, without pushing them to put words on their movements, offering prompting questions through words and intonations to further children's communication around their science ideas and observations. Therese has created a structure that supports translanguaging, and to build on this, she imitates their body language in conversations, making space for emotional engagement and connection. She frequently pauses, which provides time for the children to communicate by agentically drawing upon a range of embodied and spoken modes. These practices in turn support the children's transmodal communication around their investigations and the new meanings they are making, as well as leading to new questions. The translanguaging emerges in and from the dialectic relationship between the open-structures and the children's agentic moves. Further, the structures she provides afford diversity, as they mediate drawing on collective experiences yet affording diverse ways of communicating about what children are experiencing, seeing, and doing and understanding. The vignettes considered together highlight the complexity of children's use of verbal, visual and action modes, and show the entanglement of a range of multimodal embodied resources facilitated through translanguaging.

Sara moves her gaze from speaker to worms, repeating what they say while asking key questions. Relatedly, Therese's translanguaging pedagogy builds upon and emerges from the children's translanguaging. She uses questions, the space, the children's ideas and experiences, and their multimodal, materially grounded, and embodied interactions and expressions as resources. In this sense, children's transmodal communication is seen through asset-based lenses that shift instructional spaces to those that value wider ranges of interactions, ways of communication, and sense-making (Warren et al., 2020). There is an openness to what she allows to happen through space and time, and this affords opportunities for the children to

agentically draw upon a range of modes to engage, interact, and express their experiences as we saw across the three vignettes.

The dialogic pedagogical approach builds from conversations happening in circle time and enables the children, regardless of their level of language mastery, access to the topic of conversation (e.g., "Show me with your hands how big the worm is") and to communicate with each other as they make sense of what is happening in the classroom. There is a flow of emotion, and the translanguaging served to sustain and facilitate communication and interaction, keeping the engagement open, accessible, and supported. Such embodied, enthusiastic engagement is not simply an added value *for* science learning, rather, such engagement in investigating phenomena *is* science learning. The children were able to translanguage with each other and with the teacher in ways that were driven by excitement and interest. In this process, the children sustained engagement, furthered their explorations, and relatedly furthered development of science understandings. This aligns with recent research that has highlighted how children's' translingual participation supports their social and academic engagement and furthers their science learning (Lemmi & Pérez, 2024). As was shown in all three vignettes, the structures mediated communication between children that allowed for co-construction and the development of the "explanation of science phenomena" competence aligned with and building from children's repertoires. This was mediated by their ability to participate with their communicative repertoires, enabling all children to participate in class, which is basis for inclusion and equity.

Young children's interactions are inherently multimodal (Bengochea et al., 2018; Kress et al., 2001). In this classroom, Therese embraces an understanding of this as is demonstrated in the opportunities she sets up for her students. We see opportunities for the children to draw from various resources as they first observe the worms, and then move to communicate their understandings in translanguaging spaces that are mediated by the open-ended structures. Therese supports this as she, (i) creates the open structure in which dynamic discussions happen, allowing children to use different resources to communicate, explore and make meaning. This brings much bodily movement to a classroom situation, and with that also brings interest and embodied participation and engagement of the children that are verbally participating less in the interactions. Further, (ii) the structures allow for children to guide conversations, thereby guiding language use and related communication choices; for example, Therese imitating the caterpillar movements and allowing for the use of body language as in all the excerpts from vignette 3, or Eric and Matthieu choosing the language in the interaction with Sara, and Sara following this choice.

Suárez (2020) suggested a need to understand how teachers can support science classrooms becoming translanguaging spaces, and our analysis has contributed one perspective toward that end, through demonstrating how Therese and Sara engaged a responsive pedagogy, in which they opened themselves up to listening to the children in ways that embraced and built from children's diverse and complex ways of communicating and sense-making.

6 | IMPLICATIONS, CONCLUDING THOUGHTS, AND A VIEW FORWARD

This study provides insight into how open science learning spaces afford students opportunities to take agency, and does so by building on theories of translanguaging pedagogies as we examined how students mobilized communicative resources in their embodied, materially grounded experiences within the open-ended structures. An implication from this work relates to the

