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by

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SUPPORTING PRIMARY EDUCATION THROUGH SCIENCE TEACHING FOR MULTILINGUAL LEARNING CONTEXTS

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To all my *family*, from blood and heart, who have always supported my dreams and celebrated my accomplishments. Especially my ***mom***, for giving us "wings to fly" and being our ***safe haven***[1].

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Supporting primary education through science teaching for multilingual learning contexts

Abstract

This is the story of a teacher-researcher collaboration within a school-university partnership that supports primary teacher professional development in science education in Luxembourg. The Luxembourgish education system is highly stratified (Eurydice, 2022), and Luxembourgish, German, and French are languages used throughout primary education, adding another layer of complexity to the system. The SciTeach Center is a resource center, where pre-service and in-service teachers have access to materials (e.g., books, models) and professional development courses, that aims to support primary teachers to implement inquiry-based science education. Here, the center is acknowledged as a school-university/research-practice partnership (e.g., Goodlad, 1991; Coburn et al., 2013) that operates as a third space, both physically created and negotiated (respectively, Bhabha, 2004; Gutierrez et al., 1999), and it hosts different projects, such as this one. This partnership enables teachers and researchers to come together and co-develop and co-teach professional learning opportunities for other teachers in Luxembourg. Currently, the team consists of eight researchers, eight primary teachers, and two administrative staff. The teaching team members work together to be contextually responsive, also addressing emergent uncertainties (e.g., Manz and Suárez, 2018). Within this context, the workshop *Science and Language* was co-developed between 2021 and 2022 and co-taught during the school-year 2022-2023. Using qualitative research approaches, including participatory research and critical ethnography lenses, data sources comprised field and observation notes, video recordings and interviews, from which patterns emerged. Participants included researchers, in-service primary teachers, and workshop participants. Through interpretive analysis, this research examines how team members span their boundaries as part of a community of practice (manuscript 1), how the partnership navigates uncertainties (such as language diversity, teacher profile and changing curricula), discussing contextual complexities faced by teachers and demonstrating how the partnership tries to respond, by creating a safe and trusting space for dialogue and reflection (manuscript 2) and how learning happens in three levels, identified as: *individual*, as one teacher and one researcher learn from co-researching; *project*, as the team became aware of several concerns of putting science and language into dialogue (such as the structural challenge of the teacher profile); and *partnership*, from where three events show how the partnership changed the shape of the organization (manuscript 3). The emergent research has worked with different conceptual frameworks, including discussions from

collaborative structures, community of practice, distributed leadership, co-generative dialogues, and boundary spanning, resulting in an analytical framework over interactional structures and achievements. Findings reveal the partnership's dynamics (built on a reflect-dialogue-act process – Wilmes, te Heesen et al., 2018) and highlight the potential of structured partnerships for sustainable teacher education, offering insights for ongoing open dialogue and trust-building.

Keywords

Primary education, Science education, Multilingual context, Teacher-researcher collaboration, School-university partnership, Case Study

Soutenir l'école fondamentale par l'éveil aux sciences pour les contextes d'apprentissage multilingues

Résumé

Il s'agit de l'histoire d'une collaboration enseignant-chercheur au sein d'un partenariat école-université qui soutient le développement professionnel des enseignants du primaire en enseignement des sciences au Luxembourg. Le système éducatif luxembourgeois est très stratifié (Eurydice, 2022) et le luxembourgeois, l'allemand et le français sont des langues utilisées dans l'ensemble de l'enseignement primaire, ce qui ajoute une autre couche de complexité au système. Le SciTeach Center est un centre de ressources, où les enseignants en formation et en exercice ont accès à du matériel (par exemple, des livres, des modèles) et à des cours de développement professionnel, qui visent à aider les enseignants du primaire à mettre en œuvre un enseignement des sciences basé sur l'investigation. Ici, le centre est reconnu comme un partenariat école-université/recherche-pratique (par exemple, Goodlad, 1991; Coburn et al., 2013) qui fonctionne comme un troisième espace, à la fois créé physiquement et négocié (respectivement, Bhabha, 2004 ; Gutierrez et al., 1999) et il héberge différents projets, comme celui-ci. Ce partenariat permet aux enseignants et aux chercheurs de se réunir et de co-développer et de co-enseigner des opportunités d'apprentissage professionnel pour d'autres enseignants au Luxembourg. Actuellement, l'équipe se compose de huit chercheurs, huit enseignants du primaire et deux membres du personnel administratif. Les membres de l'équipe pédagogique travaillent ensemble pour être réactifs au contexte, en abordant également les incertitudes émergentes (par exemple, Manz et Suárez, 2018). Dans ce contexte, l'atelier Science et Langue a été co-développé entre 2021 et 2022 et co-enseigné pendant l'année scolaire 2022-2023. En utilisant des approches de recherche qualitative, y compris la recherche participative et les perspectives d'ethnographie critique, les sources de données comprenaient des notes de terrain et d'observation, des enregistrements vidéo et des entretiens, à partir desquels des modèles ont émergé. Les participants comprenaient des chercheurs, des enseignants du primaire en exercice et des participants à l'atelier. Au moyen d'une analyse interprétative, cette recherche examine comment les membres de l'équipe dépassent leurs limites dans le cadre d'une communauté de pratique (manuscrit 1), comment le partenariat navigue dans les incertitudes (telles que la diversité linguistique, le profil de l'enseignant et les changements de programmes), en discutant des complexités contextuelles auxquelles sont confrontés les enseignants et en démontrant comment le partenariat tente de répondre, en créant un espace sûr et de confiance pour le dialogue et la réflexion (manuscrit 2) et comment l'apprentissage se déroule

à trois niveaux, identifiés comme : individuel, lorsqu'un enseignant et un chercheur apprennent de la co-recherche ; projet, lorsque l'équipe a pris conscience de plusieurs préoccupations liées à la mise en dialogue de la science et de la langue (comme le défi structurel du profil de l'enseignant) ; et partenariat, à partir duquel trois événements montrent comment le partenariat a changé la forme de l'organisation (manuscrit 3). La recherche émergente a travaillé sur différents cadres conceptuels, y compris des discussions sur les structures collaboratives, la communauté de pratique, le leadership distribué, les dialogues cogénératifs et le franchissement des limites, ce qui a donné lieu à un cadre analytique sur les structures et les réalisations interactionnelles. Les résultats révèlent la dynamique du partenariat (fondée sur un processus de réflexion-dialogue-action – Wilmes, te Heesen et al., 2018) et soulignent le potentiel des partenariats structurés pour une formation durable des enseignants, offrant des perspectives pour un dialogue ouvert continu et l'instauration de la confiance.

Mots-clés

École fondamentale, Éveil aux sciences, Contexte multilingue, Collaboration enseignant-chercheur, Partenariat école-université, Étude de cas

Unterstützung der Grundschule durch naturwissenschaftlichen Unterricht für mehrsprachige Lernkontexte

Zusammenfassung

Dies ist die Geschichte einer Lehrer-Forscher-Zusammenarbeit im Rahmen einer Schul-Universitäts-Partnerschaft, die die berufliche Weiterbildung von Grundschullehrern im naturwissenschaftlichen Unterricht in Luxemburg unterstützt. Das luxemburgische Bildungssystem ist stark geschichtet (Eurydice, 2022) und Luxemburgisch, Deutsch und Französisch sind Sprachen, die in der gesamten Grundschule verwendet werden, was dem System eine weitere Komplexitätsebene verleiht. Das SciTeach Center ist ein Ressourcenzentrum, in dem angehende und berufstätige Lehrer Zugang zu Materialien (z. B. Büchern, Modellen) und Kursen zur beruflichen Weiterbildung haben, die darauf abzielen, Grundschullehrer bei der Umsetzung eines forschenden naturwissenschaftlichen Unterrichts zu unterstützen. Hier wird das Zentrum als Schul-Universitäts-/Forschungs-Praxis-Partnerschaft anerkannt (z. B. Goodlad, 1991; Coburn et al., 2013), die als dritter Raum fungiert, der sowohl physisch geschaffen als auch ausgehandelt wird (bzw. Bhabha, 2004; Gutierrez et al., 1999) und verschiedene Projekte wie dieses beherbergt. Diese Partnerschaft ermöglicht es Lehrkräften und Forschern, zusammenzukommen und gemeinsam berufliche Lernmöglichkeiten für andere Lehrkräfte in Luxemburg zu entwickeln und zu unterrichten. Derzeit besteht das Team aus acht Forschern, acht Grundschullehrern und zwei Verwaltungsmitarbeitern. Die Mitglieder des Lehrteams arbeiten zusammen, um kontextbezogen reagieren zu können und auch auf aufkommende Unsicherheiten einzugehen (z. B. Manz und Suárez, 2018). In diesem Zusammenhang wurde der Workshop „Wissenschaft und Sprache" zwischen 2021 und 2022 gemeinsam entwickelt und im Schuljahr 2022-2023 gemeinsam unterrichtet. Unter Verwendung qualitativer Forschungsansätze, einschließlich partizipativer Forschung und kritischer ethnographischer Perspektiven, umfassten die Datenquellen Feld- und Beobachtungsnotizen, Videoaufzeichnungen und Interviews, aus denen Muster hervorgingen. Zu den Teilnehmern gehörten Forscher, berufstätige Grundschullehrer und Workshop-Teilnehmer. Durch interpretative Analyse untersucht diese Forschung, wie Teammitglieder ihre Grenzen als Teil einer Community of Practice überschreiten (Manuskript 1), wie die Partnerschaft mit Unsicherheiten (wie Sprachenvielfalt, Lehrerprofil und sich ändernde Lehrpläne) umgeht, wie kontextuelle Komplexitäten diskutiert werden, mit denen Lehrer konfrontiert sind, und wie die Partnerschaft versucht, darauf zu reagieren, indem sie einen sicheren und vertrauensvollen Raum für Dialog und Reflexion schafft (Manuskript 2) und wie Lernen auf drei Ebenen stattfindet, die

wie folgt definiert sind: individuell, da ein Lehrer und ein Forscher durch gemeinsames Forschen lernen; Projekt, da das Team sich mehrerer Bedenken hinsichtlich des Dialogs zwischen Wissenschaft und Sprache bewusst wurde (wie die strukturelle Herausforderung des Lehrerprofils); und Partnerschaft, von wo aus drei Ereignisse zeigen, wie die Partnerschaft die Form der Organisation verändert hat (Manuskript 3). Die entstehende Forschung hat mit verschiedenen konzeptionellen Rahmenbedingungen gearbeitet, darunter Diskussionen über kollaborative Strukturen, Community of Practice, verteilte Führung, ko-generative Dialoge und Grenzüberschreitungen, was zu einem analytischen Rahmen über Interaktionsstrukturen und Erfolge führte. Die Ergebnisse zeigen die Dynamik der Partnerschaft (basierend auf einem Reflexions-Dialog-Handeln-Prozess – Wilmes, te Heesen et al., 2018) und unterstreichen das Potenzial strukturierter Partnerschaften für eine nachhaltige Lehrerausbildung, indem sie Erkenntnisse für einen kontinuierlichen offenen Dialog und Vertrauensbildung bieten.

