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Science and Heritage Language Integrated Learning (SHLIL): Evidence of the effectiveness of an innovative science outreach program for migrant students

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Abstract

Migrant students tend to underperform in Science, Technology, Engineering, and Mathematics (STEM) subjects and are less likely to pursue higher education in STEM when compared with their nonmigrant peers. Given the substantial increase in migration, this disparity has been a central concern in science education in many European countries. The purpose of this study was to investigate the effectiveness of an innovative science outreach program that brings together migrant students and STEM professionals with the same linguistic and cultural backgrounds. The program consists of one-off workshops that follow an inquiry-based approach and include hands-on activities and science communication in the students' heritage language. Using surveys with adapted scales and open-ended questions, we applied a randomized block design with waitlist control groups and repeated measures. Eighty-three Portuguese-speaking migrant students aged 6–17 years participated in the workshops in Germany and the

United Kingdom. Results indicate that both the students and STEM professionals evaluated the program positively and that students who participated in the workshops tended to demonstrate an increase in their attainment value for science and an increase in their self-concept of ability for the heritage language 4 weeks after the intervention when compared with students in the control condition. These effects were particularly pronounced for students with low prior motivation to study science or speak the heritage language. Our results thus show that it is possible to foster migrant students' attainment value for science and increase their self-concept of ability regarding the heritage language through a brief science outreach intervention.

KEYWORDS

heritage language, intervention program, migrant students, motivation, role models, Science and Heritage Language Integrated Learning (SHLIL), science outreach

1 | INTRODUCTION

With the growing mobility and diversification of migration (United Nations, 2019), schools across Europe have increasingly welcomed students from various cultural and linguistic backgrounds (Banks et al., 2016). Such cultural and linguistic diversity can pose challenges for both the migrant students themselves and the schools they attend. First- and second-generation migrant children often fall significantly behind their nonmigrant peers in terms of academic achievement. In addition, although migrant students cannot be described as a homogenous group because they differ in many individual characteristics, they have been found to be at greater risk of developing lower self-esteem and of underperforming in Science, Technology, Engineering, and Mathematics (STEM) subjects when compared with nonmigrant students (e.g., European Commission, 2017; Martin et al., 2016; UNESCO, 2019).[1] Multiple factors can account for migrant students' underachievement, including an identity crisis, language barriers, low science capital (i.e., reduced exposure to science-related knowledge, attitudes, experiences, and resources; see Archer, Dawson, et al., 2015), low parental engagement, and issues of prejudice and perception toward their heritage. For this reason, fostering migrant students' achievement and motivation is of great educational and societal relevance, and effective approaches are urgently required to compensate for this group's disadvantages (see Martin et al., 2016).

After-school science learning experiences are one promising way to meet this objective. To date, few studies have focused on minority students' experiences in afterschool settings or how they respond to culturally relevant pedagogical practices (see Gutierrez, Blanchard, et al., 2022). Here, we considered that such learning experiences might be particularly beneficial for migrant students when delivered in the students' respective heritage languages by practicing STEM professionals[2] who share the students' cultural and linguistic backgrounds (e.g., Easterbrook & Hadden, 2021; Laursen et al., 2007; Osborne et al., 2003). Thus, we evaluated a science outreach program that brings together multilingual migrant children and STEM professionals through 90-min-long interventions involving inquiry-based hands-on science interactions in the students' heritage language. Heritage languages are the languages spoken at home to young children and adolescents in situations where these languages are not the dominant language of the larger society.[3] For example, Russian, Turkish, and Polish are widely spoken heritage languages in Germany. Science interventions delivered in the heritage language have previously been shown to facilitate the students' identification with the scientists and might thus enable the students to perceive these multilingual scientists as role models (see Dasgupta, 2011; Easterbrook & Hadden, 2021; Eccles, 2009). Moreover, the scientists can offer positive, motivating learning experiences and demonstrate the relevance of science to their own and the students' daily lives (e.g., Jarvis & Pell, 2002; Laursen et al., 2007; Osborne et al., 2003). However, although evaluations of the effectiveness of such after-school approaches are essential, empirically valid evaluation studies are still scarce (e.g., Laursen et al., 2007), and most such studies have not examined migrant or minority samples (Lawner et al., 2019).

The goal of the present study was to evaluate an innovative science outreach program for migrant students created by Native Scientists (https://www.nativescientists.org/), a multiaward-winning European nonprofit organization (see Golle et al., 2022). In this program, science topics and careers are discussed in the students' heritage language (La Morgia et al., 2018); the workshops thus follow a Science and Heritage Language Integrated Learning (SHLIL) approach, which we describe here as a variation of "classic" Content and Language Integrated Learning (CLIL) approaches. In CLIL education, students learn new content (across a range of disciplines, including but not limited to the natural sciences) through a foreign language (see Coyle et al., 2010; Marsh, 2008). By contrast, in SHLIL education, students learn specifically about STEM subjects through their heritage language. The interaction between scientists and students occurs in workshops, which include an inquiry-based learning approach, multiple science hands-on activities, and science communication with possible role models (see Clark et al., 2016; Colburn, 2000; Dasgupta, 2011; Meyer & Crawford, 2015). The aim of the workshops is to foster migrant students' interest and motivation to study science subjects and to support their heritage language development. Our main research question was whether participation in the workshops would have a positive effect on the migrant students (i.e., their motivation to do science and their motivation to speak their heritage language). In this paper, we present the intervention, show the impact and observed effects on students, and discuss our intervention model to explain the positive impact. To analyze the workshops' effectiveness on the one hand and to understand the ongoing processes on the other hand, we used a mixed-methods approach (see Leech et al., 2010) and complemented the quantitative analyses with qualitative data (open-ended questions).

1.1 | Students' motivation (to do science)

Several theoretical approaches have been used to describe the development and formation of students' motivation and the complex interplay of the factors involved. We chose Eccles et al.'s (1983) expectancy-value theory (EVT; recently revised as Situated Expectancy Value Theory [SEVT]; Eccles & Wigfield, 2020) to provide the theoretical framing of the study for two main reasons. First, in this theory, ideas from social cognition, developmental sciences, as well as sociocultural perspectives are considered in the elaborated classic expectancy-value models, and thus, SEVT provides a comprehensive model for studying migrant students' motivation. Second, the theory focuses on differences and diversity rather than deficits. In the following, we explain the SEVT, the important role of cultural identity in this model, its connection to identity development theory, and finally, existing intervention approaches in and beyond the SEVT. In doing so, we provide the basis for understanding the processes that are assumed to occur in our science intervention program for multilingual migrant students, as this program combines inquiry-based and hands-on science activities with role models who share the students' linguistic and cultural backgrounds and heritage language practice (see Dasgupta, 2011; Easterbrook & Hadden, 2021; Eccles, 2009).

1.1.1 | SEVT

According to Eccles et al.'s (1983) SEVT, achievement-related choices in a domain are directly influenced by people's expectations of success and their subjective task value (STV) (interest-enjoyment value, attainment value, utility value, and cost) for this domain. That is, students demonstrate higher achievement and are more likely to pursue an activity in the short term or long term if they expect to do well in it (e.g., expressed through their self-concept) and if they value the activity (expressed by STVs; see Eccles & Wigfield, 2002). Furthermore, SEVT includes a socialization component declaring the roles of culture and teachers in forming students' achievement-related beliefs (Eccles et al., 1983). Eccles et al. particularly emphasized the important role of cultural background, as the development of a person's expectation of success and STV are influenced by social and cultural processes (Wigfield & Eccles, 2019, see Figure 1). Eccles et al. classified such social and cultural processes as macro level ("Cultural Milieu" box), more proximal ("Socialization" box), and micro level processes (e.g., "Interpretation of Experience," "Affective Memory" boxes). They presented the model as a map of key processes and constructs at multiple levels and timeframes of functioning.

Associations between students' expectations of success and STVs and their achievement-related choices have been reported for several domains, including science. For example, elementary and secondary students' science self-concepts of ability and intrinsic interest have both been shown to be positive predictors of science learning and understanding as well as sustained science engagement (for a review, see Wigfield et al., 2016). Thus, fostering science motivation through science workshops might build an important base for continued engagement and achievement in scientific topics. However, the majority of studies that targeted adolescent students' motivation to learn STEM subjects included samples of European or American middle-class students (see Rosenzweig & Wigfield, 2016, for a systematic review). Only a few studies included ethnicity or socioeconomic status in the

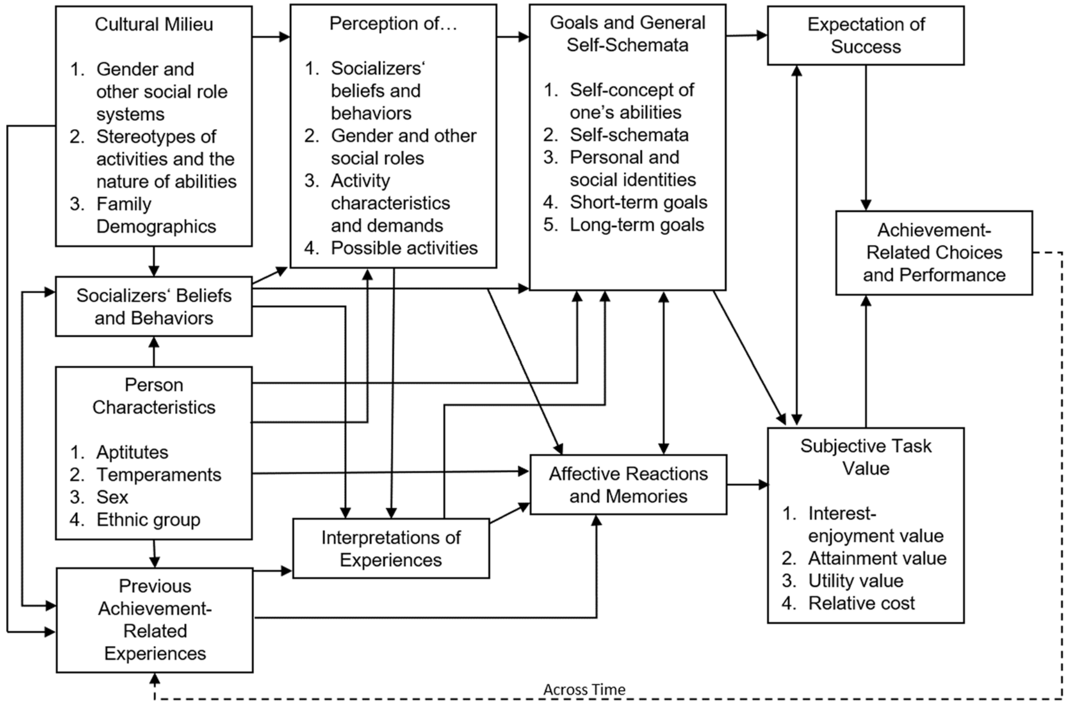

FIGURE 1 Eccles et al. expectancy-value model of achievement-related choices and performance (from Eccles & Wigfield, 2020).

analyses to examine the impact of these covariates on the effectiveness of their intervention, and these studies also reported ambiguous findings (e.g., Harackiewicz et al., 2016; Hulleman & Harackiewicz, 2009; Star et al., 2014). Such ambiguous findings (i.e., that some interventions have been found to be beneficial for minority groups, whereas others have not) underline the need for further research on interventions targeting minority students and on the mechanisms that may potentially be relevant for migrant students in such interventions.

