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From founding voices to future visions: languages and literacies in science education

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ABSTRACT

Over the past decades, languages and literacies have become a prominent focus in science education research and practice. While there is broad consensus on the central roles of disciplinary, representational, and cultural languages and their associated literacies in learning and teaching science, the field faces a critical moment. An ever-growing number of new theoretical and methodological perspectives have revealed rich facets of the multilingual and multimodal nature of learning processes in science. These developments prompt us to reflect on the distinct identity and impact of languages and literacies on the contemporary discourse in science education, especially in light of technological innovations (e.g. large-language models) and societal developments (e.g. multilingual contexts). This position paper offers an opportunity to assess the field's past developments and future directions, building on a recent meeting of the Special Interest Group (SIG) on Languages and Literacies in Science Education under the European Science Education Research Association (ESERA). We present viewpoints from four founding members of the SIG, discussing current trends, challenges, and visions for the future. Ultimately, this paper invites our global community to engage in informed dialogues on the role and value of languages and literacies in science education today.

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Introduction

The intersection of language and science education offers a rich backdrop against which we can study and understand how learners make meaning of science. From classroom discourse and multimodality to reading, writing, and translanguaging, languages and

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literacies have emerged as central themes in contemporary discourse on science education research and practice (Kelly, 2021; Tang & Danielsson, 2018; Yore et al., 2003; Yore & Treagust, 2006). As science education will have to adapt to changing societal demands (e.g. in multilingual contexts) and technological innovations (e.g. with the rise of large language models), the role of language – as both a resource for instruction and an object of study – is likely to take on even greater significance in the future.

The intersection of language and science education has a long history going back to several meetings that brought together scholars from diverse fields. The most notable events were the 'Crossing Borders' conference in 2001 (Saul et al., 2004) and the 'Island Group' conference in 2002 (Hand et al., 2003; Yore et al., 2004). These conferences have collectively highlighted the challenges and opportunities of engaging students in science literacy practices within the social, economic, and technological contexts during that period. They also positioned the need for different groups of researchers (e.g. science education and language education) to engage in meaningful dialogue about the role of language in science education. In this evolving context, the historical backdrop of these conferences two decades ago provides a crucial link between the foundational understanding of language's role in science education and the current focus on adapting to the multifaceted developments of contemporary society and modern technology.

Despite, or perhaps owing to, these developments, scholars working in the field of languages and literacies in science education find themselves at a critical junction. On the one hand, our theoretical perspectives and methodological tools have matured, and recent years have seen much exciting work on 'how the languages of science and their associated literacies afford, mediate, support, or hinder science teaching and learning' (ESERA, 2018). Besides, multiple new perspectives have appeared and converged, providing rich and nuanced insights into the multimodal, multilingual, embodied, and embedded nature of science teaching and learning (e.g. Amin & Badreddine, 2020; Charamba, 2020; Kersting et al., 2023; Larsson & Stolpe, 2022; Moro et al., 2020; Prain & Tytler, 2022; Siry & Gorges, 2020; Sjøberg et al., 2022; Tang, 2022; Tang et al., 2022).

On the other hand, these developments prompt us to pause and reflect on the distinct identity of the research field specifically and the impact of languages and literacies on the contemporary discourse in science education more broadly. As this area continues to evolve and expand, embracing an ever-broadening spectrum of perspectives, new concerns arise. The increasing diversity of perspectives can, paradoxically, obscure the focus of scholars working at the intersection of languages, literacies, and science education. Consequently, there is the risk of losing our shared focus and identity as a Special Interest Group (SIG) on Languages and Literacies in Science Education. We seek to create spaces for increasing diversities of perspectives, while working to maintain a unified focus that supports informing science classroom teaching and learning effectively.

The integration of knowledge allows for leveraging differences constructively and such deliberate integration can also work against the risk of possible connections between research and practice being drawn too thin. After all, we want to avoid that the implications of research findings become elusive and difficult to apply in educational practices. There lies a balancing act: while deconstructing the myriad aspects of science learning processes is crucial for detailed exploration in research, it is equally important not to

lose sight of reconstructing these elements into a coherent understanding that connects and contributes to furthering practice and empowers teachers. This coherent understanding is a requirement for responding to ongoing societal and technological developments successfully. As such, reflexive considerations of how we navigate this balance are crucial to maintaining the impact and shaping the identity of our field.