Schlüsselwörter

Grundschulbildung, naturwissenschaftlicher Unterricht, mehrsprachiger Kontext, Zusammenarbeit zwischen Lehrern und Forschern, Schul-Universitätspartnerschaft, Fallstudie

Apoio à educação primária por meio do ensino de ciências para contextos de aprendizagem multilíngue

Resumo

Esta é a história de uma colaboração professor-investigador no âmbito de uma parceria escola-universidade que apoia o desenvolvimento profissional dos professores primários no ensino das ciências no Luxemburgo. O sistema educativo luxemburguês é altamente estratificado (Eurydice, 2022) e o luxemburguês, o alemão e o francês são línguas utilizadas ao longo do ensino primário, acrescentando outra camada de complexidade ao sistema. O SciTeach Center é um centro de recursos, onde os professores em formação e em exercício têm acesso a materiais (por exemplo, livros, modelos) e cursos de desenvolvimento profissional, que visa apoiar os professores primários na implementação da educação científica baseada na investigação. Aqui, o centro é reconhecido como uma parceria escola-universidade/investigação-prática (e.g., Goodlad, 1991; Coburn et al., 2013) que funciona como um terceiro espaço, tanto fisicamente criado como negociado (respetivamente, Bhabha, 2004; Gutierrez et al., 1999) e acolhe vários projetos, como este. Esta parceria permite que professores e investigadores se reúnam e co-desenvolvam e co-ensinem oportunidades de aprendizagem profissional a outros professores no Luxemburgo. Atualmente, a equipa é constituída por oito investigadores, oito professores primários e dois funcionários administrativos. Os membros da equipa docente trabalham em conjunto para responder contextualmente, abordando também as incertezas emergentes (e.g., Manz e Suárez, 2018). Neste contexto, o workshop Ciência e Linguagem foi co-desenvolvido entre 2021 e 2022 e co-leccionado durante o ano lectivo 2022-2023. Utilizando abordagens de investigação qualitativa, incluindo investigação participativa e lentes etnográficas críticas, as fontes de dados incluíram notas de campo e de observação, gravações de vídeo e entrevistas, das quais emergiram padrões. Os participantes incluíram investigadores, professores primários em serviço e participantes em workshops. Através da análise interpretativa, esta investigação examina como os membros da equipa ultrapassam os seus limites como parte de uma comunidade de prática (manuscrito 1), como a parceria navega pelas incertezas (tais como a diversidade linguística, o perfil dos professores e a mudança curricular), discutindo as complexidades contextuais enfrentadas pelos professores e demonstrando como a parceria tenta responder, criando um espaço seguro e de confiança para o diálogo e a reflexão (manuscrito 2) e como a aprendizagem acontece a três níveis, identificados como: individual, à medida que um professor e um investigador aprendem através da co-investigação; projeto, à medida que a equipa foi tomando consciência de várias preocupações em

colocar a ciência e a linguagem em diálogo (como o desafio estrutural do perfil do professor); e parceria, de onde três eventos mostram como a parceria alterou a forma da organização (manuscrito 3). A investigação emergente trabalhou diferentes estruturas conceptuais, incluindo discussões de estruturas colaborativas, comunidade de prática, liderança distribuída, diálogos co-geradores e ultrapassagem de fronteiras, resultando numa estrutura analítica sobre estruturas e realizações interacionais. Os resultados revelam a dinâmica da parceria (construída num processo de reflexão-diálogo-acção – Wilmes, te Heesen et al., 2018) e realçam o potencial das parcerias estruturadas para a formação sustentável de professores, oferecendo perspetivas para um diálogo aberto contínuo e para a construção de confiança.

Palavras-chave

Ensino primário, Ensino das ciências, Contexto multilingue, Colaboração professor-investigador, Parceria escola-universidade, Estudo de caso

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Introduction

This dissertation unpacks the dynamics of a teacher-researcher collaboration within a school-university partnership in Luxembourg, in which neither the teacher nor the researcher is trying to teach something to each other, but rather seeking to learn from each other. The teacher-researcher collaboration emerged from the shared understanding that we (with the support of our team) could develop a professional development course for in-service teachers in Luxembourg's primary schools to support the dialogue between science and language. This is how the research starting point became the overarching question ***How can we support primary education through science teaching in multilingual learning contexts?***, represented in the title of this dissertation. And why is this topic relevant?

In the context of Luxembourg, children in primary school are exposed to three languages, and they might have one (or even two) other language(s) in their repertoires. Science serves as a comprehensive (interdisciplinary) learning platform that enables children to feel comfortable to use and develop language skills. Now, let me present the context in which the collaboration was established, the co-development and co-teaching of the workshop *Science and Language*, and the teacher-researcher collaboration itself, showing how the research unfolded and what have we learned (core manuscripts – Chapters V and VI) and the satellite stories (complementary manuscripts – Chapters I, III, IV and VII).

Luxembourg has a complex population scenario, with a highly diverse resident population (Statec, n.d.). Added to this complexity, the country has three administrative languages (Luxembourgish, German, and French – Luxembourg, 1984) that are used throughout all schooling (taking shifts as language of instruction and learning of language), and the school system is highly stratified (Backes & Hadjar, 2017). In general terms, the languages are used as lingua franca for instruction in the following ways (MENJE, n.d. e): Luxembourgish is used during Cycle 1 (ages 4-6); between Cycles 2-4 (ages 6-12), German becomes central for primary education, starting with literacy in Cycle 2; and, for secondary education, the language of instruction depends on the student's track (for example, there is a transition from German to French during classic secondary education), but it can focus on the use of French in *Lycée classique*.

The SciTeach Center was founded in 2016 as a joint project between the University of Luxembourg, the Ministry of Education (MENJE – *Ministère de l'Education nationale, de l'Enfance et de la Jeunesse*), the National Research Fund (FNR – *Fonds National de la Recherche*), and, and The Ministry of Research and Higher Education (MESR – *Ministère de l'Enseignement supérieur et de la Recherche*). As a resource center for teachers in Luxembourg, we have a varied set of science teaching materials that can be borrowed by in-service teachers and pre-service teachers while they undertake the teaching internships (which are mandatory each semester; *stage*). Alongside the materials available, the Center also provides teacher professional development courses (workshops), all accredited by the Institute for National Education Training (IFEN – *Institut de Formation de l'Éducation Nationale*). These Center-based resources (materials for loan and formation continue) enabled the first contact with teachers for supporting primary science education. The workshops have been mainly offered on campus (we also offer school-based workshops) and aim to support the Luxembourg competency-based primary science education curriculum (MENFP, 2011), guided by the inquiry-based teaching approach (Bybee, 2014; te Heesen et al., 2022); as also recommended by the European Commission (2007).

The Center started with researchers collaborating with two primary teachers (teacher-leaders) to develop the first initiatives. A protocol with the MENJE's Service for Innovation (SCRIPT – *Service de Coordination de la Recherche et de l'Innovation pédagogiques et technologiques*) was established to allocate hours for the teachers to come to the Center and work with the researchers. The initial collaboration provided insights to develop school-based resources, and a new protocol was established, now with IFEN, as the SciTeach Center hosts a new FNR-funded research project: Sci2School (Science Teaching to Support Children Learning Science). This second project facilitated school-wide professional development courses, doing research with teachers, and developing pedagogical resources (***Lët'z teach science***, a "How to" compendium based on the experiences with the partner schools).

In 2020, mainly due to the COVID-19 crisis, the SciTeach Center team developed initiatives to support primary science education while responding to the changing context (Barbu et al., in review): ***Science Doheem*** (Science at home) to respond to the school closure by providing science investigation ideas to be carried out at home; and ***A/B-Wochen*** (A/B-weeks) to support science education with materials that could be used during the alternating week children were not at school. Thus, the SciTeach Center is a partnership linking two fields, school and university (research and practice), aiming to support science education through offering professional learning opportunities for primary teachers in Luxembourg. As all projects and initiatives from the Center are accompanied by related workshops, this is how the workshop *Science and Language* emerged.

Now, this PhD research is based on the overarching research question *How can we support primary education through science teaching in multilingual learning contexts?*, and the work done around the workshop *Science and Language*. The research examines the social phenomenon of collaboration at various levels, focusing on the structures that facilitate its emergence and sustainability. To present the research, this dissertation comprises nine chapters (seven manuscripts), three chapters tell the story of this dissertation (core chapters), and four chapters are used to contextualize the research (satellite chapters). One chapter (Chapter II) presents the theoretical and methodological frameworks that are used across the different chapters, and the last chapter (Chapter IX) offers my reflections about my PhD journey.

Chapter I, which includes the article ***Researching primary science education in a country with cultural and linguistic diversity: the relevance of understanding historically the context of Luxembourg***, serves to set the context of primary education in Luxembourg, with a special focus on science education. Chapter III (State of the Art), that contains the manuscript ***What tendency for "inquiry" and "language": examining key journals in science education***, and Chapter IV (Review), with a manuscript proposal entitled ***Primary science education in multilingual contexts: a scoping review***, serve to outline the research field that connects primary education, science education and multilingual contexts. These chapters have given insights about a possible research gap and opened the stage to methodological discussions. These three chapters are satellites for outlining contexts and emerge as relevant to a deeper understanding of the relevance of researching context in itself.

Chapter V presents the research from its starting point, the school-university partnership. This chapter comprises two manuscripts, one that explores how we as team members (individuals in collaboration) span our boundaries, showing the structures that enable the boundary spanning and how we reflect about our roles and positionalities (***Exploring boundary-spanning in teacher education: supporting elementary science education through a school-university partnership***). The other manuscript navigates the school-university partnership in order to uncover what are the features of the partnership that enable it to sustain and address emergent uncertainties (***Examining a school-university partnership in Luxembourg: supporting primary science education in times of uncertainty***).

Chapter VI is about how we learn within the school-university partnership and consists of one manuscript ***Organizational learning as emergent from collaboration: a case study from a professional development module within a school-university partnership***. Learning happens in three levels (individual, project, and partnership) and all learning events change us, how we design and conduct our projects, and how the partnership functions.

As there were not many interviews, I decided to use the data in a joint article, where we used the sociodynamic perspective to show how time, space, conditions and their effects are relevant to research that uses oral testimonies. The views from the field were used on the last satellite manuscript ***The sociodynamic perspective for studies in education: a multidimensional approach to oral testimonies*** (Chapter VII).