Identity formation within the framework of the SEVT

Within the SEVT framework, Eccles et al. (1983) particularly emphasized the important role of cultural identity for the development of students' motivation. This relationship is relevant for explaining the processes that were expected to result from the present study's intervention, which brought together migrant students and STEM professionals with the same linguistic and cultural backgrounds. Eccles et al. described that social and cultural processes (see Figure 1, "Cultural Milieu" and "Socializers' beliefs and behaviors" boxes) influence the development of STV and that these processes are linked to identity development. Identities (Eccles, 2009) encompass both personal identities, which relate to who student thinks they are or what makes them feel unique, and collective identities, which ties students to others through their social groups or relationships. Eccles (2009) specified that identities contain schema about types of behaviors, tasks, and activities that fit or do not fit with the identities. For example, ethnic minority and migrant children form beliefs about which behaviors, roles, and interests are appropriate with respect to their ethnic background (see "Childs' perception" box, Figure 1). Because individuals seek to confirm their identities, they place more value on tasks that match their identities (Eccles, 2009). More specifically, Eccles (2009) derived from theory that individuals' identities form through external and internal comparison processes, psychological interpretative processes, social influences (e.g., parents, teachers, and peers), modeling, and vicarious learning. This corresponds to identity models (Stereotype Inoculation Model, Dasgupta, 2011; Identities in Context Model, Easterbrook & Hadden, 2021), which also emphasize the salience of certain social and cultural factors (e.g., prevalent negative stereotypes and expectations of performance in education; lack of positive ingroup representation in academic contexts; and a negative disposition of the ingroup toward education). For example, migrant students are at risk for an absence of positive ingroup representations, which can be alienating and demotivating for students and can even lead them away from education because they can hardly imagine themselves deriving benefits from education (Easterbrook & Hadden, 2021). On the contrary, after seeing a successful ingroup member, minority group members tend to have more positive perceptions of themselves (Brewer & Weber, 1994).

Relating the SEVT to identity development theories

Because the SEVT includes constructs from identity theories, we want to relate the SEVT to identity development theories (e.g., Dasgupta, 2011; Easterbrook & Hadden, 2021). Such theories explain why it is easier for students to connect and identify with ingroup members who share a similar cultural background and speak the same heritage language.[4] Lee (2002, 2003, 2004); Lee et al. (2005); Lee and Fradd (1998) formulated an instructional congruence framework as part of the cultural congruence literature, which is aimed at making academic content accessible and meaningful for students. It emphasizes the development of congruence between students' cultural expectations and interactional norms in the learning situation as well as between academic disciplines and students' linguistic and cultural experiences, focusing on the latter. Congruence between a student's language and culture fosters the student's acquisition of their home language and the language used to teach science. Furthermore, such a congruence helps students behave competently across social contexts and get closer to becoming multilingual and bicultural (Lee, 2003). The utilization of ethnic and linguistic minority students' cultural and linguistic experiences as educational resources in the school context has been found to significantly increase their science achievement (for a review, see Lee, 2002) and dramatically improve their commitment and empowerment (Tan et al., 2012). These findings are pertinent to the present study, as we also intended to create congruence between the students' and scientists' linguistic and cultural backgrounds as well as their personal backgrounds (being multilingual, having a migration background, and almost always having a connection to Portugal or a Portuguese-speaking country).

1.2 | Science interventions to foster motivation and achievement among migrant students

To foster students' (science) motivation and interest, several intervention approaches and design principles have been developed on the basis of the SEVT framework (Linnenbrink-Garcia et al., 2016; Pintrich, 2003; Rosenzweig & Wigfield, 2016). We followed a top-down approach by moving from a broad(er) overview on research regarding the effectiveness of science interventions to more specific interventions or intervention elements that have overlap or similarities with the present intervention program. Drawing on the previous section and focusing on the target group of multilingual migrant students, interventions should particularly consider students' linguistic and cultural backgrounds, which are connected to their identity (Krulatz & Duggan, 2018; Krulatz et al., 2018; Lee et al., 2005). Role models are thus one promising way to foster (migrant) students' motivation in STEM. A meta-analysis of 45 studies detected a small but significant positive overall effect of ingroup role models in field studies on the STEM performance and interest of underrepresented groups in STEM fields (Lawner et al., 2019). Underrepresented groups of students may identify with a role model if the role model acts like a typical group member (Dasgupta, 2011; Turner, 2006) or if the role models are similar in ethnicity and gender (e.g., Fuesting & Diekman, 2017). A systematic review of 55 articles identified role model and student characteristics that act as moderators of a role model's effectiveness and recommended that role models be portrayed as competent and successful, accessible to the students, similar to the students, and exposing role models who are underrepresented in STEM (Gladstone & Cimpian, 2021). If students subjectively identify with a role model, they tend to show a higher sense of belonging and domain identification, feel more competent, and express more positive attitudes toward a domain (Covarrubias & Fryberg, 2015; Dasgupta, 2011; Lockwood, 2006; Walton & Cohen, 2007).

Role models are also often part of science outreach programs in which students read a text, watch a video, or even meet scientists who have something in common with them, which increases their chances of identifying with the scientists and seeing them as role models. Poliakoff and Webb (2007) defined science outreach programs as any kind of scientific communication that addresses a nonacademic audience. For example, universities, colleges, and companies can foster students' interest in STEM and their motivation to pursue a career in STEM through (in-school and out-of-school) outreach activities, which these organizations develop along with secondary education (Vennix et al., 2018). A common implementation of a brief-duration science outreach program is the so-called "Scientist in the Classroom" (SIC) intervention, where scientists visit a school, give a presentation, lead a hands-on activity, or discuss scientific careers with students (see Laursen et al., 2007). Particularly when combined with inquiry-based approaches (e.g., "Present Your PhD Dissertation to a 12-Year-Old" and "Shadow a Scientist"), the SIC intervention seems to increase students' enthusiasm for science and their scientific knowledge; however, no causal inferences can be drawn due to the lack of adequate designs (e.g., Clark et al., 2016; Shin et al., 2015) or the absence of evaluations at all (see Neresini & Bucchi, 2011).

Other well-established approaches for fostering (migrant as well as nonmigrant) students' (science) motivation and achievement are inquiry-based instruction (where students are engaged in essentially open-ended or guided, student-centered activities; see Blanchard et al., 2010; Colburn, 2000; Furtak et al., 2012). Inquiry learning and hands-on programs are less dependent on language proficiency than other programs due to the practical implementation and nonverbal nature of hands-on programs. They also highlight the active role of students and emphasize collaboration by providing students the opportunity to engage with science and scientific language in a low-stress and collaborative working environment (Hart & Lee, 2003; Lee, 2005; Lee & Buxton, 2013; Lee et al., 2008). It has been demonstrated that considering students' linguistic and cultural backgrounds (see Estrella et al., 2018) and using students' "home language" (referred to as the heritage language here) can be beneficial. Using students' home/native language was found to maintain learners' interest and motivation and thereby increase their science and mathematics achievement (Castillo-Llaneta, 2010) and their attitudes toward science (Morales, 2015, 2016).

1.3 | The present study

The goal of the present study was to evaluate an innovative science outreach educational program that brings STEM professionals together with migrant students for after-school science workshops in the students' heritage language (SHLIL). A cohort of students speaking Portuguese as the heritage language in Germany and the United Kingdom was selected for this study on the basis that (a) these are countries in Europe with the largest numbers of immigrants (13 million and 9 million, respectively), (b) Portuguese-speaking immigrants are large immigrant communities in these countries, and (c) Portuguese-speaking migrant students can be reached through an already existing network of teachers of Portuguese as the heritage language. In this study, the students and the STEM professionals who were brought together shared at least the fact that they had a connection to Portugal or a Portuguese-speaking country, had (family) connections to these countries, were multilingual (at least German-Portuguese or English-Portuguese), and had a migration background. The workshops included an inquiry-based approach, various hands-on activities, and science communication in the heritage language with the STEM professionals (see Figure 2). Our main research question was whether the workshops had a positive effect on the students. We predicted that the students' science and heritage language intrinsic interest, attainment value, or self-concept of ability, as well as their intention to participate in science in the future would be fostered by their participation in a STEM workshop delivered in their heritage language by STEM professionals with whom the students shared a cultural and linguistic background.

To evaluate the science program, we used a mixed-methods approach. First, we describe students' and scientists' evaluations of the workshops and report the feedback they gave when they were surveyed at the end of the intervention

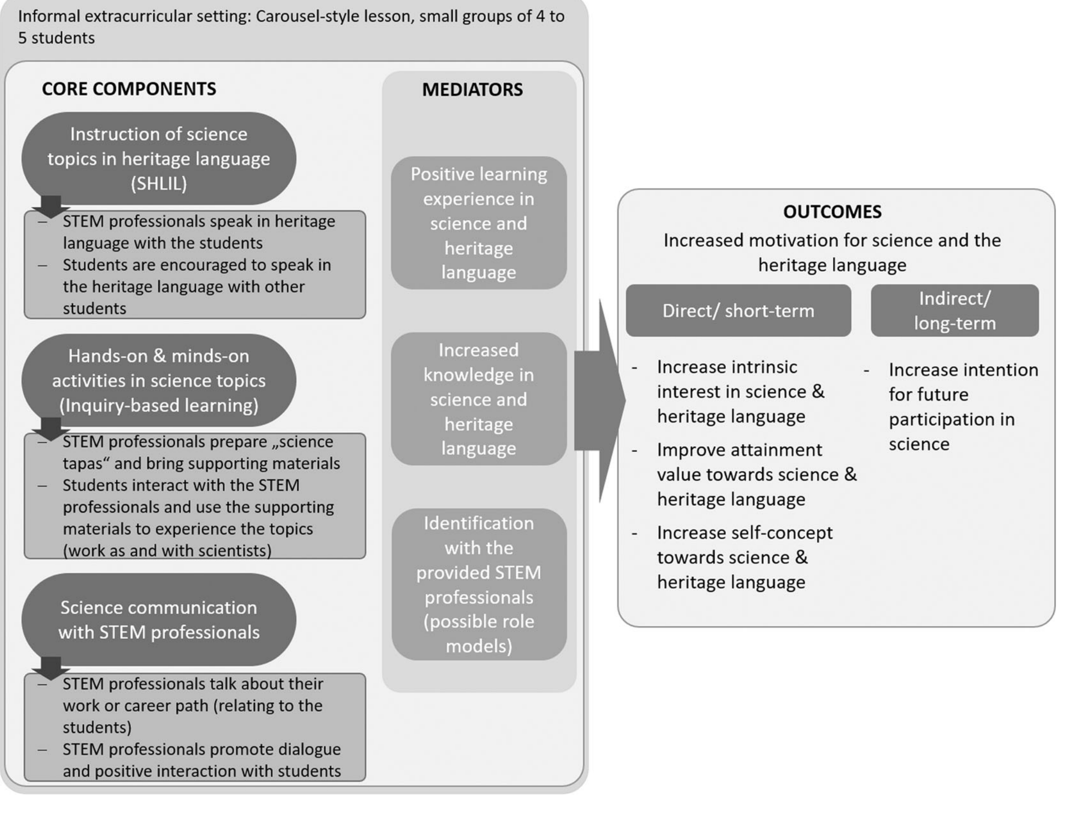

FIGURE 2 Integrated intervention change and logic model for the science workshops. SHLIL, Science and heritage language integrated learning; STEM, Science, Technology, Engineering, and Mathematics.