To address such concerns, we need to take a step back and reflect on past achievements, current trends, and future possibilities to spark dialogues, raise critical questions, and guide our community in taking deliberate and orchestrated actions. Members of the ESERA SIG6 Languages and Literacies in Science Education are ideally suited to facilitate such reflective dialogues. Ultimately, our aim is to invite our global community to engage in informed dialogues on the role and value of languages and literacies in science education in our current times.

History & mission of ESERA SIG6

The ESERA SIG6 was founded in 2018 to establish an international network linking researchers with interest in three broad and overlapping areas of research on language issues within science education: (a) the languages of students' cultures and communities, including their local vernaculars, standardised national languages, and everyday terms and registers, (b) the languages of specific disciplines that have unique ontological, epistemological, linguistic and pedagogical characteristics and (c) the languages of multimodal representations consisting of speech, written words, images, symbols, graphs and gestures that are essential to scientific meaning-making (ESERA, 2018). The overarching mission of SIG6 is to advance the research and understanding of languages and literacies within the context of science education. To realise this mission, the special interest group facilitates contact and collaboration among researchers across institutions and disciplinary areas, disseminates and discusses research findings through regular journal club meetings, coordinates invitations and calls to joint symposia, seminars, conferences, and special issues, and supports early career researchers with a community of established and more experienced scholars.

Over the past six years, the SIG has grown into a lively community with more than 300 affiliated members. In September 2023, SIG6 hosted a meeting in Copenhagen with about 30 international scholars participating in vibrant discussions on languages and literacies in science education. This position paper, a central outcome of the SIG6 Meeting, aims to promote informed dialogues and raise critical questions on the role and value of languages and literacies in science education, thereby offering visions for the future of our field. To do so, we first present the viewpoints of four founding members of SIG6, who engaged in a panel discussion on current trends, challenges, and future directions of languages and literacies in science education. These viewpoints, while inherently selective, present and contrast diverse perspectives, thereby offering an excellent starting point to reflect on the distinct identity of our community and the impact of our efforts on science education practice[1] We then comment on and contextualise the viewpoints by identifying interconnections and cross-cutting themes and by integrating these themes with insights from the presentations and discussions at the SIG6 Meeting and recent research literature.

Four viewpoints on current trends, challenges, and future directions

In line with the overarching goal of this position paper to promote informed dialogues and raise critical questions on the role, value, and impact of languages and literacies in science education, we tasked the four panellists of the SIG6 Meeting to summarise their contributions to and insights from the panel debate in the form of short written viewpoints. Together, these four founding voices of SIG6 represent a wide range of academic and cultural backgrounds and, thus, bring nuanced insights into languages and literacies across different regions and contexts. These insights address challenges such as language barriers, access to resources, and teacher preparedness, as well as opportunities, including cultural and linguistic diversity and integrating multimodal approaches in science classrooms. We invite readers to consider their local contexts and experiences when considering the four individual viewpoints and contemplate the nuances of each perspective. Through such open and reflective engagement, our community may collectively build shared understanding and advance languages and literacies in science education.

Christina Siry – embracing uncertainty in science education

The intricacies of languages and literacies as related to science education have been a focus of research for many years, and the field continues to evolve new foci, understandings and questions. Journal special issues provide a lens on trends, with several recently exploring intersections of languages, literacies and science learning. For example, an *International Journal of Science Education* issue a few years ago (Salloum et al., 2020) highlighted research in multilingual societies, shedding light on the intricacies of multilingual science education and the opportunities and challenges for students and teachers. The complexities of communication in science are a focus of an in-progress issue for the *Journal of Research in Science Teaching* (Pérez et al., 2022) that will highlight translanguaging perspectives to motivate discussion about the importance and nuances of language and languaging in science and engineering education. Related trends are visible in a recent issue of *Research in Science and Technological Education* (Wilmes et al., 2024) focusing on the role of the material and the embodied in science education, which has the overall goal of valuing and drawing understandings across different frameworks and contexts. These are just a few examples, providing snapshots into new views, innovations, and questions in an area of interest that has been growing in our field for multiple decades.

My perspectives are emergent from the multilingual, and rapidly changing, context of Luxembourg, where issues of equity are closely bound to languages. I collaborate with a team of teachers and researchers through our work at the SciTeach Center at the University of Luxembourg[2] where we design and advocate for open-ended approaches to early childhood and elementary science that build from children's highly complex and diverse array of resources, as we consider how to work towards wider notions of what counts as science participation, engagement, and learning. A challenge is that as the linguistic profiles of students rapidly shift and diversify, knowledge is often equated with language-related competencies, reducing languages as well as science to that which is already known. Questions that we grapple with, and which I encourage others to

reflect upon, include: What counts as science learning, and how is communication valued? How do language and communication support science learning, and how can all students engage in developing and communicating new understandings? How can science education become more inclusive, both in who can access it as well as in considering whose science is being valued?