Finally, Chapter VIII presents the research concluding remarks and discussion, where the story of the school-university partnership is summarized and the teacher-researcher collaboration is highlighted, and a reflection on why science education matters and where research implications are presented.

Chapter I –
Luxembourg and its education context

This chapter outlines the context of Luxembourg and its education system. A brief history of the country is included in order to understand its migration flux, which has direct implications for the diversity of the student population. The primary education system is described, and its curriculum is presented and reflected upon regarding its structure and how science is positioned. Lastly, the legislation and policies relevant to this research are outlined.

The single-authored manuscript (Maiza Trigo) included in this chapter has been accepted for publication at *Revista Portuguesa de Pedagogia* [Portuguese Journal of Pedagogy].

He is the only Luxembourgish student in his classroom, again...
They [the school] are not worried about giving him the support for French...

[Luxembourgish parent, discussing wish for his son to receive school support in French]

Researching primary science education in a country with cultural and linguistic diversity: the relevance of understanding historically the context of Luxembourg[2]

Luxembourg is a country where multiculturalism and multilingualism have played a crucial role in its development, enabling the co-existence of several ethnolinguistic communities. Due in part to the trilingual status of the country and the resulting multilingual learning contexts, students' migration background has an impact on their educational path. This scenario is bounded by issues of equity, access, and language, as a high percentage of students do not speak the languages of instruction at home. Therefore, this paper explores the relevance of working to understand the nuances and complexities of such a multilingual learning context, by introducing Luxembourg as a national state with a focus on identities (as related to understanding its schooling and multilingual learning contexts) and outlining the country's history (that has led to the development of a multicultural and multilingual environment through openness), by exploring its school system and how student diversity shows evidence of inequalities, and, lastly, by reflecting about how primary science education emerges on the national curriculum.

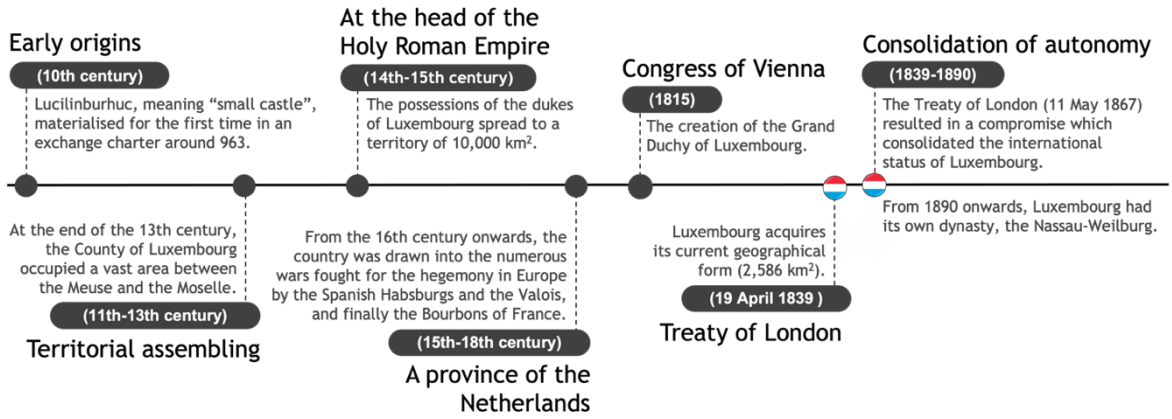
Keywords
primary education
science education
relevance of context
Luxembourg

1. Luxembourg: one State, several nationalities

1.1. The historical rise and grounding identity

Being the only Grand Duchy in the world and the only microstate to take part in the foundation of the United Nations (UN) and the European Union (EU), there is a long history behind Luxembourg. Luxembourg is to be considered a Giant Microstate due to its history (Eccardt, 2005), from its first known name *Lucilinburhuc* to its independence process initiated in 1815 (1835 was set as the official year), it suffered territorial downsizing and multiple occupations (Figure 1). This history of shifting borders and occupations by other nations has created a context that welcomes diversity (Thewes, 2017).

Figure 1 – Infograph about the foundation of Luxembourg



Source: adapted from Thewes (2017).

[2] This manuscript has served as a basis for a short article accepted for publication at the *Revista Portuguesa de Pedagogia* [Portuguese Journal of Pedagogy] in its Volume 57 (2023), e057011.

Not undermining that Luxembourgers are conscious of their national identity (Als, 1982), they were able to preserve their then dialect as a current national language, Luxembourgish, distinguishing it from the neighboring ones – French and German (Peporte et al., 2010; Thewes, 2017). This has contributed to supporting the Luxembourgish national identity.

The concept of national identity has been broadened as it expanded from the aspects of citizenship to a participatory approach (Baycroft & Hewitson, 2006). McLaren (2017) has researched the relationship between immigration, national identity and political trust, considering the "discrepancies between individual-level conceptualizations of national identity and official government approaches to national identity, as reflected in policies towards migrants, contribute to reduced levels of political trust in Europe" (p. 1).

A recent study in Luxembourg has outlined national identity aspects that "young people in Luxembourg consider (very) important to be 'a real Luxembourger'" (Procopio et al., 2021, p. 6), such as[3]: being born in Luxembourg (*ius soli*), having Luxembourgish ancestors (*ius sanguinis*), having lived in Luxembourg for long, speaking Luxembourgish well, and identifying oneself with Luxembourg.

1.2. Between migration and crossing-borders

Luxembourg has a history of migration trends that can be seen in different waves of immigration. This migration flux of Luxembourg is an "invention" of its labor force *status*, that went from an outflux from the poor agricultural new independent state to an influx that started with the industrial era (Peporte et al., 2010; Thewes, 2017). According to Trausch (2007), immigration to Luxembourg was manifested in three main fluxes of workers: from Germany between 1875 and 1935; some overlapping of incoming Italians from 1890 to 1935; and the last one of Portuguese coming to the country starting from 1960.

This migration history led to the current foreign population scenario, which represents almost 50% of the resident population (Statec, 2021). However, this foreign resident population cannot immediately exercise the right to vote, and had a trend, even though there is no explicit immigration policy, as confirmed by Kollwelter (2007): "While the government maintained no explicit policy regarding immigration for much of the century, the implicit policy centered on accepting mainly white, Catholic, European immigrants from Italy and Portugal". Over the years, the Portuguese community became established in Luxembourg, and currently represents the biggest ethnolinguistic community (Table 1).

[3] These aspects of national identity are linked to common basis to grant someone the country's citizenship (the first two) and the aspects of sociocultural integration (the last three).

Table 1 – Resident population in Luxembourg

Year	1981	1991	2001	2010	2015	2020
Population (x 1,000)	364.6	384.4	439.5	502.1	563.0	626.1
Luxembourgers	268.8	271.4	277.2	285.7	304.3	329.6
Foreigners	95.8	113.0	162.3	216.4	258.7	296.5
– of which: Portuguese	-	39.1	58.7	79.8	92.1	95.1
Foreigners in %	26.3	29.4	36.9	43.1	45.9	47.4

Source: Statec (2021).

In addition to its immigrant workforce, labor in Luxembourg is supplied by workers who commute each day by crossing the borders, coming from all three neighboring countries (Belgium, France, and Germany), representing over 40% of its domestic employment (Statec, 2021). However, civil service positions tend to be held by Luxembourgers as these require fluency in the three administrative languages (French, German, and Luxembourgish), while immigrants and cross-border workers tend to fall into the production, construction, services and innovation sector work.

1.3. Language policy(ies)

> This development [the remarkable spread of Luxembourgish] is a reaction to a number of factors including the rise of French as a lingua franca within the Grand Duchy, as well as the growing importance of English in an increasingly globalised world. While the former can be heard every day in the streets of Luxembourg, the latter is felt most strongly in the workplace, where English predominantly has displaced German (see Klein, 2003), and in the educational system, where English has tended to displace Latin at the secondary school level, leaving untouched French or German, the two languages which are firmly entrenched from primary school upwards. (Horner & Weber, 2008, p. 106)

Luxembourg is a country whose history enabled the development of a multicultural and multilingual environment, and the majority of Luxembourgers speak four languages (Le Nevez, 2011). Even though there are three administrative languages (hereinafter also referred as official languages) – Lëtzebuergesch (Luxembourgish), French and German (Luxembourg, 1984), French is the language used in legislative documents and is the one considered authentic for all levels of public administration; in case of disputes with texts translation, the version in French prevails (Luxembourg, 1984). Yet, Luxembourg is not marked geographically by its languages, as some countries are marked by languages and dialects, such as Belgium, Italy, Ireland, Spain and Switzerland.

The use of the three administrative languages is marked by their societal functions (Horner & Weber, 2008; Reisdoerfer, 2009). In the paper about the language situation in Luxembourg, Horner and Weber (2008) discuss “how language policy scholarship needs to be approached from a multidimensional perspective” (p. 1). Meanwhile, Reisdoerfer (2009) describes the linguistic

situation in Luxembourg based on oral and written language (Table 2), bridging the trilingual context to the uses of the official languages.

Table 2 – Uses of the official languages in Luxembourg

	RECEPTION	PRODUCTION
ORAL	• Luxembourgish and French; • German (television)	• Luxembourgish and French;
WRITTEN	• French (public domain); • German (newspapers; books; private domain); • Luxembourgish (private domain)	• French (public domain); • German and Luxembourgish (private domain)

Source: Reisdoerfer (2009, p. 139).

In 2017, the European Commission (EC) prepared a recommendation on improving language learning in Europe by 2025, as "in addition to one's mother tongue, speaking two other languages has become the norm" (European Commission, 2017, p. 11). By itself, Luxembourg has the privilege of being already a trilingual state. Yet, a trilingual nation, with a trilingual education system, is not a guarantee of proficiency in the languages of the country nor the languages of instruction, as this can be identified through different reports (e.g., LUCET & SCRIPT, 2016; 2019).