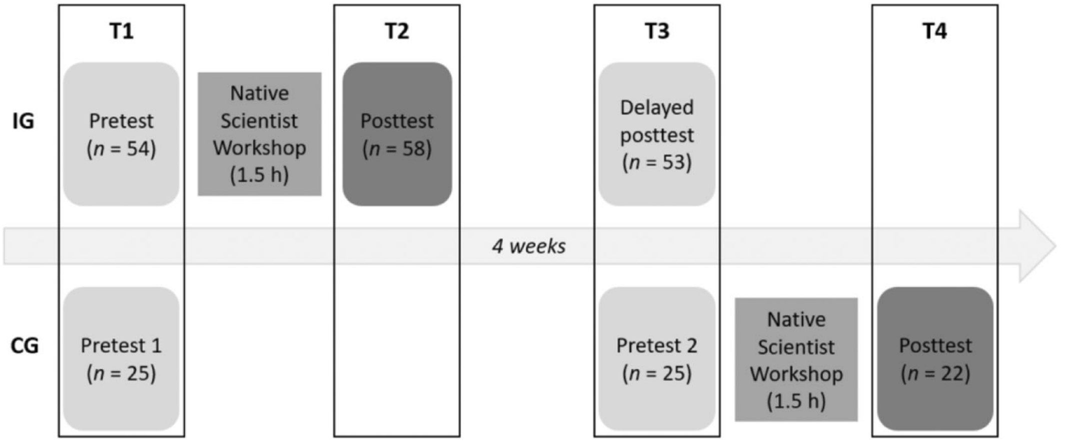

FIGURE 3 Design of the study and corresponding measurement points. The open statements of the students (feedback of the workshops) were assessed at T2 in the IC and at T4 in the CG. CG, control group; IG, intervention group; T, timepoint.

(questionnaires and open-ended questions). We look into their ratings of the success of the workshop, the students' acceptance of and responsiveness to the program (corresponding to recommendations for the evaluation of educational programs; see Humphrey et al., 2016). In this context, we also report the pre- and posttest comparisons of students' self-reports of their intrinsic interest, attainment value, self-concept of ability, intentions to participate in science in the future, and their intrinsic interest, attainment value, and self-concept of ability to speak the heritage language.

Second, we aimed to provide initial evidence of the effectiveness of the program 4 weeks after the intervention by using a randomized controlled trial (RCT) with a waitlist control group and repeated measures (see Figure 3). This design enables conclusions about causality and the effectiveness of an educational intervention (Schulz et al., 2010; Torgerson & Torgerson, 2001, 2008, 2013). On the basis of the reviewed literature, we expected to find positive effects on students' attitudes toward science and their heritage language (see Table 1). Specifically, we hypothesized that, after a period of 4 weeks, students would demonstrate an increase in intrinsic interest, attainment value, self-concept of ability, and intentions to participate in science in the future compared with the control group (Hypotheses 1a–1d). Furthermore, we hypothesized that students would demonstrate an increase in intrinsic interest, attainment value, and self-concept of ability to speak their heritage language (Portuguese) compared with the control group (Hypotheses 2a–2c). We additionally explored differential intervention effects due to the students' respective pretest scores on their motivation to study science or speak their heritage language (exploratory research questions).

2 | METHOD

2.1 | Description of the science workshops

2.1.1 | Goals and general framework

The science workshops were developed by the nonprofit organization Native Scientists (see Golle et al., 2022; La Morgia et al., 2018) that organizes science outreach workshops for migrant students in several European countries in various different heritage languages. The organization seeks to improve science education and reduce inequality by connecting children and scientists. The present study's workshops, which were representative of the workshops throughout the European program, brought together four to five STEM professionals with a migration background

TABLE 1 Summary of hypotheses and exploratory research questions.

Intervention effects	
Outcomes	*Hypotheses (confirmatory analyses) and research questions (exploratory analyses)*
Science-related variables	**H1a**: Students who participate in the workshop will demonstrate an increase in their intrinsic interest compared with students in the waitlist control group.
	Will students with high and low prior intrinsic interest benefit from the workshop in similar or different ways?
	H1b: Students who participate in the workshop will demonstrate an increase in their attainment value compared with students in the waitlist control group.
	Will students with high and low prior attainment value benefit from the workshop in similar or different ways?
	H1c: Students who participate in the workshop will demonstrate an increase in their self-concept of ability compared with students in the waitlist control group.
	Will students with high and low prior self-concept benefit in similar or different ways from the workshop?
	H1d: Students who participate in the workshop will demonstrate an increase in their intentions to participate in science in the future compared with students in the waitlist control group.
	Will students with high and low prior intentions to participate in science in the future benefit in similar or different ways from the workshop?
Heritage-language-related variables (Portuguese)	**H2a**: Students who participate in the workshop will demonstrate an increase in their intrinsic interest compared with students in the waitlist control group.
	Will students with high and low prior intrinsic interest benefit from the workshop in similar or different ways?
	H2b: Students who participate in the workshop will demonstrate an increase in their attainment value compared with students in the waitlist control group.
	Will students with high and low prior attainment value benefit from the workshop in similar or different ways?
	H2c: Students who participate in the workshop will demonstrate an increase in self-concept of ability compared with students in the waitlist control group.
	Will students with high and low prior self-concept of ability benefit from the workshop in similar or different ways?

Abbreviation: H, hypothesis.

to talk about their work to a group of 20–25 students in their heritage language (in the current workshops, the heritage language was always Portuguese).

Each workshop lasted 90 min and proceeded as follows. After a brief introduction, the students met and interacted with the STEM professionals in small groups of four to five students in a carrousel-style, speed-dating format. Students got a "taste" of different science fields and disciplines by interacting with different STEM professionals, a characteristic of the program that the organization referred to as "science tapas." After every group of students met and interacted with all the STEM professionals, the workshop ended with evaluations, closing remarks, and the distribution of certificates to participating students.

2.1.2 | Intervention change and logic models

To illuminate the mechanisms and components of the workshops that are assumed to cause the possible effects on migrant students' motivation, we specified an intervention model that was based on the reviewed literature (see Fixsen et al., 2013; Nelson et al., 2012). It comprised an *intervention change model*, which consisted of the elements that were presumed to be involved in the causal process (including the intervention's core components and the respective outcomes) and an *intervention logic model*, which consisted of the resources and concrete activities (of both the implementers and participants) necessary to operationalize the change model components (Nelson et al., 2012). The core components of the workshops (in the oval fields) and the corresponding elements (in the rectangular fields) can be summarized as follows (see Figure 2).

First, different science topics were taught in the students' heritage language (SHLIL). The scientific topics consisted of astronomy (e.g., the solar system), meteorological phenomena, molecular science, or microbiology (e.g., DNA, viruses, and bacteria) and were not limited to the natural sciences (although these were dominant). The topics might have been particularly interesting to the students, as the topics were not part of the regular school curriculum and were presented in an interactive way in which the students could try out different activities by themselves. On the basis of the instructional congruence framework (e.g., Lee, 2002, 2003; Lee et al., 2005), the STEM professionals interacted with the students in their heritage language and presented the topics' keywords in the heritage language. The students were also encouraged to use their heritage language when interacting with the STEM professionals and the other students. The students were also likely to have increased their knowledge of the heritage language (e.g., by acquiring new vocabulary or scientific terms). Thus, the scientific content and the use of the heritage language was likely to be accessible and meaningful for the migrant students and to provide a positive learning experience and memory for them in STEM as well as in their heritage language. These aspects correspond to central design principles for fostering interest-enjoyment value and attainment value (see Eccles & Wigfield, 2020), namely, the use of interesting, personally relevant, and active tasks. These practices have also been found to support students' feelings of competence, that is, through high-quality instruction with well-explained examples (see Linnenbrink-Garcia et al., 2016; Pintrich, 2003).

Second, the workshops included hands-on and minds-on activities in STEM topics, which were embedded in an inquiry-based learning approach that enabled cooperative learning through active participation, discussion, and critical reflection on the presented topics (see Akerson & Hanuscin, 2007; Blanchard et al., 2010; Brickman et al., 2009; Furtak et al., 2012; Minner et al., 2010). These activities were developed by the STEM professionals and fostered through materials that demonstrated their work, including experiential equipment (e.g., microscope, fan attached to photovoltaic panel), illustrations, infographics, game-like exercises, models, prototypes, or other supporting materials. This setup enabled the students to work *as* scientists as well as *with* scientists and was intended to increase students' STEM knowledge and enhance their autonomy (see Linnenbrink-Garcia et al., 2016; Pintrich, 2003). Minds-on activities (e.g., discussions or debates about the presented topics) were intended to additionally foster students' feelings of autonomy and to contribute to their learning and understanding (e.g., through formative assessments by and constructive feedback from the STEM professionals during the active experimentation phases).