At a panel discussion during the 2023 ESERA conference, Mauricio Pietrocola used the expression *opaque futures* in discussing the challenges of considering what skills and understandings children and youth of today will need as they get older. What types of knowledges, competencies, and actions will be needed in the future? This is not clear in looking forward, and this opacity and uncertainty pose a major challenge to education. There is a tension between a conventional educational preference for certainty and the uncertainty that is inherent in science, and it is imperative to reframe the role of science education to highlight the tentative, emergent, and shifting nature of knowing, learning, and teaching. Children are very able to deal with uncertainties, often thinking and engaging in complex, creative, and multifaceted ways, and their expressions of uncertainty can reveal an awareness of nuanced possibilities (e.g. Kirch and Siry, 2012). However, uncertainty and expressions of not-understanding may be considered as liabilities in classrooms (e.g. Watkins, et al, 2018). A possible a way forward for our field is to find ways to work with teachers towards a science education practice that values uncertainty. For example, Manz and Suarez (2018), analysed how teachers navigated ideas about uncertainty while exploring approaches to adapt and 'open up' their curriculum, examining uncertainty as a pedagogical construct, and highlighting several strategies that served as resources to teachers. Through pedagogies that embrace complexity and work with and from uncertainty, there is possibility to reimagine what counts in science learning, and in doing so to emphasise the role of languages and literacies.

Perspectives that position science as an emotional, embodied, and embedded engagement can shine a light on the ways in which people engage with languages and literacies within science learning and teaching contexts. Critical perspectives are furthered by examining translanguaging, materiality, and embodiment in science education. Methodologically, there are interesting directions visible related to multimodal approaches that highlight complexities through layering (e.g. Kristensen, 2018) and through combinations of different timescales and grain sizes analytically (e.g. Danielsson et al., 2023), with researchers exploring how feelings, sense-making, and practices *braid together* to shape science investigations and communication (e.g. Pierson et al., 2023). Exciting new work is being done that emphasises the intricacies of languages and literacies for learning science, in particular as entangled with bodies, materials, and affect (e.g. Rahm, 2024), emphasising nuances of languages, literacies, and science, and furthering wider views on what counts as science engagement, communication, and learning.

Kristina Danielsson – expanding horizons by merging perspectives

Six years after the founding of our SIG group, it goes without saying that the plurals in languages and literacies are highly relevant. The languages used in science, in the sense of the different semiotic modes, are as central for research in science education today as they were a few years ago, and as a consequence, the kinds of literacies that signify these

practices. The research community continues to move slowly along our familiar roads, though breaking new grounds, not the least concerning new perspectives on analysis. Examples from my corner of the research community (embarrassingly aware that my corner is a small one and that I do not have the overall view) are new interests in the roles of physical artefacts among those who have engaged in the multimodal practices (Tang, 2022; Tang et al., 2022), new analytical methods for analysing video data to avoid the language bias (Siry & Wilmes, 2023), new tools to analyse metaphors (Danielsson, 2016; Jahic Pettersson et al., 2020; Kersting & Kohler, 2023), retakes on the analytical framework in Lemke's (1990) often cited 'Talking Science' for analysing multimodal representations and interaction (Danielsson et al., 2023), and more.

From my perspective, I hope for two ways forward. One is to open up to merge different perspectives. What can we make visible in our analysis when shining our torch (I use Christina Siry's metaphor here) on our data from different perspectives? And, as a consequence, what – if anything – can be gained from applying our different theoretical lenses to the same set of data? One nice example is the fictive conversation between researchers from different backgrounds (Kersting et al., 2023).

The second way to move forward is connected to the societal changes and challenges following globalisation and migration, which The New London Group discussed 25 years ago (The New London Group, 1996). Science classrooms are often heterogeneous, with pupils and students coming from different backgrounds and having different cultural and linguistic resources. Also, at least in Sweden, which is my context, apart from the diversity following globalisation, teachers in all classrooms can expect to have several students with different kinds of neuropsychiatric diagnoses, such as ADD and ADHD. With such challenges being necessary to consider, some areas need development. First, we need to combine multimodal and multilingual perspectives of meaning-making in science classrooms in order to (a) highlight and identify the challenges for students learning science content and the majority language in parallel, where the juggling between modes can both be a support and a challenge in itself (b) develop teaching practices where students are encouraged to use a variety of available resources when making meaning, but also to show their knowledge in science including all languages that they have access to (e.g. Wei, 2018), (c) develop models and practices for assessment in science classrooms that can cater for the variety of resources that students might use to make meaning and show their knowledge in science (cf. 'cultures of recognition', Kress & Selander, 2012).