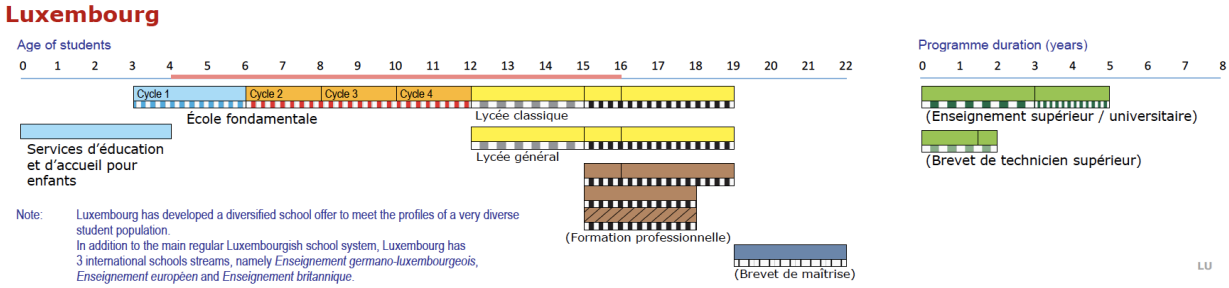
In Luxembourg, the 1984 Law established Luxembourgish as the national language and brought guidelines to the policy of language use within the school. In 2004, the government started to develop a series of actions towards the teaching of languages in Luxembourg. One can find, at least, three documents of reference: the *Profile of Language Education Policy* (MENFP & Council of Europe, 2006); the *Plan d'action pour le réajustement de l'enseignement des langues* (MENFP, 2007), even referring to the promotion of Portuguese (p. 6); and the *Bildungsstandards Sprachen* (Kühn, 2008). Nevertheless, in the school system, languages emerge with different levels of use (Horner & Weber, 2008).

2. Luxembourg Multilingual Public School System

In Luxembourg, whichever school children are enrolled in, or parents choose, a public one in their neighborhood (*commune*) or an international or European one, students will be exposed to different languages. In the case of a public primary school, children will have in their curriculum the three languages from an early stage. In addition, from the early 90's, due to the migration history of the country, several protocols were established, and language classes (languages other than the languages of instruction) started to be offered in schools, in parallel or as complement to the official curriculum on a voluntary basis (e.g., in Portuguese, and Italian).

There are a variety of characteristics of the education systems in Europe (Eurydice, 2020), but stratification is a strong mark of the Luxembourgish one (Figure 2). Schooling is compulsory from the age of four until the age of 16. *École fondamentale* is divided in four cycles and comprises the early childhood education, referred as Cycle 1 (ISCED 0), which also includes an optional year (mentioned as *précoce* and offered to children between the ages of three and four), and the primary education, in reference to the following three cycles (Cycle 2, 3 and 4 – ISCED 1).

Figure 2 – Luxembourgish education system



Source: Eurydice (2020, p. 22)

At the age of 12, the future of the student is discussed, and a decision is taken by a committee from the school, a psychologist and the student's parents, considering the child's school performance during primary education and on the *épreuves communes* (common testing) and *épreuves standardisées* (standardized testing); the last one in French, German and mathematics competencies (Weth, 2015). This decision will directly impact the students' path to access Higher Education, as secondary studies (ISCED 2 and ISCED 3) towards university are offered in two formats: the general (*Lycée général*) and the classic (*Lycée classique*). The latter is used as the main access key to university in Luxembourg or the neighboring countries.

2.1. School's Official Languages

Luxembourgish, German, and French, the country's languages, are used as languages of instruction throughout the schooling years. In cycle 1 of school (ages 4-6), Luxembourgish is used as language of instruction. Still, following the discussion on European level about multilingualism, French is being offered to children within French-speaking communities in this cycle as a pilot (MENJE, 2017).

From Cycle 2 in primary education, the lingua franca is German – children learn to read and write in German at the age of six – and French is introduced, taking 15% of the lessons allocated for language teaching. According to the current curriculum guidelines – *Plan d'Études* (MENFP, 2011), during Cycles 3 and 4, students are exposed to language instruction at a rate of 46,4% of the overall number of lessons.

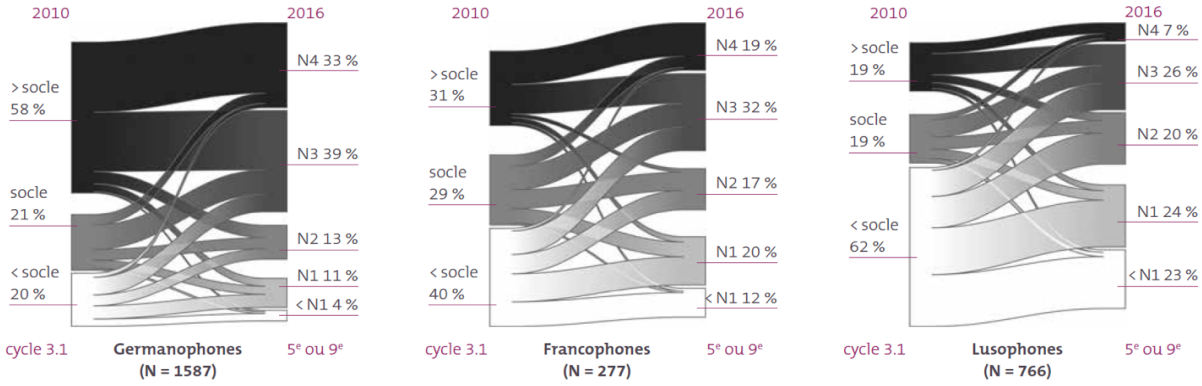
Some countries like Portugal and Italy offer parallel or complementary language courses to their communities in Luxembourg and, even though children can be stimulated to use the

language(s) spoken at home to express themselves in their social contexts, there is no official policy to support this initiative in primary education; not considering the early years.

At the end of Cycle 4, the *décision d'orientation* (orientation decision) takes place on the future schooling of the students, and languages (French and German) and mathematic proficiencies will play a role on this decision; consider that special attention is given to the students' comprehension of German, as test results have shown that children who don't speak Luxembourgish or German at home tend to have lower level of competence represented (LUCET & SCRIPT, 2016, 2019, 2022; Épstan, n.d.; Backes & Hadjar, 2017; Loureiro et al., 2019).

The role of language competences is directly linked to students' performance (e.g., repetition rates) in terms of long-term achievements (LUCET & SCRIPT, 2019) and the possibilities to also pursue higher education, also in neighboring countries. As these language competences are measured in an early stage of education (Cycle 3.1), the evolution of the development of these competences can be analyzed considering the language spoken at home. Figure 3 shows how the comprehension skills in German are marked by a decreasing level of competence when comparing Germanophones and speakers of Romance languages (French and Portuguese), bearing in mind that as students leave elementary education (where German is the lingua franca), they are confronted with a change in the language of instruction, as French becomes school's lingua franca.

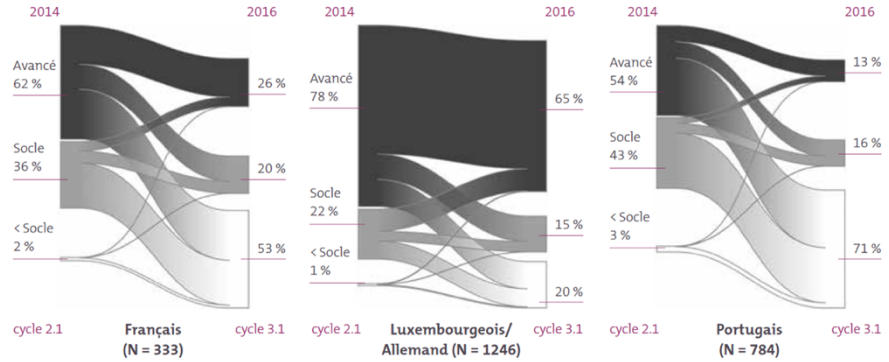
Figure 3 – Evolution of reading comprehension skills in German, considering the linguistic context



Source: LUCET and SCRIPT (2019, p. 45).

Even though the change in the language of instruction may explain the evolution of the students' skills in German between elementary education and secondary education, the introduction of the teaching of a third language (French), between Cycles 2 and 3, also shows an impact on students' skills in German (Figure 4).

Figure 4 – Evolution from reading comprehension in German between cycles 2.1 and 3.1



Source: LUCET and SCRIPT (2019, p. 92).

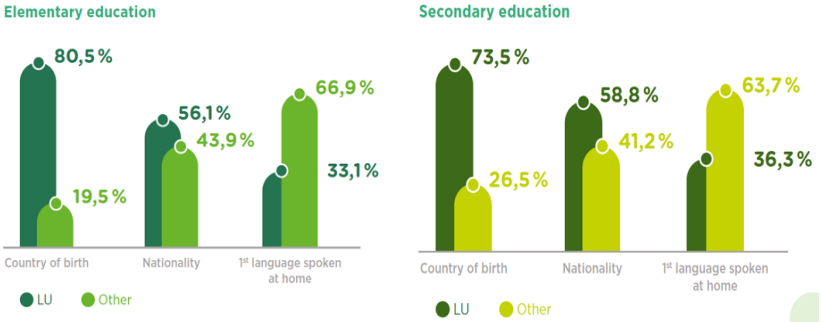
The competition between the languages of instruction, the languages taught/learned, and the language(s) spoken at home plays a central role in students' performance, and later their school placements. This is a situation where a discussion on equality, equity and justice is much needed, considering inequalities can be observed and should not be a trend.

If the trilingual status of the country and the resulting multilingual learning contexts impact students' educational path due to their (migration/linguistic) background, it is critical to work towards initiatives that push back on this, and that provide opportunities for students to excel regardless of their migration or linguistic backgrounds. Partnerships (school-university/research-practice) can provide a support for this, as multidisciplinary research groups can pair with multiprofessional practice teams to enable structures that support working towards an inclusive and integrative schooling. In Luxembourg, this kind of partnership has shown to have na impact on how teachers "see" their students' performance (for example, the FNR-funded project Sci2School), even though national testing results have not shown changes yet (due also to some impact of the pandemic; see LUCET & SCRIPT, 2022).

2.2. Diversity of students and reported inequalities

Student diversity can be presented by the use of different indicators. One of the latest reports presents the data by key figures that demonstrate diversity by "country of birth", "nationality" and "1st language spoken at home" per level of education (Figure 5).

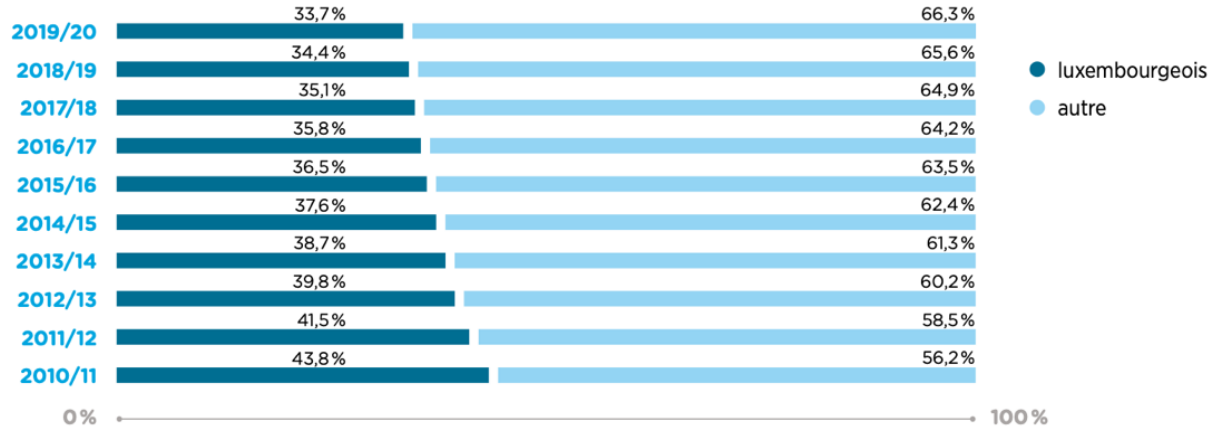
Figure 5 – Student diversity by level of education (2021-2022)



Source: SCRIPT (2022, n.p.).