Third, the workshops included science communication in the form of interactions between the students and the STEM professionals, as the STEM professionals talked about their research and career paths (e.g., how they became a scientist) and promoted dialog and positive interactions with the students. As the scientists shared the students' cultural background and communicated in the students' heritage language during the workshop, it was easy for the students to relate to the scientists, who were thus assumed to serve as good role models. The students could identify with the scientists and might recognize them as successful ingroup members (Dasgupta, 2011; Easterbrook & Hadden, 2021; Easterbrook et al., 2019; Eccles, 2009). The multilingual scientists promoted dialog and positive interactions with the students, encouraged the students to identify with them, encouraged feelings of belonging between the students and themselves, and encouraged the students' intentions to participate in science in the future. The core components of the workshops were closely related to the principles described in the so-called *Primary Science Capital Teaching Approach* (*PSCTA*), which is aimed at supporting students' engagement and identification with science, so that they feel that science is "for them," especially those belonging to minoritized communities (Chowdhuri et al., 2022; Godec et al., 2017). The pillars of PSCTA include the dimensions of "personalizing and localizing" (e.g., connecting science content to students' own lives), "eliciting, valuing, and linking" (e.g., helping children bring their own knowledge and understanding into the classrooms), and "building science capital" (e.g., supporting learners so that they think that science is "for me"). An overview of the topics of the workshops in the present study is provided in Supporting Information: Table 9. An example of a schematic schedule of the workshops is presented in Supporting Information: Table 10.

2.2 | Participants

2.2.1 | Students

The study was approved by the appropriate ethics review panel at Lancaster University and was conducted in accordance with the provisions of the Declaration of Helsinki. After obtaining written informed consent from parents, data were collected from 83 Portuguese multilingual students who participated in the science workshops in an after-school program (45 boys; age: $M = 10.7$, SD = 3.3, range: 6–17 years). All participants were enrolled in the Portuguese heritage language classes offered by the Camões Institute, the branch of the Portuguese Ministry of Foreign Affairs, which is responsible for providing heritage language education to the Portuguese diaspora (https://www.instituto-camoes.pt/en/). The Camões Institute classes are open to all students who want to learn Portuguese as a heritage language, often resulting in a mix of first-, second-, and third-generation migrant students in the same class.[5] Of note, the participating children and scientists in the program were Portuguese-speaking, not necessarily Portuguese, which means that the cohorts of students and scientists represented several countries (e.g., Portugal, Brazil, Mozambique, Cape Verde, Angola).

Our science workshops were integrated into the students' weekly heritage language classes and took place in the schools that offered these classes. The workshops had already been arranged to take place by the participating schools (i.e., they were scheduled to take place independently of the present study). Participation in the workshops was entirely voluntary for the students. Students' participation in the study was also completely voluntary, and the study coordinators (Portuguese teachers at the respective schools) explained the study to the students and informed them that their participation was absolutely voluntary. Students provided consent to take part in the evaluation. It was possible for the students to participate only in the workshops without participating in the surveys. Data collection took place in four schools in Germany and two schools in the United Kingdom during the summer semester, 2019. In terms of language background, all participants were growing up multilingually. In addition to Portuguese as a heritage language, they spoke at least one more language, namely, the majority language of the society in which they were growing up (English in the United Kingdom, German in Germany).

The workshops usually last about 90 min and were designed for students between 6 and 14 years of age. However, a small number of older students participated as well. This was either because they were siblings of younger participants and wished to take part as well or because they had lower proficiency levels in the heritage language and were therefore placed with younger learners of similar proficiency. In this study, we report the results only for our actual target group, namely, learners between the ages of 6 and 14 ($n = 64$; see the Online Supporting Information). Our intervention group (IG; four workshops) consisted of 58 students (30 boys, age: $M = 11.26$, SD = 3.51) and the control group (CG; two workshops) of 25 students (15 boys, age: $M = 9.60$, SD = 2.52). Table 2 summarizes the sample characteristics.

TABLE 2 Sample description (students).

Group	N	Female	Age M	SD	Preferred language Portuguese	School language	Both	Other	Prior exposure to scientists Yes	No	Maybe
Intervention group	58	49.1%	11.26	3.51	8.6%	29.3%	55.2%	0.0%	20.7%	63.8%	6.9%
Control group	25	40.0%	9.60	2.52	12.0%	44.0%	36.0%	8.0%	40.0%	36.0%	20.0%

Abbreviation: *N*, number of participating children.

2.2.2 | STEM professionals

Eighteen STEM professionals from different scientific disciplines (11 women, age: $M = 29.94$, $SD = 6.31$) conducted the workshops in Portuguese for small groups of four to five students (see Table 3). The STEM professionals were individuals in academia or industry, at different levels of their career, including PhD students, postdoctoral researchers, and others. All STEM professionals had a migration background and spoke Portuguese as their native language and volunteered to participate in this science outreach program. Sixteen scientists (89%) were Portuguese, and two scientists (11%) were Brazilian. According to the survey data collected, nine scientists (50%) reported speaking two languages, seven scientists (39%) reported speaking three languages, and two scientists (11%) reported speaking four or more languages. At each workshop, up to six STEM professionals were present, depending on the number of participating students (approximately one scientist per four to five students). Sixteen of the STEM professionals were working in academia or in the public sector (eight in Biology, three in Engineering, two in Biochemistry, one each in Physics, Neuroscience, and Biomedical Engineering), and two were working in industry or the private sector (Engineering). Eight scientists were currently PhD students, four were Post docs, and one each had a position as principal investigator, research assistant, development engineer, engineer, head of section, or operations manager. Before the workshops, the STEM professionals participated in a standardized 1-h online training provided by the organizers. Before the study began, all STEM professionals gave written consent for their participation.

2.2.3 | Description of the STEM professionals' training

Before the workshops, the STEM professionals participated in a synchronous online session that trained them in how to deliver the science workshops to a high standard. In the context of educational interventions, this type of training is particularly important to ensure an adequate fidelity of implementation of the program, for example, a comparable structure and procedure of the workshops in the different cities and countries (Carroll et al., 2007; Humphrey et al., 2016). However, the whole program was designed to be more human-centered rather than content-centered, so that success was not measured as students' knowledge of a specific content area but rather as students' identification with the scientists and the feeling that science was closer and more relevant to them. The training was provided by the organization that developed the workshops and included an introduction about the work of the organization, their goals, and the mission of the outreach project. Furthermore, it contained information for the STEM professionals about how to prepare their outreach activities, strategies for effective science communication (particularly considering the age of the students), a presentation of the organization's impact and health and safety guidelines, and a canvas to help each participant design and plan the activities. The processes, design principles, and methods described in the intervention model were the basis for this training (see Figure 2). During and after the online training, the STEM professionals could ask questions and discuss ideas, and they were offered the opportunity to receive further individual support by the workshop coordinator. Because this kind of support is based on individual questions and requests, the coordinators did not follow a specific framework but reacted to the needs of the STEM professionals. Typically, the coordinator supported the STEM professionals by

TABLE 3 Sample description (scientists).

		Age		Nationality		Number of spoken languages		
N	Female	*M*	SD	Portuguese	Brazil	Two	Three	Four or more
18	61.1%	29.94	6.31	88.9%	11.1%	50%	11.1%	38.9%

Abbreviation: *N*, number of participating scientists.

answering their questions, holding a rehearsal, or jointly brainstorming to help the STEM professionals conceptualize the hands-on, minds-on activities.

2.3 | Experimental design

Using a RCT, we investigated (a) the students' and scientists' evaluations of the program as well as (b) the effects after 4 weeks (delayed posttest [T3]; see Figure 3). Specifically, the IG participated in a pretest before the workshops [T1], a posttest directly after the workshops [T2], and a delayed posttest 4 weeks after the workshops [T3]. The CG participated in a first pretest approximately 4 weeks before the workshops [T1], a second pretest before the workshops [T3], and a posttest directly after the workshops [T4]. However, due to unavoidable logistical reasons (school holidays), it was not possible to randomize all of the workshops (two workshops had to be IGs). Ultimately, four of the workshops could be randomly assigned to the IG or the CG (the results for just those workshops are reported in the Online Supporting Information). Using a random number generator, the randomization was conducted by an impartial person from the first author's institution.

The tests (questionnaires) were administered by the heritage language teachers (not the STEM professionals) or the workshop coordinator during class time. Each teacher/coordinator was given instructions beforehand (in an email attachment and verbally through a call) with regard to how to administer the test. For both the IG and CG, all survey questions were read aloud to the students (in Portuguese) to ensure that the students' reading capacities did not influence their understanding of the items. The questionnaire items were written in Portuguese, and a translation into the majority language (English or German, respectively) was provided as well (see Supporting Information: Table 12).

2.4 | Measures

2.4.1 | Students

All administered scales and the corresponding descriptive statistics of all measurement points (T1–T4), Cronbach's α, and the number of items are presented in Table 4. The items of the survey with the constructs from the SEVT as well as an example of a student questionnaire are provided in Supporting Information: Tables 1 and 11. The students rated all the items on a 4-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). Negatively formulated items were recoded for further analyses. Unless explicitly stated otherwise, the scales were used at all measurement points. All scales were based on instruments whose reliability and validity had been determined previously and adapted slightly for the present study. The adaptations referred mainly to the domain (e.g., “Portuguese” or “science” instead of “math” or “reading”), the translations into Portuguese and German, and the simplification of the items for young students. We ran a pilot study 1 year before the present study (evaluation of two workshops in the United Kingdom) where the instruments were validated with the target group.

TABLE 4 Descriptive statistics for all measurement points.

Scale	*N* items		T1				T2				T3				T4			
			N	*M*	SD	*α*	*N*	*M*	SD	*α*	*N*	*M*	SD	*α*	*N*	*M*	SD	*α*[a]
Science intrinsic interest	3	IG	54	2.34	0.84	0.82	57	2.81	0.79	0.83	52	2.54	0.85	0.82	-	-	-	
		CG	25	2.39	0.90		-	-	-		24	2.56	0.93		22	2.88	0.91	
Science attainment value[r1,2,4]	3 2[r1,2,4]	IG	53	2.25	0.90	0.75	56	2.74	0.89	0.71	52	2.79	0.66	0.65	-	-	-	
		CG	23	2.57	1.05		-	-	-		25	2.75	0.93		21	2.71	0.96	
Science self-concept	4	IG	54	2.47	0.75	0.64	58	2.81	0.66	0.68	53	2.78	0.68	0.65	-	-	-	
		CG	25	2.72	0.74		-	-	-		25	3.04	0.72		22	3.23	0.42	
Science future participation	4	IG	54	2.15	0.76	0.79	58	2.58	0.83	0.86	53	2.30	0.74	0.87	-	-	-	
		CG	25	2.33	0.86		-	-	-		25	2.40	1.04		22	2.61	0.92	
Portuguese intrinsic interest	3	IG	53	3.23	0.80	0.87	57	3.42	0.66	0.87	53	3.35	0.78	0.88	-	-	-	
		CG	25	2.77	0.98		-	-	-		25	2.95	1.00		22	2.98	0.88	
Portuguese attainment value[r1,2,4]	3 2[r1,2,4]	IG	50	3.49	0.78	0.80	56	3.54	0.71	0.67	53	3.60	0.61	0.76	-	-	-	
		CG	24	3.00	1.06		-	-	-		25	3.29	0.90		22	3.18	0.96	
Portuguese self-concept	3	IG	53	3.11	0.68	0.63	56	3.10	0.73	0.62	51	3.28	0.67	0.70	-	-	-	
		CG	25	2.84	0.87		-	-	-		25	3.01	0.89		22	3.18	0.76	

Note: Scales contain all items, except scales marked with [r1,2,4] (revised at T1, T2, and T4). Revised scales contain the same items for the IG and the CG at the same measurement point.