value of MIA for shining a light on children's agentic moves through translanguaging. We intentionally use MIA as a methodology that begins analytically from what is done, rather than what is said. We do so, recognizing that the theoretical and methodological perspectives we choose matter, given that these can obscure as well as illuminate the abilities, identities and brilliance of those with whom we work. In this sense, starting with the sound off affords us wide views on children's communication. Translanguaging implies the "active use of multiple languages and other meaning-making resources in a dynamic and integrated way" (Wei, 2022, p. 172), and when analysis begins with the sound off, it potentially widens views offered through translanguaging as it allows for showing the nuances of the embodied ways in which communication emerges and unfolds and what is accomplished. This aligns with perspectives that emphasize the highly embodied complexities of communication, which Wei (2022a) and Wei (2022b) refers to as "transmodal translanguaging", as we see much of the young children's translanguaging occurring through modalities that are not lingual as such. Therese's practices show us the power of structuring open spaces for all students to engage in science, as they agentically can draw from their communicative repertoires in ways that further and reveal their sense-making. Their communication and science engagement are inseparable, and these intertwine through translanguaging when children are able to agentically draw upon diverse resources to communicate and make meaning together. Through taking a view on translanguaging beginning with broad views on children's transmodal participation through MIA, we can see how children's agentic mobilization of modes through translanguaging facilitates meaningful engagement in science.

Equitable learning environments are spaces where teachers and students honor the richness of children's sense-making and communication repertoires (Warren et al., 2020). We note that the analysis shows multiple instances where children state observations of something being "like this", as in vignette 3, and then continue the statement with gestures, facial expressions, and bodily movements to embody the remaining part of the statement, individually as well as collectively. Exploring children's participation within such open-ended spaces reveals that translanguaging emerges through the structures in dialectical relationship to children's agentic moves, allowing us views on how these structures can help work toward equity-focused science learning opportunities that broaden who can participate and how they can participate, thereby widening what counts as science engagement and communication, aligned with the potentials of translanguaging as a decolonizing project (Wei & García, 2022). In prioritizing children's equitable science sense-making, teachers position young children as capable of investigating questions and wonderings as part of developing science understandings and practices. Open-ended dialogic structures provide a way for students and teachers to come together around differences and make and communicate new meanings together (e.g., Siry & Yacoubian, 2023), and this study has shown how this is mediated by translanguaging, thereby contributing to the need that has been identified for research that shows how teachers can open up space for students to draw on their multiple language resources (Lemmi & Pérez, 2024).

In our work as Professional Developers, we often hear from teachers that they cannot implement inquiry-oriented, open-ended structures because there are "too many" students that do not speak the languages of instruction, which is seen as a barrier. This, however, is precisely why teachers should be incorporating open-ended, inquiry-oriented, investigation-driven approaches. Translanguaging is a perspective and a stance that allows us not only to understand "fluid multilingual practices within the limits and boundaries set up by these role sets, objectives and tasks, but to aim at challenging and transforming them" (Wei & Lin, 2019, pp. 211–212), a process which we work to do through teacher education. We support educators in being

open to diverse communicative resource use, and to position this diversity as a resource, and we take inspiration from Suárez (2020), who emphasized the importance of pre- and in-service teacher education for expanding teachers' capacity to develop and enact equitable pedagogical practices. For us, a key part of working toward equity and justice in science learning spaces is a teacher education praxis that is committed to collaborating through co-teaching. Co-teaching can provide a supported environment to reflexively consider the value of providing translanguaging spaces for children to engage with science sense-making in an agentic process that goes far beyond verbal utterances.

Classroom structures that create space for children to communicate with and build from their diverse repertoires can foster inclusion and equity, and the research presented herein has revealed how open-ended spaces create opportunities for engagement and communication through the mobilization of diverse resources. Research such as the work presented herein helps to understand how teachers can build from children's communication, and we hope to contribute to scholarship that desettles notions of communication as bounded (e.g., Suárez, 2020), as we try to work with teachers to deconstruct expectations for communication and push against forces that marginalize those outside of idealized notions of communication. In doing so, we seek to support teachers in creating structures that afford space for all children to communicate their understandings and wonderings in fluid and dynamic ways that are recognized, respected, and built from.

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ENDNOTES

[1] Following Roth et al. (2004), we use a Sheffer stroke to show the dialectical relationship.

[2] The SciTeach Center provides sustained in-service and pre-service teacher science education opportunities and ongoing professional learning opportunities through teacher support structures such as school-based coaching, and offers open-access pedagogical resources for teacher's classroom use (sciteach.uni.lu).

[3] The unit goals compare to the practices, concepts, and core ideas detailed in science curricula such as NGSS (NGSS Lead States, 2013) and support inquiry-oriented engagement in explore relationships between worms and their environment (NGSS-K), constructing arguments regarding worm's interactions with their environment (ESS2-2), opportunities for students to observe, collect evidence, record their evidence, and share their observations and then to build from their observations to describe patterns in the natural world and to answer scientific questions (LS1-1) (NGSS Lead States, 2013).

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