It is possible to see this evolution of this diversity by looking into different reports presented by different services of the Ministry of Education, such as the diversity of students considering the language spoken at home (Figure 6).

Figure 6 – Student distribution whose first language spoken is Luxembourgish



Source: MENJE/SCRIPT (2021, p. 17).

An older report showing the percentage of student distribution on the different school levels by their different nationalities[4] reflected inequalities on access to higher education as the stratification of the system is represented by the secondary education (*Enseignement secondaire – ES*), which leads the students to university, being attended mostly by Luxembourgers (79,9%), and technical secondary education (*Enseignement secondaire technique – EST*), which focus on providing technical (vocational/professional) training (Figures 7 and 8).

Figure 7 – School level distribution of students by nationality

	Nombre d'élèves 2016-2017				
Ordre d'enseignement	**Luxembourgeois**		**Etrangers**		**Total**
Fondamental cycle 1 - précoce	2 471	56,4%	1 909	43,6%	**4 380**
Fondamental cycle 1 - préscolaire	6 004	54,5%	5 004	45,5%	**11 008**
Fondamental cycle 2-4	17 786	53,8%	15 264	46,2%	**33 050**
Éducation différenciée	409	46,7%	466	53,3%	**875**
Enseignement secondaire	9 551	79,9%	2 399	20,1%	**11 950**
Enseignement secondaire technique	14 638	53,8%	12 583	46,2%	**27 221**
Total	**50 859**	**57,5%**	**37 625**	**42,5%**	**88 484**

Source: MENJE (2018, p. 17)

[4] Recent reports have shown references focused on Germans, French and Portuguese. This is the reason to turn to an older report, where foreign nationalities are showed more diverse.

Figure 8 – Student distribution by nationality and level of education (2016-2017)

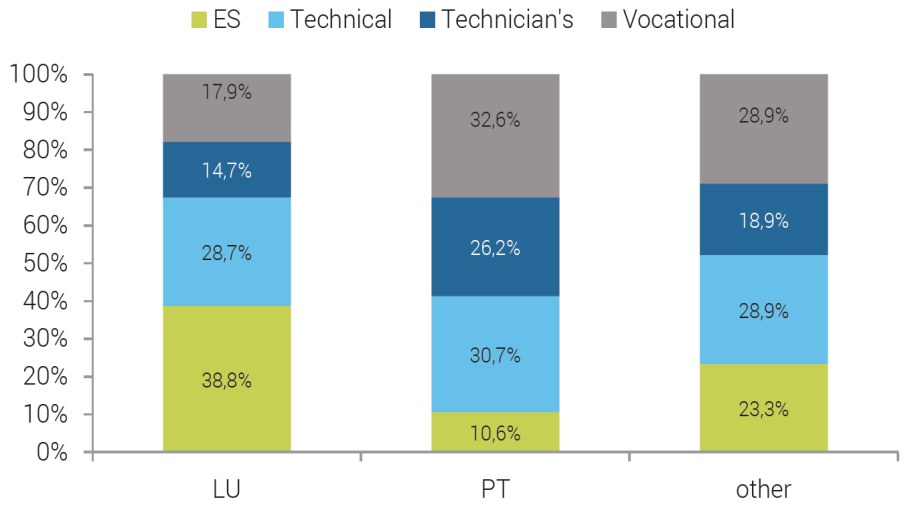
Nombre d'élèves relatif 2016-2017

	Fondamental				EDIFF	ES	EST								
luxembg.	56,4	54,5	53,8	**54,2**	46,7	79,9	36,4	16,4	50,6	64,7	58,5	56,4	53,8	**61,8**	**57,5**
portugais	15,8	20,8	23,7	**22,3**	30,4	7,3	43,7	31,8	31,0	22,7	28,7	28,4	29,4	**22,6**	**22,5**
ex-youg.	3,2	3,3	3,6	**3,5**	3,7	1,6	5,9	4,0	5,1	3,8	4,3	3,4	4,4	**3,6**	**3,5**
français	7,6	6,3	5,2	**5,7**	3,9	2,8	2,8	0,6	3,0	2,1	2,2	2,1	2,5	**2,6**	**4,3**
italiens	1,8	1,7	1,6	**1,7**	1,1	2,2	0,7	0,4	1,0	1,0	0,5	1,3	0,9	**1,3**	**1,5**
belges	2,2	2,2	2,0	**2,0**	0,8	0,8	1,2	2,2	1,7	1,4	1,4	1,3	1,5	**1,3**	**1,7**
allem.	2,1	1,4	1,4	**1,5**	0,7	1,7	0,4	0,5	0,8	0,7	0,4	2,2	0,9	**1,1**	**1,3**
autres	11,0	9,8	8,8	**9,2**	12,7	3,6	9,0	44,1	6,8	3,7	4,0	4,9	6,6	**5,7**	**7,7**
Total Etr.	43,6	45,5	46,2	**45,8**	53,3	20,1	63,6	83,6	49,4	35,3	41,5	43,6	46,2	**38,2**	**42,5**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: MENJE (2018, p. 18)

Other format of data, such as types of diplomas or certificates issued distributed by nationality, exposes the result of the stratification of the education system in Luxembourg, which represents existing inequalities in terms of accessibility to education after secondary school (Figure 9).

Figure 9 – Diplomas/certificates issued by nationalities



Source: MENJE (2018, p. 90)

Even with the multiculturalism and multilingualism existent in Luxembourg that enable the co-existence of several ethnolinguistic communities, the resulting multilingual learning contexts do not reflect inclusion yet. It is still to be perceived that having an immigrant background can affect a students' educational path (e.g., information found in national reports)[5].

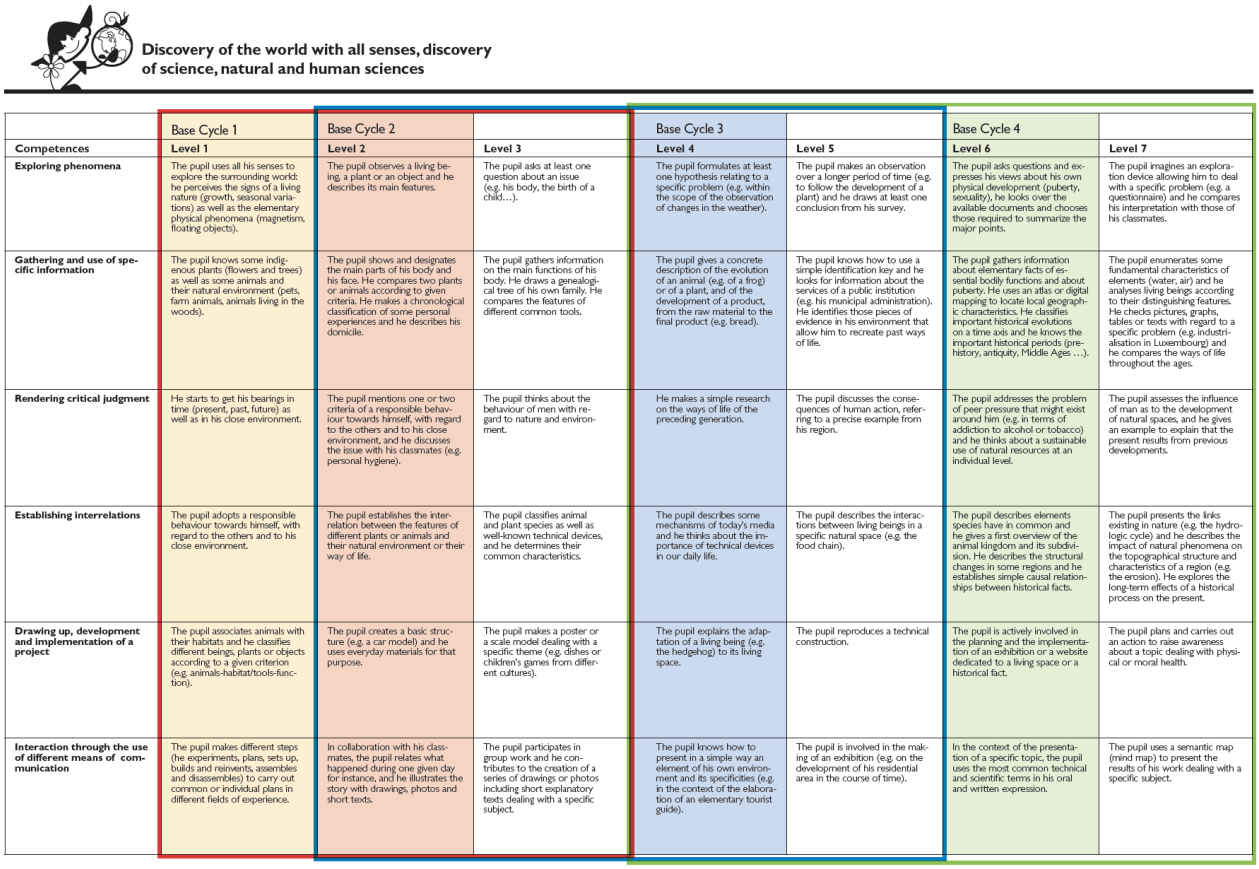
Therefore, as different reports confirm the diversity of students in Luxembourg, there is the need to understand that other studies have also shown that not speaking the language of instruction at home plays a strong role in the students' educational path, for example, when considering the relation between intercultural education and student achievement (Cummins, 2015).

[5] LUCET and SCRIPT (2016, 2019, 2021); MENJE (2021); SCRIPT (2022).

3. Primary science education in Luxembourg

Science education in primary education in Luxembourg is designated differently throughout cycles (MENFP, 2011): for Cycle 1, "Discovering the world through all the senses" (*Découverte du monde par tous les sens* – pp. 136–142); For Cycles 2 and 3, "Discovering science" (*Éveil aux sciences* – pp. 143–156); and, for Cycle 4, "Humanities and Natural Sciences" (*Sciences humaines et naturelles* – pp. 157–162). Even though the national curriculum for science is divided by the cycles, the competences to be developed can overlap due to the adoption of levels (Figure 10).