Abbreviations: *α*, Cronbach's alpha; CG, control group; IG, intervention group; *N*, number of participating children.

[a]Cronbach's *α* corresponds to the Cronbach's *α* in column T2. Cronbach's *α* was calculated for T2 and T4 together (see also Figure 2).

Motivation

To investigate students' intrinsic interest in science, we adapted an instrument by Gaspard et al. (2017) and Stalder (2013). The scale consisted of three items (e.g., "I like everything that has to do with science"). To assess the attainment value of science, we adapted an instrument by Gaspard et al. (2017) and Ramm et al. (2006). The scale consisted of three items (e.g., "Science is important to me"). To investigate students' science ability self-concept, we adapted items from an instrument by Kind et al. (2007) and Arens et al. (2011). This scale consisted of four items (e.g., "I can be a scientist if I want to"). To assess students' intentions to participate in science in the future, we adapted an instrument developed by Summers and Abd-El-Khalick (2018). This scale consisted of four items (e.g., "I would like to become a scientist"). The scales were also adapted to assess the respective measures for the heritage language (*intrinsic interest*, e.g., "I like everything that has to do with Portuguese"; *attainment value*, e.g., "Portuguese is important to me"; and *self-concept of ability*, e.g., "I find Portuguese difficult" [reversed]).

Workshop evaluation and feedback

To investigate the success of the workshop, we collected students' evaluations of the workshops (e.g., "I enjoyed meeting the scientists"; "I learned new words") via items that were rated on a 4-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*) as well as qualitative data collected via open-ended questions, which students in both the IG and the CG answered in the posttests after the workshops ("What did you like the most in today's lesson?"; "What did you learn?"). Additionally, the student survey contained questions regarding their spoken and preferred languages (e.g., "What languages do you speak?"; "What language do you prefer?") and their previous experience with scientists (e.g., "Have you met a scientist before?").

2.4.2 | STEM professionals

We also assessed several variables that pertained to the participating STEM professionals (e.g., demographics, country of origin, spoken languages, professional background, their motivation and experience with science outreach, the quality of the implementation of the workshops, evaluation and success of the workshops for the students and for themselves). These data contained items that were rated on a 5-point Likert scale (e.g., "Students were very interested in me as a person and a scientist"; "I emphasized important vocabulary to help students learn new words and concepts") ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) as well as qualitative data collected via open-ended questions (e.g., "What did you enjoy the most in the workshop?"). These data were used to characterize the participating scientists as well as to add another perspective on the workshop evaluation.

2.4.3 | Open data statement

We provide a DOI to share the materials from the study (questionnaires and anonymized data), hosted by the Marine Data Archive (MDA), managed by the Flanders Marine Institute (VLIZ), Belgium (https://doi.org/10.14284/553). Additional materials (e.g., scripts, analysis code) can be provided by the authors upon request.

2.5 | Statistical analyses

In a first step, we report descriptive statistics (means and standard deviations) for the students' and scientists' evaluations of the workshops as well as a summary of the qualitative data via open-ended questions. For these data, we report all students' (IC and CG) answers to the questions "What did you like most in today's lesson? What did you learn?" and the scientists' answers to the question "What did you enjoy most in the workshop?" In the next step, we summarized the responses and assigned the students' and scientists' answers to the core components of the workshops. We also report the comparison of the pretests and immediate posttests of all students' self-reports of their intrinsic interest, attainment value, self-concept of ability, and intentions to participate in science in the future, and their intrinsic interest, attainment value, and self-concept of ability to speak Portuguese. For this, we used *t*-tests for paired samples in R for Windows (R Core Team, 2020, package stats version 4.0.2).

In a second step, we then computed the intervention effects 4 weeks after the workshops via multiple linear regression analyses in M*plus* 8.2 (Muthén & Muthén, 2017). Before assessing the intervention effects, we assessed possible baseline differences between the IG and CG (*t*-tests for independent samples) and correlations between the outcome variables at T1 and T3. All analyses used the robust maximum likelihood estimator, which corrects standard errors for the nonnormality of the variables. The dependent variables were the *z*-standardized posttest measures (T3) from the previously described scales. The predictors in our regression models were group assignment (0 = control, 1 = treatment), and the *z*-standardized pretest score (T1) for each dependent variable (see Enders & Tofighi, 2007). For each dependent variable, we estimated the treatment effect in a separate model because the pretest score on the respective dependent variable was included as a predictor variable to increase power (see Aiken et al., 2003). Additional covariates were included in the models if we found significant mean differences between the IG and the CG on any of the continuous variables at pretest (T1). Owing to the standardization of the dependent variables, the multiple regression coefficient for the group variable indicated the standardized intervention effect (effect size, *ES*) while controlling for the corresponding pretest score. According to Cohen (1992), the effect sizes can be classified as follows: $d = 0.20$: small, $d = 0.50$: medium, and $d = 0.80$: large. To estimate differential intervention effects due to the respective pretest scores, interaction terms between group assignment and the pretest scores were added to the models in a second step.

For our analyses, we used $p < 0.05$ as the significance level. One-tailed tests of significance were used for directed hypotheses. When we had no a priori hypotheses and for the baseline comparison, two-tailed tests were used. To correct the *p*-value for multiple tests, we controlled the false discovery rate at 0.05 by employing the Benjamini–Hochberg procedure (Benjamini & Hochberg, 1995) for the reported main and differential effects.

2.5.1 | Clustered structure of the data

Our data had a clustered structure, with students nested in science workshops in the respective cities. As the clustered structure of the data violates the assumption of independence of observations (i.e., students from one school are typically more similar to each other than they are to students from other schools), the clustered structure had to be considered so that the standard errors would not be underestimated (Snijders & Bosker, 2012). Thus, to correct for the clustering of the data (children nested in science workshops), we used the analysis option *type = complex* implemented in M*plus* 8.2 (Stapleton et al., 2016) for the analyses of the effects 4 weeks after the workshops. In this case, in the standard error computation, residuals are not summed over each observation but for each observation within each cluster separately (McNeish et al., 2017). This procedure is recommended for analyzing hierarchical data in cases where the research question does not refer to a specific multilevel question because it has fewer assumptions and the results are more intuitive to interpret than multilevel procedures (McNeish et al., 2017).

2.5.2 | Missing data

Overall, data from 83 students were used in the analyses. Seventy-nine students participated at T1 (IG: $n = 54$, CG: $n = 25$) and 78 at T3 (IG: $n = 53$, CG: $n = 25$). Furthermore, 58 students from the IG participated at T2 (direct posttest), and 22 students from the CG participated at T4 (direct posttest). Due to illness or other reasons, some children were not able to participate in all the measurement points. In the comparison of the pretest and posttest scores (direct effects), we needed to exclude 16 students from a workshop in the United Kingdom because the data could not be matched between the two measurement points because the questionnaires were missing their codes. Overall, there was no differential dropout between the IG and the CG on any of the instruments used in the present study (see Figure 3). We used the full information maximum likelihood approach implemented in M*plus* 8.2 to deal with the missing values. This analysis can be used to handle missing data in a direct estimation approach that uses all available information in the data to calculate parameter estimates and standard errors (Schafer & Graham, 2002).

3 | RESULTS

3.1 | Description of our sample (students)

When asked about their preferred language in terms of daily use, 51.9% of the participants stated that they preferred both languages (the majority language and the heritage language), 35.4% preferred the respective majority language, and 10.1% preferred the heritage language (Portuguese). The remaining participants (2.5%) indicated that they preferred to communicate in another language altogether. When asked whether they had met a scientist before participating in our workshops, more than half of the participants (59.7%) stated that they had never met a scientist before, 28.6% stated that they had already met a scientist, and 11.7% stated that they were not sure if they had met a scientist before.

3.2 | Workshop evaluation

3.2.1 | Students' responses

Figure 4 reports the results of the participating students' (IG and CG groups) evaluations of the success of the workshops. The students' ratings indicated that they generally liked the lesson, enjoyed meeting the scientists, learned new science stuff, and also learned new words in their heritage language. Regarding the (open) question about what they liked most and what they learned, students mostly described their increased knowledge in STEM (e.g., “I liked everything; I learned things about the earth, the atmosphere, the brain”; “I liked learning about cells a lot”) as well as meeting and interacting with the scientists (e.g., “I most liked knowing what a scientist does”; “I liked today's class because I learned a lot about the things scientists do. And now I know different types of scientists”). A complete list of students' answers is provided in Supporting Information: Table 2. A summary and categorization of those answers is provided in Table 5.

3.2.2 | Scientists' responses

Figure 5 reports the results of the STEM professionals' ratings of workshop success. The results indicate that the STEM professionals mostly agreed that the workshops ran on schedule, everyone seemed to be happy after the workshop, and the speed-dating format worked well. The STEM professionals also reported their perceptions of the impact of the workshop. For example, they mentioned that the students engaged well with the materials or activities that they prepared or that the students learned a lot of new scientific concepts or were interested in them as a person and as a STEM professional. The STEM professionals also reported their adaptability to the context. For instance, they mostly agreed that they asked questions and waited for answers, emphasized important vocabulary to help students learn new words and concepts, or conversed in the workshop's language (Portuguese) as much as possible. They also reported their perceptions of the outcomes of the workshops. Here, they strongly agreed that participating in the workshops helped the students use

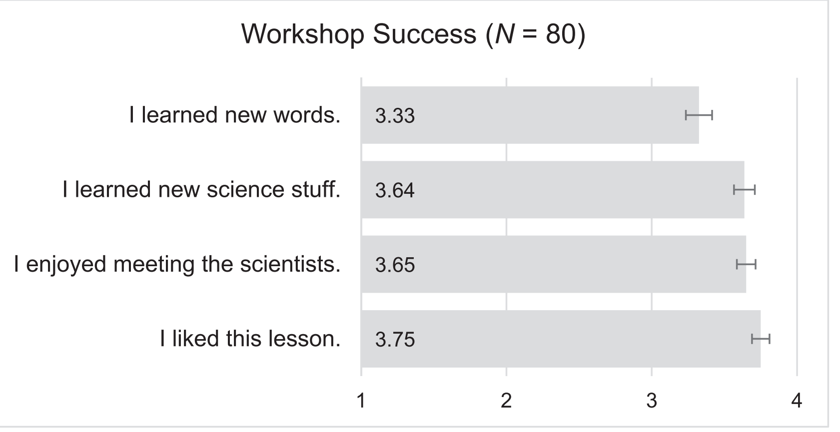

FIGURE 4 Evaluation of the workshop – Students' agreement with items about the success of the workshop. 1 = *I strongly disagree*, 2 = *I disagree*, 3 = *I agree*, 4 = *I strongly agree*. Means and standard deviations are given in the figure.