Eduardo Mortimer – revisiting familiar concepts with a renewed perspective

The presentations at the ESERA Conference 2023 within the SIG6 Symposium '*Promising Scholars of SIG6 Languages & Literacies in Science Education: New Research on Multimodality*' and in the symposium '*Integrate Language and Science Education – Resources and Possibilities*' expressed the major tendencies I see in our field: we are increasingly concerned with materialism, embodiment and action, all these occurring in the context of multimodal interaction. In other words: we depart from approaches that privileged mind and language, both decontextualised and hypothetical, to approaches that valorise different material objects and embodied actions (Tang, 2022). Science education researchers have long acknowledged the importance of material resources, but usually within a narrow range of ideas associated with practical work (Tang, 2022). This new

materialism arising from contemporary studies broadens our perspective, acknowledging that 'an exclusive attention on human actions has the danger of obscuring or ignoring the role of non-human actors (i.e. material objects) in producing joint interaction and meaning (Latour, 2005),' (Tang, 2024, p. 18).

I see a common trend in the articles presented at ESERA conference 2023 and in other works on multimodality: (1) The embodied modes (gesture, drawings, material objects) lower the level of abstractions, and this also means that you can manipulate the modes, make actions with them, etc. (2) Modes are multiplicative and not additive: this means that with the use of intermodal analysis we can have an effect that is stronger than the simple addition of the modes.

As multimodal analyses gain terrain in our field, an interesting possibility is to revisit some old subjects with these new multimodal approaches. This is the case with metaphors, featured in two studies across the mentioned ESERA symposia. Metaphors are traditionally used in science to express abstract concepts in a concrete way. What is new is the conclusion that 'the teachers often drew on non-verbal modalities such as gestures, drawings or material objects to cue the source domains, thereby enacting the metaphors' (Kersting & Kohler, 2023, p. 411) and that metaphors tend to be used with gestures in the source domain and with verbal language in the target domain (Sowinski & Abels, 2023).

From the work on metaphors, we can ask a further question: Which research areas will be revisited, like the metaphors, to look for multimodal effects? Shall we consider revisiting the research on misconceptions to find out what gestures are used to express conceptions such as force, heat, and chemical reaction? One way to do this is to identify the relationship between language and its functions in line with systemic functional linguistics (SFL) perspectives. Another way is looking for recurrent gestures (McNeill, 2005; Mortimer & Pereira, 2024), which are emblems used by a small community.

Another, more general, question that arises from the research in languages and literacies is how to label the semiotic modes. I came across the suggestion of Tang (2024), following Van Rooy and Chan (2017), who asserted that there are five modes commonly used in classrooms: verbal-linguistic, visual-graphic, mathematical-symbolic, gestural-kinesthetic, and material-operational. I think this way of labelling the semiotic modes incurs the same sort of mistake of linking speech with writing, which Kress criticises: 'The focus on materiality marks two decisive moves: one is the move away from abstraction: such as 'language', 'the linguistic system' and 'grammar' and a move towards the specificity of a mode and its potential as developed in social uses (…) Beyond that, the focus on materiality offers the possibility of seeing meaning as embodied – as in our bodies: a means of getting beyond separations of those other abstractions, mind and body, of affect and cognition.' (Kress, 2010, p. 83). Unifying speech with writing, with their different materialities, the different logics of time and space, of sequence and simultaneity – exposes the improbability of the mode called 'language' (Kress, 2010). Speech, for example, has loudness and pitch as material characteristics. Writing, in turn, has paragraphs, bold, etc, as material characteristics. This is why we should avoid expressions as 'non-verbal' or 'verbal-linguistic' in studies on multimodality. This would reinforce the centrality of speech and writing (modes to express the 'verbal language'), and this is not intended.

We should also acknowledge that although research on languages and literacies has brought new theories and empirical studies to science education, their practical result

is still limited. Most teachers continue to use mainly initiate-respond-evaluate patterns to interact with their students. Shall we have a word on how to disseminate our research results?