Figure 10 – Example of levels of competences for primary science education in Luxembourg



Discovery of the world with all senses, discovery of science, natural and human sciences

	Base Cycle 1	Base Cycle 2		Base Cycle 3		Base Cycle 4	
Competences	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**
Exploring phenomena	The pupil uses all his senses to explore the surrounding world: he perceives the signs of a living nature (growth, seasonal variations) as well as the elementary physical phenomena (magnetism, floating objects).	The pupil observes a living being, a plant or an object and he describes its main features.	The pupil asks at least one question about an issue (e.g. his body, the birth of a child…).	The pupil formulates at least one hypothesis relating to a specific problem (e.g. within the scope of the observation of changes in the weather).	The pupil makes an observation over a longer period of time (e.g. to follow the development of a plant) and he draws at least one conclusion from his survey.	The pupil asks questions and expresses his views about his own physical development (puberty, sexuality), he looks over the available documents and chooses those required to summarize the major points.	The pupil imagines an exploration device allowing him to deal with a specific problem (e.g. a questionnaire) and he compares his interpretation with those of his classmates.
Gathering and use of specific information	The pupil knows some indigenous plants (flowers and trees) as well as some animals and their natural environment (pets, farm animals, animals living in the woods).	The pupil shows and designates the main parts of his body and his face. He compares two plants or animals according to given criteria. He makes a chronological classification of some personal experiences and he describes his domicile.	The pupil gathers information on the main functions of his body. He draws a genealogical tree of his own family. He compares the features of different common tools.	The pupil gives a concrete description of the evolution of an animal (e.g. of a frog) or of a plant, and of the development of a product, from the raw material to the final product (e.g. bread).	The pupil knows how to use a simple identification key and he looks for information about the services of a public institution (e.g. his municipal administration). He identifies those pieces of evidence in his environment that allow him to recreate past ways of life.	The pupil gathers information about elementary facts of essential bodily functions and about puberty. He uses an atlas or digital mapping to locate local geographic characteristics. He classifies important historical evolutions on a time axis and he knows the important historical periods (prehistory, antiquity, Middle Ages …).	The pupil enumerates some fundamental characteristics of elements (water, air) and he analyses living beings according to their distinguishing features. He checks pictures, graphs, tables or texts with regard to a specific problem (e.g. industrialisation in Luxembourg) and he compares the ways of life throughout the ages.
Rendering critical judgment	He starts to get his bearings in time (present, past, future) as well as in his close environment.	The pupil mentions one or two criteria of a responsible behaviour towards himself, with regard to the others and to his close environment, and he discusses the issue with his classmates (e.g. personal hygiene).	The pupil thinks about the behaviour of men with regard to nature and environment.	He makes a simple research on the ways of life of the preceding generation.	The pupil discusses the consequences of human action, referring to a precise example from his region.	The pupil addresses the problem of peer pressure that might exist around him (e.g. in terms of addiction to alcohol or tobacco) and he thinks about a sustainable use of natural resources at an individual level.	The pupil assesses the influence of man as to the development of natural spaces, and he gives an example to explain that the present results from previous developments.
Establishing interrelations	The pupil adopts a responsible behaviour towards himself, with regard to the others and to his close environment.	The pupil establishes the interrelation between the features of different plants or animals and their natural environment or their way of life.	The pupil classifies animal and plant species as well as well-known technical devices, and he determines their common characteristics.	The pupil describes some mechanisms of today's media and he thinks about the importance of technical devices in our daily life.	The pupil describes the interactions between living beings in a specific natural space (e.g. the food chain).	The pupil describes elements species have in common and he gives a first overview of the animal kingdom and its subdivision. He describes the structural changes in some regions and he establishes simple causal relationships between historical facts.	The pupil presents the links existing in nature (e.g. the hydrologic cycle) and he describes the impact of natural phenomena on the topographical structure and characteristics of a region (e.g. the erosion). He explores the long-term effects of a historical process on the present.
Drawing up, development and implementation of a project	The pupil associates animals with their habitats and he classifies different beings, plants or objects according to a given criterion (e.g. animals-habitat/tools-function).	The pupil creates a basic structure (e.g. a car model) and he uses everyday materials for that purpose.	The pupil makes a poster or a scale model dealing with a specific theme (e.g. dishes or children's games from different cultures).	The pupil explains the adaptation of a living being (e.g. the hedgehog) to its living space.	The pupil reproduces a technical construction.	The pupil is actively involved in the planning and the implementation of an exhibition or a website dedicated to a living space or a historical fact.	The pupil plans and carries out an action to raise awareness about a topic dealing with physical or moral health.
Interaction through the use of different means of communication	The pupil makes different steps (he experiments, plans, sets up, builds and reinvents, assembles and disassembles) to carry out common or individual plans in different fields of experience.	In collaboration with his classmates, the pupil relates what happened during one given day for instance, and he illustrates the story with drawings, photos and short texts.	The pupil participates in group work and he contributes to the creation of a series of drawings or photos including short explanatory texts dealing with a specific subject.	The pupil knows how to present in a simple way an element of his own environment and its specificities (e.g. in the context of the elaboration of an elementary tourist guide).	The pupil is involved in the making of an exhibition (e.g. on the development of his residential area in the course of time).	In the context of the presentation of a specific topic, the pupil uses the most common technical and scientific terms in his oral and written expression.	The pupil uses a semantic map (mind map) to present the results of his work dealing with a specific subject.

Source: MENFP (n.d., pp. 34–35)

Outlining science education in the Luxembourgish context, the curriculum in primary education is competence-based and the competences are maintained in all cycles (MENFP, 2011): "Engaging in the exploration of phenomena" (*S'engager das l'exploration de phénomènes*); "Being informed in a targeted manner and exploiting the information gathered" (*S'informer de façon ciblée et exploiter l'information recueilie*); "Exercising critical judgment" (*Exercer un jugement critique*); "Establishing interrelationships" (*Établir des interrelations*), "Imagining, designing and implementing a project" (*Imaginer, concevoir et mettre en œuvre un projet*); and "Interacting using different modes of communication" (*Interagir en utilisant différent modes de communication*). These competences for science education are addressed through six thematic domains across the

cycles (for the exception of the last two in Cycle 4): "Mankind" (*L'homme*), "Nature" (*La nature*), "Space" (*L'espace*), "Time" (*Le temps*), "Technology" (*La technologie*), and "The child and her/his environment, citizenship" (*L'enfant et son environnement, la citoyenneté*).

Lessons in Cycle 1 are linked to the projects carried out by the teachers within their weekly plan, while the number of lessons allocated to science education decreases as students advance in cycles: 108 lessons (three per week) for Cycle 2; 72 lessons (two per week) for Cycle 3; and 36 lessons for Cycle 4 (half of the previous cycle) (MENFP, 2011, pp. 237–239). This loss, equivalent of one-third of lessons per cycle, is counterproductive due to the expected progressive complexity of the programs, as this multilingual primary school context can pose a challenge to learning science concepts and processes. Contrasted to the time allocated for language instruction (e.g., for Cycles 3 and 4, weekly lessons for the three languages dominate 46,43% of the total of lessons), science is not on the spotlight of the curriculum.

Research has revealed that science learning in this context has often focused on learning vocabulary words in the language of instruction (Siry, 2017). However, research also outlines that children can express their understandings beyond using verbal resources, especially when documenting (e.g., Doris, 1991; Gallas, 1995; Kirch & Siry, 2012; Monteira et al., 2024) and translanguaging (e.g., García, 2009). Thus, in Luxembourg, primary education teachers should look into science education beyond verbal science investigation resources to oversee children's understanding of science. The ongoing research developed within the University of Luxembourg seeks to support this process, especially through Continuous Professional Development offerings (e.g., through the accredited workshops offered by the SciTeach Center[6]).

4. Final considerations

Considering the history of the country, from occupations and migration fluxes, Luxembourg has established its identity grounded in multiculturalism and multilingualism, enabling several ethnolinguistic communities to co-exist on its lands. Luxembourgish, German and French are the languages of the State (Luxembourg, 1984), whilst many other languages emerge on the country's daily life (e.g., English, Portuguese, Italian, languages from the Balkans).

The school system is divided into the classic three parts (early childhood, primary and secondary), being mandatory from the age of four until 16 and "Luxembourg has developed a diversified school offer to meet the profiles of a very diverse student population" (Eurydice, 2020, p. 22). The languages of the country are officially used in the school system, having different places when playing the role of the main language of instruction (e.g., for primary education,

[6] The SciTeach Center is a resources center for science materials, which are available for both pre- and in-service teachers. Open-source materials and workshops are continuously uploaded to the website www.sciteach.uni.lu.

Luxembourg, 2009a; MENPF, 2011); for example, bearing in mind that science is a subject taught in Luxembourgish in early years, German during primary education, and then mainly French is used in secondary schools.

Different reports (LUCET & SCRIPT, 2016, 2019, 2021; MENJE/SCRIPT, 2021; SCRIPT, 2022) have confirmed the diversity of students, outlining key figures mainly by nationality and language spoken at home. However, the same reports offer evidence of existing inequalities, such as students' achievements in national exams (e.g., LUCET & SCRIPT, 2019) or certificates (e.g., MENJE, 2018). The context becomes even more relevant when observing how primary science is placed in the education system. Language instruction takes a major part of the allocated school time, whilst the number of science lessons per week decreases as the cycles progress (MENFP, 2011). This counterbalance can pose a challenge for both teachers and students when, for example, you consider the shift in the language of instruction in Cycle 2 (at the same time children are learning how to read and write in German, science is taught in German).

Therefore, there is the need to consider that subjects shouldn't compete for time of instruction as topics/themes are much more effective for learning, especially taking into account that "Effective learning is learning that is lifelong and life-wide. This means a whole-of-student approach, underpinned by cognitive development, social and emotional learning, well-being and resilience" (OECD, 2022, p. 6). Science plays a key role in developing skills through curiosity and, considering the inquiry-based approach (e.g., Bybee, 2014), children can learn a lot from exploring when given certain cognitive stimuli (Vygotsky, 1978). Therefore, teachers should be aware that

> Effective pedagogy demands that specific learning methods are chosen in relation to the characteristics of the content, the knowledge and understanding the students already possess, their previous experiences, needs and interests, the need for variety of classroom activity, the availability of resources, specific teacher expertise and so on. (Hodson, 2014, p. 2538)

Finally, this reflection on the country's history and its school system was the core goal of this article, offering the elements to understand that the nuances and complexities of such a multilingual learning context need to be investigated considering the Luxembourg context not only as background but also through the connections between the settings (Dewey, 1939; 1985/2008). It is important to understand the context, looking back to (better) understand the present and to (help) build a better future, especially considering the need to strengthen the role of science education in the curriculum.