TABLE 5 Summary and coding of the students' open answers.

	What did you like most in today's lesson?						What did you learn?		
	Everything/ general evaluation	Know/learn about work of scientists	Know/learn about topic/ content	Interest - enjoyment	Interest on a specific topic	Didactic concept/ what they did	Topic/ new content	Work of scientist	General
Frequency of answers	19	2	21	8	2	11	48	4	4

Note: Multiple responses were possible.

and develop their heritage language skills in a new setting or connect science to their everyday lives. Regarding the (open) question about what they enjoyed most in the workshop, the STEM professionals primarily mentioned the students' interest and questions (e.g., "I enjoyed listening to the young participants' questions and realized once more how important it is to work with future generations and help them dream about and achieve what they want to be"), their interactions with the students ("The interaction with the audience and their curiosity"), as well as doing scientific outreach (e.g., "The chance to look back at my work, find a way to simplify it, and be able to communicate a message"). A complete list of STEM professionals' answers is provided in Supporting Information: Table 3. A summary and categorization of the answers is provided in Table 6.

3.2.3 | Comparison of the pretests and immediate posttests

To get initial evidence of a possible change in students' science and heritage language motivation, we report the comparison of the pretests and immediate posttests of all students in the IG and CG (see Table 7). The results indicate that students' intrinsic interest, $t(59) = 5.11$, $p < 0.001$, $ES = 0.53$, attainment value, $t(57) = 5.71$, $p < 0.001$, $ES = 0.60$, self-concept of ability, $t(61) = 3.32$, $p = 0.001$, $ES = 0.47$, intention to participate in science in the future, $t(61) = 4.63$, $p < 0.001$, $ES = 0.50$, as well as their intrinsic interest in Portuguese, $t(59) = 3.54$, $p < 0.001$, $ES = 0.30$, significantly increased directly after the workshop. No differences between the pretest and immediate posttest were found for Portuguese attainment value, $t(56) = 0.75$, $p = 0.227$, $ES = 0.04$, or for Portuguese self-concept of ability, $t(58) = 0.85$, $p = 0.199$, $ES = 0.04$.

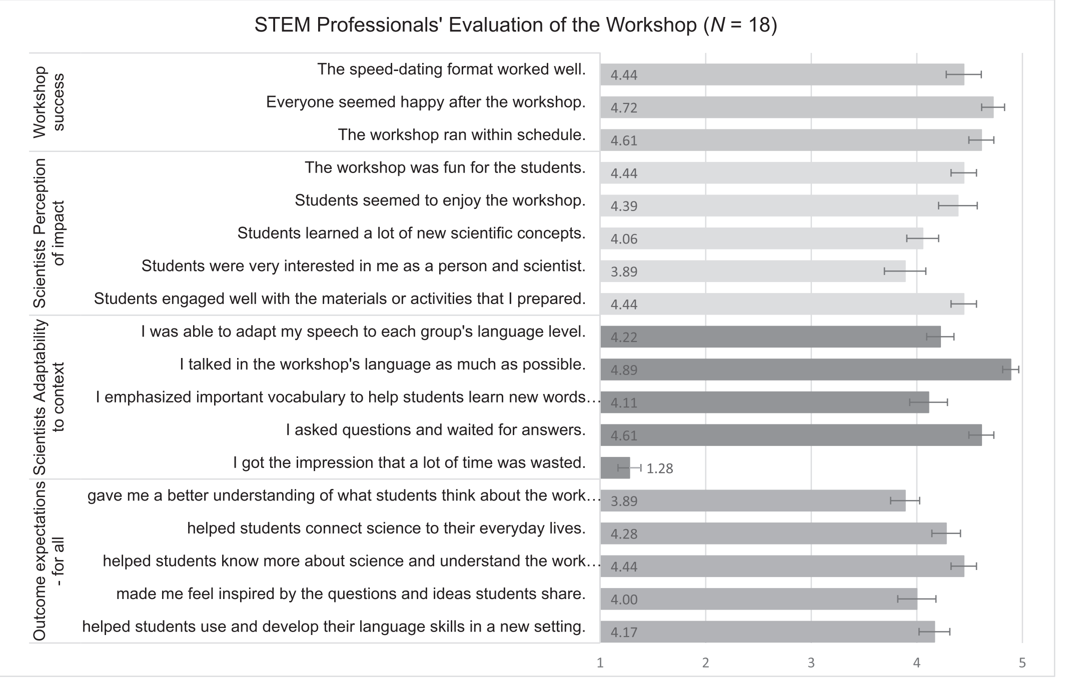

FIGURE 5 Evaluation of the workshop – STEM professionals. STEM professionals were asked “How much do you agree with the following?” for workshop success, scientists' perceptions of impact, and scientists' ability to adapt to the context, as well as “Participating in this Native Scientist workshop…” for outcome expectations – for all. 1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*. Means and standard deviations are given in the figure. STEM, Science, Technology, Engineering, and Mathematics.

TABLE 6 Summary and coding of the scientists' open answers.

	What did you enjoy most in the workshop?							
	Enthusiasm/ Enjoyment/ Excitement of students	Students understood essential STEM message	Interest/ questions of students	Interaction with students/ their reaction	Explain science to children	Doing scientific outreach	Heritage language use	Teaching new concepts
Frequency of answers	4	1	6	6	3	9	1	1

Note: Multiple responses were possible.

Abbreviation: STEM, Science, Technology, Engineering, and Mathematics.

3.3 | Effectiveness of the program

3.3.1 | Preliminary analyses

As not all workshops could be randomly assigned to the IG and CG, we analyzed the characteristics of, and differences between, the IG and CG at T1. The students in the IG and CG did not show statistically significant differences in gender, $\chi^2(1, N = 83) = 0.26$, $p = 0.613$; their preferred language, $\chi^2(3, N = 83) = 6.98$, $p = 0.072$; intrinsic interest in science, $t(44) = 0.25$, $p = 0.801$; science attainment value, $t(37) = 1.24$, $p = 0.224$; science self-concept of ability, $t(47) = 1.38$, $p = 0.173$; future participation in science, $t(42) = 0.91$, $p = 0.369$; intrinsic

TABLE 7 Results of the paired *t*-tests (pretest vs. posttest).

Scale	*t*	*df*	*p*	Pretest			Posttest			95% CI		*d*
				N	M	SD	N	M	SD	LL	UL	
Science intrinsic interest	5.11	59	<0.001	62	2.29	0.83	65	2.73	0.82	0.23	Inf.	0.53
Science attainment value	5.71	57	<0.001	62	2.19	0.87	63	2.71	0.86	0.36	Inf.	0.60
Science self-concept	3.32	61	0.001	63	2.52	0.76	66	2.85	0.64	0.16	Inf.	0.47
Science future participation	4.63	61	<0.001	63	2.12	0.76	66	2.52	0.83	0.24	Inf.	0.50
Portuguese intrinsic interest	3.54	59	<0.001	62	3.19	0.81	65	3.41	0.67	0.12	Inf.	0.30
Portuguese attainment value	0.75	56	0.227	59	3.45	0.78	64	3.48	0.74	−0.09	Inf.	0.04
Portuguese self-concept	0.85	58	0.199	62	3.11	0.69	64	3.14	0.70	−0.06	Inf.	0.04

Note: Some students' data had to be excluded because they could not be matched between the pretest and the immediate posttest due to technical reasons. The *t*-test requires the sample means to be normally distributed. For some variables, the sample means seemed uniformly distributed rather than normally distributed. To account for this, we additionally used the Wilcoxon Signed Rank Test to test for differences between the two paired samples. The results were very similar to the results of the paired *t*-tests. The significance level was calculated for one-tailed tests ($\alpha = 0.05$).

Abbreviations: CI, confidence interval; *d*, effect size (Cohen's *d*); *df*, degrees of freedom; Inf., infinitive (because a one-tailed test is used, the UL of the CI is infinitive); LL, lower limit; *N*, number of participating children; UL, upper limit.

TABLE 8 Correlations between the dependent variables at T1 and T3.

Scale	1	2	3	4	5	6	7
1. Science intrinsic interest	0.75**	0.73**	0.47**	0.78**	0.23*	0.15	0.08
2. Science attainment value	0.68**	0.74**	0.35**	0.75**	0.32**	0.35**	0.25*
3. Science self-concept	0.27*	0.15	0.64**	0.36**	0.06	0.13	0.42**
4. Science future participation	0.76**	0.72**	0.28*	0.78**	0.28*	0.26*	0.11
5. Portuguese intrinsic interest	0.44**	0.30**	−0.05	0.38**	0.83**	0.82**	0.46**
6. Portuguese attainment value	0.31**	0.33**	−0.08	0.23*	0.75**	0.85**	0.50**
7. Portuguese self-concept	−0.08	−0.09	0.38**	−0.19	0.17	0.27*	0.75**

Note: Correlations at T1 are presented below the diagonal, correlations at T3 above the diagonal. The diagonal displays the correlations between a scale at T1 and at T3.

*$p < 0.05$.; **$p < 0.01$.

interest in Portuguese, $t(40) = -2.01$, $p = 0.051$; Portuguese attainment value, $t(35) = -2.01$, $p = 0.052$; or Portuguese self-concept of ability, $t(39) = -1.35$, $p = 0.186$. However, students in the IG were significantly younger than students in the CG, $t(63) = -2.39$, $p = 0.020$, and had significantly less exposure to scientists before the workshops than students in the CG, $\chi^2(2, N = 83) = 7.47$, $p = 0.024$. All administered scales as well as their corresponding descriptive statistics at all measurement points (T1–T4) and Cronbach's α values are presented in Table 4. Intercorrelations between all outcome variables at T1 and T3 are shown in Table 8. At T1, the highest positive correlations were found between intrinsic interest in science and science attainment value ($r = 0.68$), intrinsic interest in science and future participation in science ($r = 0.76$), science attainment value and future participation in science ($r = 0.72$), and intrinsic interest in Portuguese and Portuguese attainment value ($r = 0.75$). The correlations at T3 showed quite similar patterns. The retest correlations ranged from 0.64 to 0.85.