Clas Olander – advocating for the plural forms of languages and literacies

Is the concept of languages and literacies worth advocating for? The title of SIG6 encompasses languages and literacies, both notions that have been discussed and, at times, contested. Such debates are not surprising in today's context with increased migration, developments in digital technologies and media landscapes and, not the least, global threats like climate change, all of which contribute to an opaque future. This viewpoint focuses on the plural forms of these notions and the prefixes 'multi-' and 'trans-' to highlight important trends, along with the challenges and possibilities these trends evoke for our community.

First, consider the term literacies. On the one hand, it has become a trend to apply the term literacy to various domains, for example, climate literacy, media literacy, chemical literacy, etc. This trend can introduce new perspectives and methodologies but may dilute the notion of literacy. On the other hand, the OECD, in the upcoming PISA 2025, toned down the use of science literacy (OECD, 2023). The reasons for this are not evident but could mirror the movement that argues for a renewed focus on core scientific knowledge. However, advocating for expanding the purpose of science education towards literacies is an important position. Not the least since literacies point towards action, personal development (bildung/dannelse), and responses to existential challenges like climate change. After all, the purpose of science in schools is, first and foremost, to contribute to shaping decent, informed and democratic citizens. Arguments that favour an emphasis on literacies are rooted not only in seminal works on the fundamental and derived sense of literacy (Norris & Phillips, 2003) and visions (Roberts & Bybee, 2014), but also in recent trends at the intersection of general literacy and different disciplinary literacies (Tang & Danielsson, 2018).

When it comes to languages, the discussion revolves around pluralistic notions such as multi-language, multi-cultural, multi-identities, and the like. Often, these approaches refer to translanguaging and the idea that in order to communicate, we make use of all available language resources (Karlsson et al., 2019). This idea also points towards the importance of expanding beyond verbal language: we communicate, not the least in science classrooms, with drawings, gestures, formulas, songs, comics, representations, models, graphs, animations, metaphors, etc. In short, we depend on multimodality (Olander et al., 2018). Our usage of different named languages, social languages and multiple modalities underscores that we are all multilingual. Let us make this multilingualism less of a problem and more of an asset.

For research, these trends present a great opportunity, inviting us to work more transdisciplinary and explore research fields with different methodologies and theoretical underpinnings. Transdisciplinary studies between science education and linguistics have indicated the special linguistic characteristics found in science classrooms, such as specific words, grammar and semantic patterns (Lemke, 1990; McComas et al., 2018). However, details of how these characteristics play out in science classrooms across multilingual, multicultural and multimodal settings remain still much of a black

box. For example, the multimodal communicative patterns between teachers, students, and materials in action are under-researched. From case studies, we know details about, for example, dialogic patterns (Mortimer & Scott, 2003), embodiment and new materialism (Kersting & Kohler, 2023; Siry & Wilmes, 2023), but a comprehensive perspective is still lacking.

One promising way forward may involve collaboration on the collection of classroom transcripts to develop a joint corpus of classroom transcripts for quantitative, qualitative, and mixed-methods analyses. The potential for corpus linguistic research would be huge if the transcripts in such a corpus were multimodal, with annotations highlighting all languages. For example, could meaning-making-in-action become a unit of analysis, helping us uncover specific materialities or habits? Could classroom discourse analyses reveal the oppression or privileging of certain voices?

Summarising and synthesising perspectives on languages and literacies in science education

Collectively, the four viewpoints offer a far-reaching view of the dynamic and evolving landscapes of languages and literacies in science education, identifying trends, challenges, and future directions. Of course, trends (with their associated challenges and opportunities for breaking new ground) always respond to their times. Indeed, the panellists' observations, questions, and visions for the future unfold against a backdrop of rapid societal transformations where climate change, geopolitical crises, and increased migration on a global scale translate to heterogeneous and multilingual classrooms in local contexts (International Commission on the Futures of Education, 2021). Besides, quickly evolving digital technologies, with generative artificial intelligence (AI) currently leading the way (International Commission on the Futures of Education, 2023), outstrip the pace of curriculum development and leave educators navigating uncharted territory and facing uncertain futures. Such developments demand a re-evaluation of educational practices and paradigms. It is, therefore, not surprising that even the very notion of literacy is currently contested, as demonstrated by the new OECD PISA framework that has dropped the notion of scientific literacy altogether (OECD, 2023).

All the more, it is timely and relevant to reflect on the past achievements of our community and contrast disparate views of trends and challenges in our field so that we can raise questions and spark dialogue about future directions. This commentary sets to achieve this way forward by identifying interconnections and cross-cutting themes among the four viewpoints. To give structure to this synthesis, we look at challenges, trends, and future directions separately, always keeping in mind that languages (understood in their broadest sense as disciplinary, representational, and cultural languages) are both a resource for instruction and an object of study, both a medium and a subject, for science education researchers.