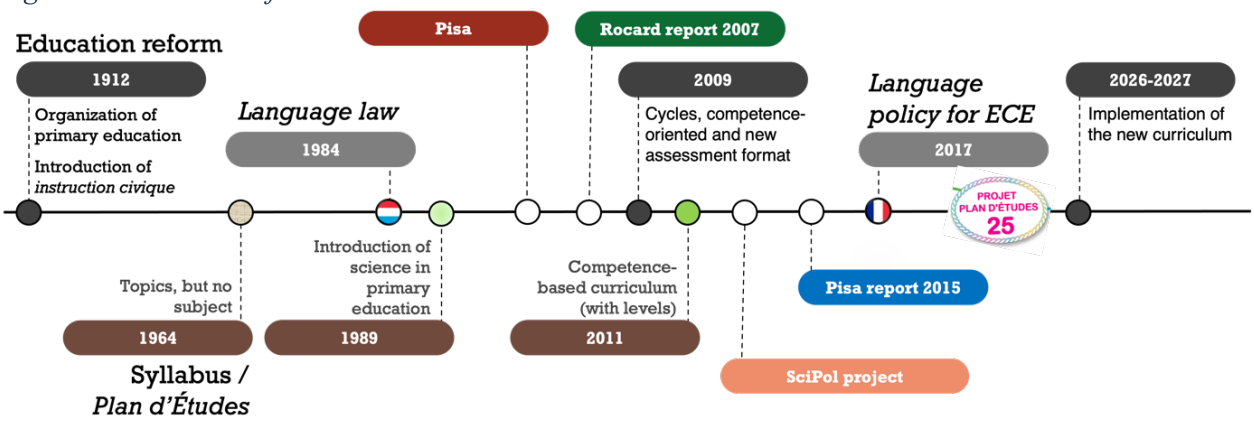
Legislation for Elementary Education

The recent curricular reform occurred in 2009, with the publication of the Education Law from February 6th, 2009 (for the organization of the elementary education – Luxembourg, 2009a), and the subsequent publication of the curriculum (*Plan d'Études*) through the Grand Ducal Regulation of August 11th, 2011, which establishes the study plan for the four cycles of elementary school (MENFP, 2011).

The previous reform dated from 1912, which is known as the "Loi Braun", aimed to modernize the school system in order to respond to the new context (by introducing new subjects) and distancing the church from its role within education (Luxembourg, 1912). The next reform is undergoing the formulation process, which started in 2022 and has working groups bridging the policymakers and the practitioners. The new curriculum is expected to be put in place for the school year of 2026-2027, which will be preceded by one year dedicated to professional development offerings to all in-service teachers to adapt to the new framework (SCRIPT, 2023).

The Law of February 24, 1984, which establishes the language regime (Luxembourg, 1984), addresses three main issues: the national language (Art. 1), "The national language of Luxembourgers is Luxembourgish"; the language of legislation (Art. 2), " When legislative and regulatory acts are accompanied by a translation, only the French text is authentic", except if a language other than French is used by "an organ of the State, municipalities or public establishments", "only the text in the language used by this organ is authentic"; and the administrative and judicial languages (Art. 1), all three languages (French, German or Luxembourgish) may be used. However, regarding administrative requests (Art. 4), "When a request is written in Luxembourgish, French or German, the administration must use, as far as possible, the language chosen by the requester for its response".

Figure 11 – Timeline of Education Acts and Policies



Note: adapted from Rohstock and Lenz (2011); Lenz et al. (2013); Gómez Fernández and Quintus (2020); and the following normative documents: Education Laws (Luxembourg, 1912; 2009a); Language Laws/Policies (Luxembourg, 1984; MENJE, 2017); and the Syllabus (Luxembourg, 1964; MENJE, 1989; MENFP, 2011).

When looking back into the science syllabi used starting from the 20th century (Figure 11), "the new syllabus for upper primary schools of 1939 (the last before World War II) codified different contents of the natural sciences for different schools and classes, designing special agricultural, viticultural, artisanal, and mine worker courses for different regions" (Lenz et al., 2013).

1. The curriculum: *Plan d'Études*

In 1964, science was present as a topic, but not a school subject with allocated teaching time ("*Le programme de l'école primaire ne prévoit pas de leçons spéciales pour l'enseignement des sciences naturelles*"[7] – Luxembourg, 1964, p. 98). Yet, the *Plan d'Études 1964* proposed the use of other subjects to tackle science and also outlined the purpose of doing it:

> Les leçons occasionnelles de sciences ont pour but essentiel de susciter auprès des élèves l'amour de la nature, l'intérêt pour les animaux et les plantes, le respect de la vie. Elles permettront un premier contact des élèves avec la méthode de travail scientifique, basée sur l'observation directe et exacte.[8] (Luxembourg, 1964, p. 98)

In 1989, science education is placed in the curriculum, outlining (MENJE, 1989): the *general methodology* to be used ("Spiralischer Aufbau des Curriculums"; "Direkte Umweltbegegnung"; "Handelndes Lernen"; "Soziales Lernen"[9]) (p. 35–36); two *general goals* ("Kinder erschließen ihre Umwelt durch ihre Sinne und durch ihrem Alter angepaßte Denkstrukturen. Handelndes Lernen soll ihnen die Voraussetzung geben, eine grundlegende, positive Werthaltung gegenuber ihrer Umwelt einzunehmen und ein Verständnis für Zusammenhänge aufzubauen."[10]) (p. 36); and the respective *objectives* (Förderung der Sinneserfahrung; Aufbau von Denkstrukturen; Entwicklung von Einstellungen und Verhaltensweisen; Anwendung spezifischer Arbeitsweisen und Arbeitstechniken; Problemorientiertes Lernen; Sicherung der Unterrichtsergebnisse[11]) (p. 36). The curriculum also indicates that *discovery of science* (*éveil aux sciences*) and *natural sciences* (*sciences naturelles*) would be the subjects for lower and upper grades, respectively (MENJE, 1989).

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[7] Free translation: "The primary school curriculum does not provide for special lessons for the teaching of natural sciences."

[8] Free translation: "The essential aim of occasional science lessons is to arouse in students a love of nature, an interest in animals and plants, and a respect for life. They will allow students' first contact with the scientific working method, based on direct and exact observation."

[9] Free translation: "Spiral structure of the curriculum"; "Direct encounter with the environment"; "Active learning"; "Social learning".

[10] Free translation: "Children explore their environment through their senses and through thought structures appropriate to their age. Active learning should give them the prerequisites to adopt a fundamental, positive attitude towards their environment and to develop an understanding of connections."

[11] Free translation: "Promoting sensory experience"; "Building thought structures"; "Developing attitudes and behaviors"; "Applying specific working methods and techniques"; "Problem-oriented learning"; "Securing the teaching results".

In 2009, the new syllabus introduces four cycles of learning (each cycle consisting of a two-year school-set), a competence-oriented curriculum (clustered within thematic dimensions), and a new evaluation system (during and at the end of every cycle) (Luxembourg, 2009a). Also, it establishes the distribution of hours per subject and the languages of instruction per cycle (MENFP, 2011). In 2017, a new policy concerning the early years enabled French to be used as language of instruction (Luxembourg, 2017) and, in 2022, a pilot was conducted using French as language of literacy (Luxembourg, 2022).

The in-development *Plan d'Études Project 2025* is exploring a new framework, which includes four main features (SCRIPT, 2023, pp. 15–24): the school duties (*Les devoirs de l'école*), which include "qualification", "socialization", "subjectivation" and "citizenship"; a holistic approach to learning (*Approche holistique*), based on the need to learning being child-centered; the key skills and transversal approach (*Compétences clés et approche transversale*), outlining the competences of multiliteracy (*multilittératie*), of the self- (*soi*), social (*sociale*), reflective (*réflexive*) and transformative (*transformatrice*); and, the four pillars of the new curriculum (*Les piliers du nouveau Plan d'études*), being well-being (*bien-être*), participation, plurilingualism (*plurilinguisme*) and digitality (*digitalité*).

2. School functioning

Schooling is free of charge and mandatory between the ages of four and 16 in Luxembourg and (MENJE, 2024). Currently, primary schools in Luxembourg mainly function full day on Mondays, Wednesday and Fridays, and half-day on Tuesdays and Thursdays (Just arrived, n.d.). Children attend primary school for 26/28 hours per week (Luxembourg, 2009a) and, outside school hours, families have access to the service of daycare centers (e.g., *maison relais*), provided by the municipalities (Guichet, n.d.).

Depending on the distribution of tasks within a school, teachers have a workload that includes less direct teaching hours than the ones needed for one classroom (Luxembourg, 2017). This leads to any primary classroom to have two teachers: a main teacher (*titulaire*), who is taken as responsible for the students and usually focus on the instruction of subjects included on national exams (languages and math); and a second teacher (*surnuméraire*), who will take the remaining hours to teach the other subjects (such as science, arts, sports etc.).

Families arriving in Luxembourg have access to the School Integration and Welcoming Service (SIA – *Service de l'intégration et de l'accueil scolaires*), a mediation service from the Ministry of Education, which "welcomes all families who have recently arrived in Luxembourg; offers information and counseling for the pupils and their parents on all questions related to the Luxembourgish school offer; [and] provides an individual monitoring during two years" (MENJE,

n.d. a). Through this service, families follow four stages to welcoming children in the school system (MENJE, n.d. b): ***appointment***, requested by the family to start the school integration process; ***support***, where a dossier is opened for each child and an intercultural mediator can be brought to assist the family; ***guidance***, when orientation to adequate school placement is provided; and ***monitoring***, which follows the children for two years, mainly through the reception classrooms (*accueil*) in the school for language development.

3. Teacher education

In order to be a primary teacher in Luxembourg, one must hold a minimum of a bachelor degree, comprising 240 ECTS (MENJE, n.d. c), which can be obtained by two paths at the University of Luxembourg: the Bachelor of Education (*Bachelor en sciences de l'éducation* – BScE), where the students will "gain the pedagogical and teaching skills necessary to meet the challenges of a multilingual and multicultural school environment"; and the Bachelor in Teacher Training (*Bachelor en formation pédagogique* – BFP), which comes as a substitution of the "Quereinsteiger" program and addresses the holders of a bachelor degree on a related field to education to obtain "additional qualification to prepare them for teaching in primary education (cycles 2-4) in Luxembourg schools". For both courses, the language requirement is proficiency in Luxembourgish, French, German, and English (UL, n.d. a; n.d. b). Once the pre-service teachers finish their course, they are eligible to participate in a school placement scheme (*concours* – MENJE, n.d. d).