3.3.2 | Intervention effects

Our first set of hypotheses (Table 1, H1a–H1d) concerned the workshop's enhancement of students' science motivation after a period of about 4 weeks. Regression analyses were used to assess the effectiveness of the science workshop on students' intrinsic interest, attainment value, self-concept of ability, and intentions to participate in science in the future. Group assignment (IG vs. CG) and the respective pretest score were utilized as predictors. Age was used as a control variable, as there were significant differences in age between students in the IG and CG. The findings revealed that intrinsic interest ($B = 0.09$, $p = 0.353$), self-concept of ability ($B = -0.10$, $p = 0.335$), and intentions to participate in science in the future ($B = 0.04$, $p = 0.378$) did not increase at T3 for the students assigned to the IG compared with the students in the CG (see Model 1 in Table 9). However, a marginally significant intervention effect was found for attainment value ($B = 0.38$, $p = 0.075$), which indicates that the perceived importance of doing well in science tended to increase for students in the IG, compared with students in the CG even a couple of weeks after the workshop. However, after applying the Benjamini and Hochberg (1995) procedure to correct for multiple testing, the significance level of this effect was above 0.10.

The second set of hypotheses (Table 1, H2a–H2c) concerned the effects of the workshop on students' intrinsic interest, attainment value, and self-concept of ability in their heritage language (Portuguese). The findings indicate that intrinsic interest ($B = -0.01$, $p = 0.476$) and attainment value for Portuguese ($B = 0.13$, $p = 0.126$) did not increase at T3 for the students assigned to the IG compared with the students in the CG (see Model 1 in Table 10). Still, a marginally significant intervention effect was found for self-concept of ability ($B = 0.15$, $p = 0.092$), which indicates that after a couple of weeks, the perceived self-concept of ability in Portuguese tended to increase for students in the IG compared with students in the CG. However, after applying the Benjamini and Hochberg (1995) procedure, the significance level of this effect was above 0.10.

3.3.3 | Differential intervention effects

In a next step, we checked whether the intervention effects depended on students' prior motivation by including a Treatment × Pretest interaction between the respective outcome variable in the models (exploratory research question). The findings revealed (see Model 2 in Tables 9 and 10) that there were significant interactions between the T1 measures and assignment to the treatment or control condition for intrinsic interest in science ($B = -0.27$, $p < 0.001$), science attainment value ($B = -0.47$, $p < 0.001$), future participation in science ($B = -0.42$, $p < 0.001$), attainment value for Portuguese ($B = -0.18$, $p = 0.013$), and self-concept of ability for Portuguese ($B = -0.32$, $p = 0.050$). These results mean that the intervention effects depended on students' prior motivation. More specifically, students with lower motivation to do science and embrace their heritage language benefited more from the workshop compared with students with higher levels of motivation (see Figure 6). Four out of five interactions remained significant after we applied the Benjamini and Hochberg (1995) procedure. No differential intervention effects that depended on students' prior motivation were found for science self-concept of ability ($B = -0.26$, $p = 0.274$) or intrinsic interest in Portuguese ($B = -0.14$, $p = 283$).

4 | DISCUSSION

This study tested the impact of an innovative science outreach program that offered after-school science workshops in the heritage language of multilingual migrant students and aimed to provide positive learning experiences in the students' heritage language (SHLIL). Specifically, we were interested in determining

TABLE 9 Workshop effectiveness for science constructs.

	Intrinsic interest				Attainment value				Self-concept				Future Participation			
	B	SE	*p*	*p* adj.	*B*	SE	*p*	*p* adj.	*B*	SE	*p*	*p* adj.	*B*	*SE*	*p*	*p* adj.
Model 1																
Treatment[a]	0.09	0.23	0.353	0.407	0.38	0.26	0.075	0.175	−0.10	0.24	0.335	0.407	0.04	0.14	0.378	0.407
Age	−0.06	0.09	0.519		0.01	0.08	0.874		−0.17	0.09	0.077		−0.07	0.06	0.276	
Pretest score (T1)	0.73	0.06	<0.001		0.78	0.15	<0.001		0.61	0.09	<0.001		0.75	0.13	<0.001	
Explained variance (R^2)	0.56				0.57				0.44				0.60			
Model 2																
Treatment[a]	0.12	0.20	0.284		0.45	0.22	0.021		−0.06	0.25	0.410		0.09	0.14	0.262	
Age	−0.09	0.09	0.320		−0.04	0.07	0.604		−0.20	0.10	0.045		−0.11	0.07	0.106	
Pretest score (T1)	0.90	0.07	<0.001		1.05	0.02	<0.001		0.78	0.20	<0.001		1.00	0.01	<0.001	
Pretest score (T1) × Treatment[a]	−0.27	0.06	<0.001	0.005	−0.47	0.12	<0.001	0.005	−0.26	0.24	0.274	0.396	−0.42	0.11	<0.001	0.005
Explained variance (R^2)	0.58				0.61				0.45				0.64			

Note: All continuous variables were *z*-standardized. All analyses used the robust maximum likelihood estimator, which corrects the standard errors for the nonnormality of the variables. For the pretest score and the treatment, one-tailed significance levels are reported because we tested directional hypotheses. *p* adj., *p*-values adjusted according to the Benjamini and Hochberg (1995) procedure.

[a]The treatment was dummy-coded: 0 = control group; 1 = intervention group.

TABLE 10 Workshop effectiveness for Portuguese constructs.

	Intrinsic interest				Attainment value				Self-concept			
	B	SE	*p*	*p* adj.	*B*	SE	*p*	*p* adj.	*B*	SE	*p*	*p* adj.
Model 1												
Treatment[a]	−0.01	0.14	0.476	0.476	0.13	0.11	0.126	0.221	0.15	0.11	0.092	0.184
Age	0.03	0.07	0.704		−0.08	0.05	0.134		0.01	0.05	0.898	
Pretest score (T1)	0.83	0.07	<0.001		0.82	0.06	<0.001		0.73	0.10	<0.001	
Explained variance (R^2)	0.68				0.71				0.56			
Model 2												
Treatment[a]	−0.03	0.13	0.411		0.10	0.10	0.149		0.11	0.09	0.101	
Age	0.04	0.08	0.601		−0.08	0.05	0.108		0.03	0.05	0.587	
Pretest score (T1)	0.91	0.06	<0.001		0.91	0.05	<0.001		0.90	0.03	<0.001	
Pretest score (T1) × Treatment[a]	−0.14	0.14	0.283	0.396	−0.18	0.07	0.013	0.046	−0.32	0.16	0.050	0.140
Explained variance (R^2)	0.68				0.72				0.59			

Note. All continuous variables were *z*-standardized. All analyses used the robust maximum likelihood estimator, which corrects the standard errors for the nonnormality of the variables. For the pretest score and the treatment, one-tailed significance levels are reported because we tested directional hypotheses. *p* adj., *p*-values adjusted according to the Benjamini and Hochberg (1995) procedure.

[a]The treatment was dummy-coded: 0 = control group, 1 = intervention group.

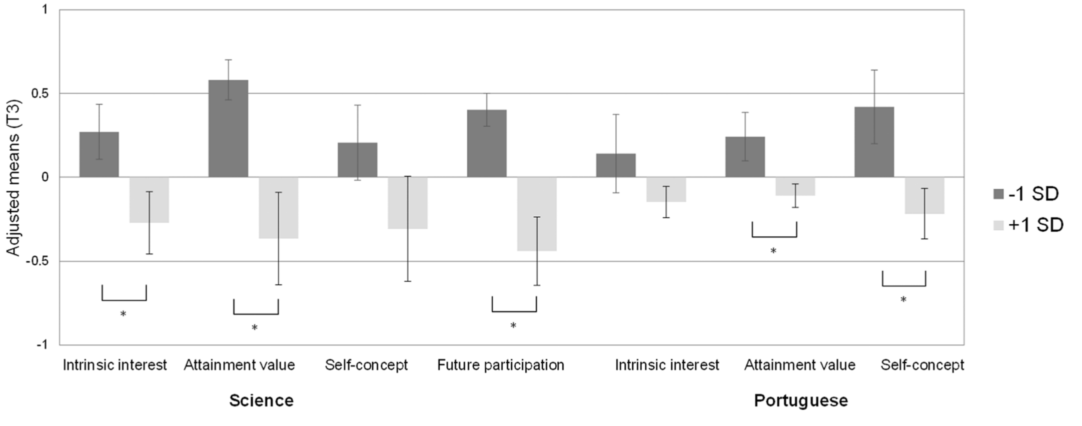

FIGURE 6 Adjusted means and standard errors at T3 for students with pretest values ±1SD.

whether this new type of intervention could positively affect students' interest in science and in their heritage language. Students' and scientists' evaluations of the workshops were reported, and intervention effects for students in terms of intrinsic interest, attainment value, and future participation in science, as well as intrinsic interest, attainment value, and self-concept of ability for Portuguese were assessed by applying a RCT as well as open-ended questions and feedback. Below, we discuss how the results can be embedded in the theoretical background as well as its implications and recommendations.

4.1 | Fostering multilingual migrant students' motivation in the context of the SEVT

SEVT was used to frame the study around the central motivational outcomes and the understanding of the assumed components and processes that were presumed to be involved in the causal process of the intervention. Even after 4 weeks, we found positive effects on migrant students' attainment value for science and self-concept of ability for the heritage language. Thus, two central elements postulated in the SEVT (expectation of success, and one-dimension of STVs, see Eccles & Wigfield, 2020) could be addressed. Additionally, the comparison of the pretests and immediate posttests demonstrated an increase (medium effect sizes) in students' intrinsic interest, self-concept of ability, intention to participate in science in the future, as well as their intrinsic interest in Portuguese. This indicates that students' future intentions for science were addressed, which refer to the indirect/long-term aims of the intervention and are an important prerequisite for students' science education or possible science careers.

Our findings correspond to research that has demonstrated that even brief interventions have the potential to be effective and to foster students' interest and motivation (see, e.g., studies on short-term relevance interventions, Gaspard et al., 2015, 2021; or studies on wise interventions, Walton & Yeager, 2020). One interpretation is that the SHLIL interventions might have served as an "aha-moment" for multilingual migrant students with the same language background as the scientists who delivered the intervention. Students' statements about interest-enjoyment value and excitement (e.g., "I liked everything"; "It was a lot of fun to learn") support this idea. This aha-moment may particularly be the case for learners with low prior motivation to do science and speak their heritage language. It is also possible to conclude that the workshops triggered students' situational interest (e.g., "It was interesting to know how many satellites are in outer space and how they read the weather"), which is an important prerequisite for maintained situational interest, emerging individual interest, and well-developed individual interest (see Hidi & Renninger, 2006). Furthermore, the students increased their science knowledge (e.g., "I learned things about the earth, the atmosphere; about the brain") and enjoyed meeting and interacting with the scientists ("I liked today's class because I learned a lot about the things scientists do. And now I know different types of scientists"). This corresponded to the scientists' feedback, who confirm students' interest-enjoyment value and excitement (e.g., the scientists stated that they enjoyed most the students' questions, how excited the children were, the interaction with the audience and their curiosity, or the kids' enthusiasm).