Challenges in languages and literacies in science education

The individual perspectives outlined by the panellists reveal several challenges that span educational and research practices and that are intensified by the rapid evolution of societal and technological landscapes. One challenge that cuts across all four viewpoints

is the increasing heterogeneity of science classrooms that now encompass a wide variety of learners, including those for whom the language of instruction is foreign. Working with teachers and researchers in the multilingual and culturally diverse Luxembourg, such heterogeneity is at the top of the mind of Christina Siry, who asks us to push against equating knowledge solely with language-related competencies. Instead, Siry wonders how we can support all students in developing and communicating their understandings of science, be it through processes of translanguaging or emotional, embodied, and embedded ways of participation.

Complementing these thoughts on linguistic and cultural diversity, Kristina Danielsson addresses the additional challenge of traditional assessment methods, which may hinder (rather than facilitate) science learning. She endorses varied assessment forms, echoing the need for our instructional practices to adapt so language does not become an obstacle in exploring science. Here, the incorporation of multimodality arises as a critical theme since diverse assessment forms indicate the integration of multiple semiotic modes – visual, gestural, and material – alongside the verbal.

Equally important is the essential role of teacher education in this process. Eduardo Mortimer brings attention to the challenge of research findings to resonate with teachers and within actual classrooms, ensuring that academic advances have a tangible impact on science education practices. He urges us to bridge the ubiquitous divide between science education theory and practice since science teachers often still follow the traditional initiate-respond-evaluate pattern. One way of realising this goal is through targeted efforts in teacher education programmes, informing pre-and in-service teachers about the value and role of languages and literacies in science education. According to Mortimer, and in agreement with the other panellists, we can only build bridges between theory and practice and move beyond traditional classroom discourse patterns, if we embrace the multifaceted nature of communication. This observation ties back to the notion of multimodality and our all-too-common bias towards privileging speech and writing.

Related to this observation is the challenge for science education researchers to categorise semiotic modes within the research on multimodality. In exploring this challenge, we encounter a divergence of perspectives amongst the panellists. Mortimer criticises using terms such as 'non-verbal' or 'verbal-linguistic,' arguing that these contradict the intent to value all modes of expression equally. In contrast, Danielsson expresses her conviction about the continued importance of verbal communication, even in a context that acknowledges multiple modes of expression. This juxtaposition of views underscores the evolving conversation in our field and invites further deliberation on how to harmonise these perspectives. It becomes clear that both positions offer insightful contributions: Mortimer points us towards a more holistic approach to modes of expression, while Danielsson reminds us of the foundational role that verbal language plays within multimodal interactions.

In addition, Clas Olander points to the dilution of the notion of literacy as a pressing concern, with the introduction of various types of literacies – climate, media, and AI, among others. This proliferation calls for careful consideration of what we mean by literacy and how to preserve the integrity of this notion. Similarly, Siry confronts the 'opaque futures' of science education, pondering the evolving role of language and literacy in embracing complexity amidst uncertainty. She identifies the tension between

a conventional educational preference for certainty and the opacity of our futures as a significant challenge for science educators, hoping that this challenge will prompt our community to reimagine what counts in and as science learning.

The final challenge that underpins the panel discussion is the rapid pace of technological progress brought about by generative AI. It is crucial to recognise that language plays a central role not only in science teaching and learning (Lemke, 1990), but also in the functioning and use of AI. This is because generative AI is powered by large language models that rely on the use of language to recognise and generate multimodal texts, as well as to interact with users. Given this shared foundation on the role of language, research in languages and literacies in science education offers invaluable ideas and insights into the pedagogical use of generative AI in science education (Tang, 2024). With a rich intellectual history of research in this area, SIG6 is well positioned to lead the conversation on the potential use of AI to reshape the way we learn science.

In sum, the challenges in languages and literacies identified by the SIG panellists – ranging from classroom diversity to learners 'opaque futures' – reflect a critical intersection between current societal and technological shifts and science education. Consequently, the feasibility of addressing these challenges must lie in a multifaceted approach that likewise navigates the rapid societal and technological developments. We return to a discussion of such an approach after having synthesised the trends and visions that the four panellists raised during their debate.

Trends in languages and literacies in science education

Distilling current trends from the viewpoints, we can see that they clearly respond to the challenges outlined above. These trends, primarily emerging within the research and academic sphere, signal a shift in thinking among science education researchers that may progressively influence educational practices.