4.2 | Relevance of the results in the context of identity theories and science capital

Our intervention model is based on the mechanisms of identity development described by the SEVT (Eccles & Wigfield, 2020) and considered students' linguistic and cultural backgrounds (e.g., Cuevas et al., 2005; Easterbrook & Hadden, 2021; Krulatz & Steen-Olsen, & Torgersen, 2018). Complementary to the SEVT, identity theories (e.g., Stereotype Inoculation Model, Dasgupta, 2011; Identities in Context Model, Easterbrook & Hadden, 2021) can be used to explain the intervention effects and students' ratings of the workshops. Our results highlight the effectiveness of SHLIL at decreasing motivational gaps between migrant students with fewer or more motivational resources. As the workshops are aimed at taking into account the role of cultural identity by using STEM professionals as role models for science and the students' heritage language, the students with lower motivation could be reached (also corresponding to the instructional congruence framework; e.g., Lee, 2002; Lee et al., 2005). We did not ask the students to what extent they identified themselves with the scientists (as an important aim of the workshops is to combine SHLIL completely naturally in a familiar atmosphere). However, as both, students and the scientists were multilingual, had a migration background in their family and had a connection to Portugal or a Portuguese speaking country. Consequently, the STEM professionals might have served as particularly suitable role models or ingroup members for the participants due to their shared linguistic, ethnic, or cultural backgrounds (see Dasgupta, 2011;

Gladstone & Cimpian, 2021; Walton & Cohen, 2007). Thus, students might have easily identified and connected with them as outlined in the instructional congruence framework (e.g., Lee, 2002; Lee et al., 2005). Most of the students' met a scientist for the first time, and could associate this experience with their own personal background. Consequently, students' personal as well as collective identity (Eccles, 2009) might have been positively affected and increased their perception that science might be "for them" (i.e., at the pretest 46.2% of the students affirmed the question "I can be a scientist if I want to," 62.9% affirmed this after the workshop). Seeing and interacting with STEM professionals with a similar cultural and language background could help have reduced their perceptions of identity incompatibility (Oyserman et al., 2006) and increased their intended future participation in science, which is an important prerequisite for further science-related choices and performances (see Eccles & Wigfield, 2020).

Another way to explain the results is to consider the concept of *science capital*. Science capital is conceived of as a "conceptual device for collating various types of economic, social and cultural capital that specifically relate to science" (Archer et al., 2014, p. 5). The fostering of science capital is important, as it is (positively) related to students' cultural capital, school attainment, future plans regarding studying or working in science, self-efficacy in science, or feeling that others see them as a "science person" (Archer, Dawson, et al., 2015). The science workshops are designed to target students who typically have low science capital (i.e., reduced exposure to science-related knowledge, attitudes, experiences, and resources; see Archer, Dawson, et al., 2015) and are aimed at improving the extent to which students have meaningful connections with science and a good relationship with it, making it more relevant for them. It can be argued that the science workshops fostered migrant students' science capital and consequently boosted their motivation (Archer, Dewitt, et al., 2015).

4.3 | Implications and recommendations

First, it can be assumed that the central core element of our intervention (SHLIL, where students learn specifically about science through their heritage language) was ultimately successful in fostering interest for science in multilingual migrant students. We combined this innovative approach with hands-on and minds-on activities in science and science communication with STEM professionals. The workshops enabled migrant students to increase their knowledge in different scientific domains (e.g., "I learned much about satellites," "I learned something about the brain") and the heritage language (e.g., "I learned new words"), as well as their identification with the STEM professionals they met (e.g., "I enjoyed meeting the scientists"). Our findings strengthen the need for positively connotated learning experiences in the heritage language (SHLIL), which might serve as an important supplement to "classical" approaches, where the learning of new content is combined with a second or foreign language (CLIL; Coyle et al., 2010; Marsh, 2008). It should be noted that the respective school language is an important prerequisite for school success and integration (Prevoo et al., 2016). However, the present study indicates that learning experiences in the heritage language can also be beneficial for students' intrinsic interest-enjoyment value, attainment value, and self-concept, and that SHLIL might be an important supplement to the fostering of language proficiency in the school language. SHLIL is simultaneously a successful example of science communication in an after-school context (Márquez & Porras, 2020). This finding fits with recent research on the relevance of heritage speakers in science education in Europe as well as in the US (e.g., Montrul, 2011; Sharif Matthews & López, 2019). Both students and scientists valued the personal interactions, and the scientists confirmed that the workshops helped the students develop their heritage language skills in a new setting and helped connect science to their everyday lives. Considering the emergence in this field of the STEM outreach adaptations STEAM (where "A" stands for Arts) and STEMM (where "M" stands for Medicine), we propose to the scientific community the STEM + LANG denomination for this (and similar) approaches, that is, approaches that combine science and language outreach and help science reach more diverse audiences, attenuating some of the drawbacks of the English hegemony in science.

Second, some elements of SHLIL might be transferred to the school context, for example, through the implementation of programs (e.g., "SIC"; see Laursen et al., 2007) that could also include multilingual or migrant scientists. Besides the approach of having STEM experts come to schools (SIC), students or school classes could alternatively come to labs or work places to meet different kinds of scientists (with different linguistic or cultural backgrounds) who can provide positive learning experiences. It might also be promising to embed the workshops in the school science classes (which are offered in the respective school language), for example, by preparing students beforehand and subsequently following up on the students' experiences in their regular classes. Furthermore, in line with previous studies, we assume that the further training of teachers with regard to the valuation and support of multilingualism in class might be promising (e.g., Gartziarena & Villabona, 2022).

4.4 | Limitations and directions for future research

Although our study demonstrated the beneficial effects of an SHLIL outreach program for multilingual migrant students, some limitations should be considered when interpreting the results. First, as we used a multicomponent intervention, no conclusions can be drawn about which intervention elements caused the observed effects, and we could not systematically test the intervention model within the scope of the present study. This corresponds to the complexity inherent in the SEVT (Eccles & Wigfield, 2020) or identity theories (e.g., Easterbrook & Hadden, 2021; Stout et al., 2011). Future studies might address this question, for instance, by comparing different core components of the intervention or analyzing the effectiveness of the present program offered in the heritage versus the school language of the multilingual students.

Second, it should be considered that we do not know exactly how to characterize the multilingualism of the participants. The sample of students as well as the scientists has to be described as very heterogeneous. Some of the STEM professionals reported that, occasionally, they used both languages in the workshops, and therefore (probably unintentionally) used a technique known as translanguaging (García et al., 2017; García & Kleifgen, 2020; García & Wei, 2014; Pierson et al., 2021), which is also a promising learning approach but which was not the focus of the present study. Future studies might benefit from collecting more information about students' language proficiencies or even conduct a linguistic analysis of the language used in the workshops.

Third, it cannot be assumed that all possible effects of the science outreach program were captured in the present assessments, which had to be reduced to a minimum for organizational reasons as well as to avoid overtaxing the students, some of whom were as young as 6 years old. Future research might include additional outcome variables and covariates (e.g., science and language identity, other dimensions of motivational value beliefs, science capital), and it might also be promising to try to capture the emotional connotation that could be assumed due to the combination of science learning and the heritage language (see Archer, Dewitt, et al., 2015; Walton & Cohen, 2007).

Finally, we used a RCT, which could only be implemented with some constraints; for instance, there was no control group for the comparisons between the pretest and posttest. However, our results indicate that participation in the 90-min workshops was most likely the driver of the increase, even though effects of repeated testing (see Aldridge et al., 2017) cannot be ruled out. Future studies could follow up on our study by including the evaluation of more workshops (e.g., in more European countries and other heritage languages) by using a completely randomized design. Furthermore, the design and measures we used could only address the complexity of the content and the heterogeneity of the target groups to some extent. Future studies could include more qualitative elements (e.g., video analyses or interviews) to study such complex and multifaceted phenomena, such as identity construction, learning, motivation, and their interplay in multilingual students (see, for instance, Blanchard et al., 2023; Gutierrez, Blanchard, et al., 2022).

4.5 | Conclusion

This study investigated the effectiveness and acceptance of an SHLIL outreach program for multilingual migrant students. The science workshops were offered by multilingual scientists with a cultural and linguistic background that was similar to the participating students. Students' and scientists' evaluations of the workshops were very positive and provided an example of successful science outreach and science communication (see Márquez & Porras, 2020). The findings indicate that the integrated learning of science topics in the heritage language (SHLIL) has the potential to affect aspects of migrant students' motivation to do science as well as to embrace their heritage language (Portuguese). Thus, the workshops were successful in providing positive learning experiences and promoting multilingual migrant students' interest-enjoyment vale, attainment value and their self-concept to speak their heritage language. This is in line with the proposed elements of the SEVT (Eccles & Wigfield, 2020). Our intervention is a positive example for supporting educational equity and implementing equity pedagogies, which stresses the importance of centering students' cultures and identities across content areas and grade levels (see Gutierrez, Beck, et al., 2022). Schools and governments should consider this program when thinking about education as a means to promote the integration and empowerment of ethnic minority students. In the long run, it can inspire students to pursue higher science education and to participate as active citizens in a society facing social, technological, or scientific challenges.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Marine Data Archive (MDA), managed by VLIZ at Schiefer, J. et al. 2022 https://doi.org/10.14284/553.

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ENDNOTES

[1] As one of our reviewers pointed out, the low rate of participation in STEM in higher education does not apply to all students from migrant backgrounds. In fact, in some disciplines, migrant students tend to be overrepresented (see Codiroli Mcmaster, 2017, for a discussion).

[2] Most of the participating professionals were working in the field of science. However, we use the term "STEM professionals" as some of the scientists were also working in the field of engineering or technology.

[3] Heritage languages are also known as immigrant minority languages, home languages, community languages, or migrant languages.

[4] Cultural background encompasses several dimensions, including place of birth and upbringing, spoken language(s), gender, ethnicity, religious beliefs, and lifestyle choices (e.g., Wunder, 2017), all of which together form a person's culture at a given moment in time. Cultural background can also be fluid according to context and undergoes development for each person during their lifetime.

[5] The Camões Institute promotes the learning and dissemination of the Portuguese language in its multitude and diversity. In the classes offered by the Camões Institute, most students are heritage language speakers of one of the regional varieties of European Portuguese, but it is also common to find speakers of the Brazilian or African varieties. All varieties of Portuguese are welcomed and valued at the Institute.

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