First, acknowledging the multiplicity of communication forms, Olander identifies the intentional use of plural endings in 'languages' and 'literacies' as a major trend. This trend underscores the recognition that languages and literacies are diverse, evolving, and situationally specific rather than static and uniform constructs. Besides, Olander points out that we are witnessing increased usage of the prefixes 'multi-' and 'trans-' – signifying an interest in multilingual and translanguaging approaches, as well as transdisciplinary collaborations. This observation is echoed by Siry, who draws on two special issues about multilingual science education (Salloum et al., 2020) and translanguaging perspectives in science and engineering education (Pérez et al., 2022) to identify trends that recognise and value the rich linguistic resources students bring to the science classroom.

Second, across all viewpoints, there is the recognition of a marked shift from perspectives privileging the mind and language towards a focus on materialism and embodiment in science education (Hetherington et al., 2018; Kersting et al., 2021; Milne & Scantlebury, 2019; Wilmes et al., 2024). As Mortimer and Siry suggest, researchers are moving their focus to the tangibility of material objects and the significance of embodied actions in science teaching and learning. One example illustrating this trend is a recently published special issue on the role of the material and embodied aspects of science education (Wilmes, Siry, and Tang, 2024) that explores the entanglements of materials and

bodies in science teaching and learning. Another example is the topic of metaphors that are examined not just linguistically but from enactive and multimodal perspectives (Gallagher & Lindgren, 2015; Kersting & Kohler, 2023; Larsson & Stolpe, 2022; Lindgren et al., 2016). Mortimer and Danielsson both draw attention to this renewed interest, recognising the decisive role that metaphors play in learning processes across different modes of expression.

Finally, Mortimer and Danielsson indicate a trend toward re-evaluating established theories to adapt to current educational contexts and challenges. It seems that science education researchers are looking backward to move forward, re-examining old ideas through contemporary lenses. This critical reassessment underscores the importance of maintaining continuity with research and reviewing existing concepts with new perspectives. Reflecting on the language-science education 'Island Group' Conference, the concept of a 'fundamental sense of scientific literacy' proposed by Norris and Phillips (2003) was a key seminal idea that advanced our understanding two decades ago. While the premise that literacy is essential to science learning still remains relevant today, our understanding of literacy has evolved from a primarily verbal focus to a broader view that encompasses multimodal uses of physical artifacts, metaphors and classroom interactions.

In sum, identifying current trends in languages and literacies within science education points to a dynamic scholarly discourse that is beginning to influence and inform instructional practices. Naturally, the feasibility of integrating these trends into practice is tightly interwoven with visions for the future of our field to which we now turn in more detail.

Future directions in languages and literacies in science education

In reflecting on the future of languages and literacies in science education, the panellists identify shared visions for educational practices and for research practices. With regard to educational practices, a shared vision among all panellists is pushing towards holistic integration on the one hand and transformative advancement on the other: an embrace of multilingual realities as advocated by Olander, an overhaul of assessment practices as proposed by Danielsson, alignment between educational research and classroom practices as Mortimer deems essential, and a pedagogical shift that builds from childrens' imaginative and creative ways of being as implied by Siry.

Differences, however, highlight each panellist's distinct perspective regarding this dual vision of integration and transformation: Olander and Danielsson address externally driven considerations such as global challenges, the make-up of assessment systems, and the enduring role of scientific literacy. In contrast, Mortimer and Siry focus on the internal mechanisms of education – the need to better prepare pre – and in-service teachers to diversify their instructional practices, the need to embrace embodied, emotional, and embedded ways of learning and doing science, and the need to empower students to pull resources from multiple languages and semiotic systems into a meaningful whole. Incidentally, such diversified instructional practices could also do justice to Lemke's (1998) key observation that science concepts are semiotic hybrids, integrating verbal language, mathematical symbols, graphical representations, and action-oriented practices. Suppose we support students in combining diverse resources in embodied and embedded inquiries. In that case, their learning processes will likely mirror the

hybridity of science concepts themselves, thus fostering integrated and interconnected scientific understanding.

With regard to research practices in science education, one vision that emerges from the viewpoints is the invitation to push the boundaries of our current practices. Indeed, all panellists invite us to be bold and innovative in our research: Siry's commentary on the introduction of new pedagogical terminology – such as 'braiding together' practices, feelings, and sense-making ' and 'layering' different analytical approaches – complements Mortimer's insight that multimodality allows for the multiplication of meanings. In particular, we continue to discover the meaning potential of new modes, such as the material one (Tang, 2022). In a similar vein, Olander's suggestion to work more transdisciplinary with a variety of research fields with different methodologies and theoretical underpinnings resonates with Mortimer's insight that different disciplines such as education psychology, linguistics, sociology, or anthropology (to name a few), have brought new perspectives and foci to science education research at different time periods and will continue to do so. Finally, Danielsson's vision of combining different analytical and theoretical viewpoints aligns well with Olander's vision of creating a shared corpus of classroom transcripts within our research community.

Moving forward, the feasibility of these visions hinges on a more flexible curriculum design, allowing for multimodal and embodied learning experiences and assessment practices. Of course, this transition in instructional practices is contingent on teacher education programmes that equip science teachers with culturally responsive pedagogies and a solid understanding of diverse communicative forms. Similarly, future work could also prioritise curricular models that foster adaptability and resilience to acknowledge the 'opaque futures' and the uncertainty of our times. Not the least, advancements in AI are likely to push practices of scientific literacy, necessitating intentional use of large-language models in science classrooms. Concrete steps toward this future include adopting transdisciplinary research methodologies and forging collaborative networks for sharing classroom practices and data. Besides, re-evaluating established educational theories in light of new trends suggests an ongoing dialogue within the academic community to ensure our theoretical frameworks adapt to meet the needs of contemporary learners.

Conclusion

In conclusion, languages and literacies, understood in their multimodal and plural forms, continue to hold central importance in science education research and practice. The visions shared by the panellists chart a future that embodies holistic integration, transformative advancement, and transdisciplinary collaboration. These visions express a view of science education and science education research, by extension, as an ongoing, adaptive endeavour rather than a fixed body of knowledge and practices. Importantly, in this view, linguistic and semiotic diversity serves as a rich resource for constructing more inclusive and impactful science education practices. The individual contributions of the panellists highlight the ambition behind these visions by proposing concrete measures, such as the adoption of innovative assessment forms and the leveraging of knowledge from various disciplines to foster diversification in expression and embodied forms of engagement. Collectively, the four voices call for a sustained commitment to bridging theory and practice, and they reinforce the necessity of ongoing dialogue and collaboration to navigate

uncertainties and drive progress in and beyond the field of languages and literacies in science education.

Finally, we recognise that the discussions presented in this position paper are by no means exhaustive of the possible topics, trends, and developments currently influencing the field of languages and literacies in science education. Pertinent issues such as the cultivation of scientific literacy in the age of epistemic challenges, including the discernment of reliable information amidst misinformation and the prevalence of social media, remain crucial to address (Höttecke & Allchin, 2020; Osborne & Allchin, 2024; Sharon & Baram-Tsabari, 2020). Furthermore, the rapid advancements in generative AI and the application of large language models in educational contexts have the potential to reshape the landscape of language learning and literacy practices significantly (Tang, 2024). Although not featured extensively in our position paper, these emerging areas are acknowledged as critical dimensions that warrant further exploration by the research community. Our hope is that this position paper serves as a catalyst for continued scholarly inquiry into the evolving complexities of languages and literacies in science education.

Notes

1. We acknowledge that the selection of panel members does not encapsulate the entire breadth of opinions and expertise that exists within the broader field. By choosing a focused group of four founding members of SIG6, we aimed to distil key concepts and challenges, but we also acknowledge that this does not begin to cover the full spectrum of perspectives within our community.
2. sciteach.uni.lu

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Author contributions

This position paper represents a collaborative effort, reflecting the shared expertise and contributions of all authors. Magdalena Kersting, as one of the current coordinators of SIG6 and host of the 2023 SIG6 Meeting in Copenhagen, has coordinated the activities of all authors. She has written the introduction and initial draft of the commentary section and was responsible for the final copyediting and proofreading of the manuscript. Kristina Danielsson, Eduardo Mortimer, Clas Olander, and Christina Siry, as founding members of the Special Interest Group 6 of ESERA, have each authored their viewpoints presented within the paper. Their viewpoints were based on their participation in a panel debate on current trends, challenges, and future directions in languages and literacies in

science education. Additionally, they have read and provided feedback on the final version of the paper. As a founding coordinator of SIG6 and serving in this capacity for six years until the end of 2023, Kok-Sing Tang enriched the introduction and commentary with his profound insights. His contributions include adding historical developments, integrating relevant literature references, and broadening the context of the discussion, thereby enhancing the overall quality of the paper and anchoring its relevance in contemporary educational research. All authors have approved the final version of the position paper for submission.

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