Every three-year period, primary teachers in Luxembourg need to comply with 48 hours of attendance of professional development courses (*formation continue*) (Luxembourg, 2017). All courses need to be accredited by the Institute for National Education Training (IFEN – *Institut de Formation de l'Éducation Nationale*) and teachers can check the offerings and proceed with the enrollment through the institute's website (www.ifen.lu). Each offer is presented in detail with the context of the course, its objectives, content and methodological approach (IFEN, n.d.).

Chapter II –
Theoretical and Methodological Frameworks

This chapter outlines the theoretical framework and grounding concepts used throughout this PhD dissertation, which lies at the intersections of science education and teacher education, framed by an understanding of learning, teaching, and learning to teach as being social phenomena, in order to introduce you (the reader) to the overarching conceptual groundings guiding this study. The chapter also outlines the methodological framework, including the research approach and philosophical assumptions, the research design, and descriptions of the datasets.

As theories illuminate so they obscure.

[Tobin, 2015, p. 4]

How do you distance yourself from your research?

[Provocation about my position on qualitative research being "subjective"]

Theoretical grounding concepts

Each chapter of the dissertation presents its own theoretical framework, with this chapter introducing the overarching theoretical concepts that ground the research conducted with the aim of elucidating the conceptual choices used and placing the boundaries to the current theoretical framework.

> A theoretical framework illuminates social reality, but it only shows what the theory is capable of showing. Different theories can provide different landscapes for what is happening and why it is happening. For example, theories about expressed emotions might give interesting accounts of facial expression of emotion, emotions represented by prosody, and use of gestures when emotions become excessive. However, as rich as these insights might prove to be they will be silent about more issues than they illuminate. As theories illuminate so they obscure (Tobin, 2015, p. 4).

A manuscript-style dissertation affords illuminating different components of the research. Multiple theories are brought together in this dissertation across the different chapters, providing views on the different landscapes Tobin (2015) refers to. In considering the work as a whole, three dimensions are relevant and introduced next: Science Education, Teacher Education, and Social Phenomena.

1. Inquiry-based science education

The teacher education initiatives developed and offered by the SciTeach Center team are guided by inquiry-based approaches to science education (IBSE). IBSE (also referred to interchangeably herein as inquiry-based approach, inquiry-based learning, inquiry-based teaching) refers to an open-ended, practice-oriented approach to science education. Different models present different ways to approach science through open inquiry, and two are drawn upon in the work of the SciTeach team, and thus are central to the teacher education offerings developed through this study.

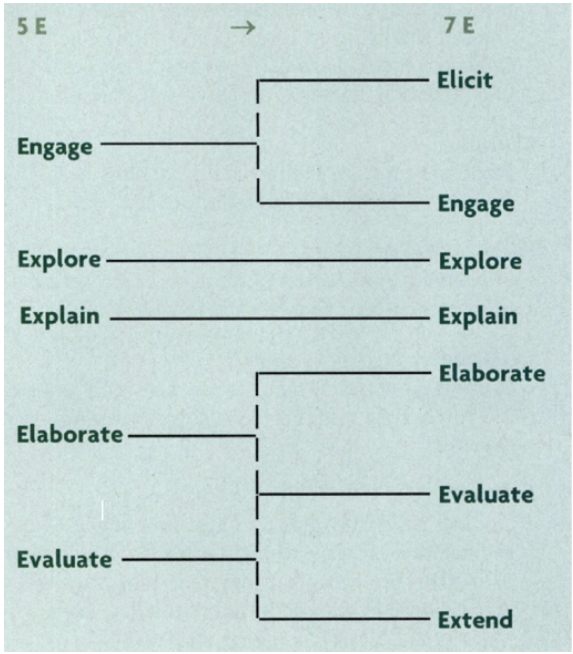
The research circle (*Forschungkreis* – Marquardt-Mau, 2011) is a model that presents six steps showing how to engage children into investigating science phenomena: Ask nature a question (*Frage an die Natur stellen*); Collect ideas and predictions (*Ideen & Vermutungen sammeln*); Try it out and investigate (*Ausprobieren & Versuch durchführen*); Observe and describe (*Beobachten & Beschreiben*); Document the results (*Ergebnisse dokumentieren*); and, Discuss the results (*Ergebnisse erörtern*).

The 5E approach relies on a cycle of five actions to take upon investigating or taking a science task (Bybee, 2014): *Engage*, which is built upon the previous knowledge; *Explore*, in order to produce new knowledge; *Explain*, that helps to construct meta-skills, from doing science to

explaining the process of doing it; *Elaborate*, applying the next step towards expanding/deepening understandings; and, finally, *Evaluate*, grounded on (self-)assessing and moving learning forward.

Eisenkraft (2003) proposed an expanded model of 7E, which "emphasizes 'transfer of learning' and the importance of eliciting prior understanding" (p. 56). By adding *Elicit* as first step and *Extend* as the last one, the 7E model proposes the unfolding of the 5E model (Figure 12), by splitting the focus on eliciting prior understandings (*Elicit*) to the capturing the student's attention (*Engage*) and regrouping the steps of knowledge application, *Extend* as an unfolding of *Elaborate*, grounded on reaffirming the "transfer of learning" (through *Elaborate – Evaluate – Extend*).

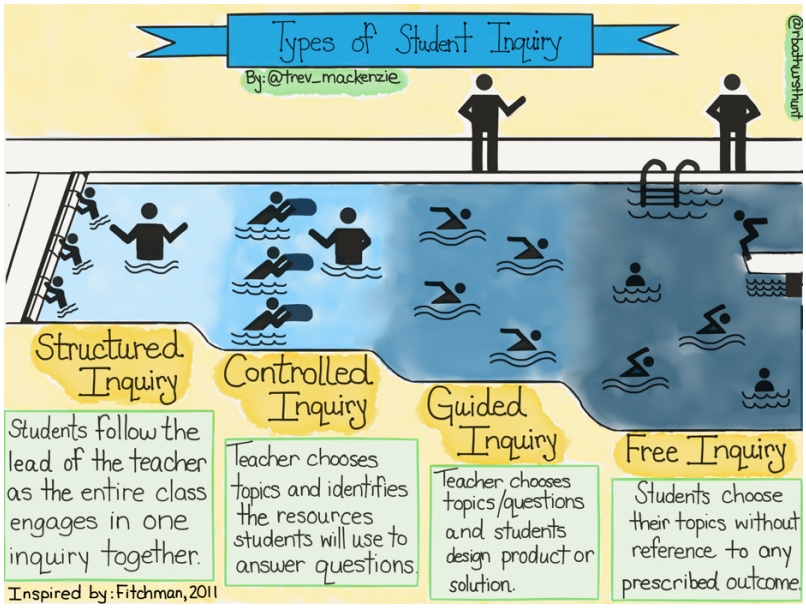
Figure 12 – The proposed 7E learning cycle and instructional model



Source: Eisenkraft (2003, p. 57)

Two relevant aspects to consider for this study are the positioning of the teacher within the inquiry process, and the adaptation of the inquiry to different levels of students' needs (or teachers' needs). The first aspect can be exemplified by what Ann MacKenzie (2001) has explored: "the importance of a teacher's stance in making the inquiry process come alive (...) Her [the teacher's] questions reflected her attitude of science as an endeavor surrounded by inquiry, curiosity, and possibilities". As of the different levels onto which inquiry can take place, Trevor MacKenzie (n.d.) proposed four types of student inquiry, by using the analogy of learning to swim (Figure 13). The role of the teacher and the student in inquiry is presented through the comparison to teaching swimming – thereby placing the teacher from an active inside role to an observer outside role of the process (see "movement" of the arms and where the teacher is in relation to the *pool*) (Figure 13).

Figure 13 – Types of student inquiry



Source: T. MacKenzie (n.d.).

Banchi and Bell (2008) present inquiry-based learning as a continuum (confirmation, structured, guided, open), outlining the importance of acknowledging the existence of levels of inquiry and that

> As students experience the multiple levels of inquiry, they will develop the abilities and understandings of scientific inquiry. Students need to experience science through direct experience, consistently practicing the inquiry skills and seeking deeper understanding of science content through their investigations. Accomplishing these goals is feasible once you can identify the level of inquiry in science curriculum materials and revise them as needed to provide students with a range of complexity in their inquiry experiences (Banchi & Bell, 2008, p. 29).

Inquiry-based science education relates to the teaching/learning approach grounded on open-ended investigation process, placing the student in the center of the learning process, acknowledging the importance of questions (Wilmes, 2017), whilst the teacher structures opportunities for children to pursue questions in open-ended ways, taking a step back and positioning her/himself in a more passive role, thereby facilitating an approach to engage the students into leading their science investigations.

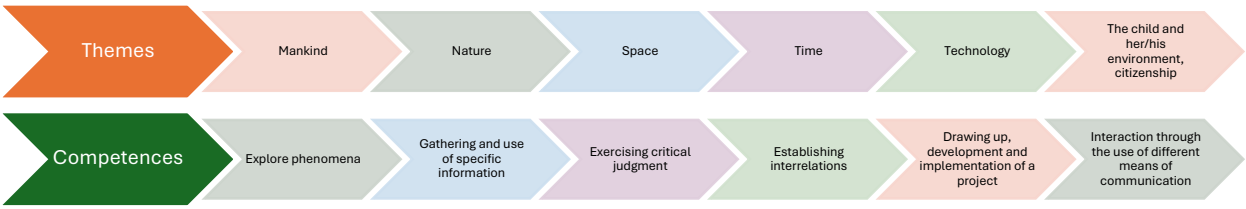
2. Competence-based curriculum in Luxembourg

The current curriculum in Luxembourg is a competence-based one (*Plan d'Études* –MENFP, 2011), as already introduced in Chapter I, which includes mainly the topics of *languages* (the language, the Luxembourgish language and the initiation to languages – Cycle 1; the Luxembourgish language – Cycles 2–4; The acquisition of literacy and the German language; the French language), *mathematics* (the logical and mathematical reasoning, the mathematics), *sciences* (discovery of the world with all senses, discovery of science, natural and human sciences),

physical education (body expressions, psychomotor activities, sports and health), *arts* (creative expression, discovery of aesthetics and culture in the field of visual arts and music) and *life and society* (living together and values, moral and social education and religious education).

For sciences, six themes are put together with six competences in order to offer the teachers a framework they can work on (Figure 14). The *Plan d'Études* offers several examples on how to perform the competences within the themes, adding to the end of each theme (per cycle), recommended contents are listed, alongside with mandatory themes and projects (e.g., a mandatory project organized around "the progress of the day or the four seasons" – MENPF, 2011, p. 142).

Figure 14 – Science education in the Luxembourg curriculum



Source: adapted from MENFP (2011)

Here, when addressing the competence-based curriculum in Luxembourg, the reference is to the competences and examples of performance available in the *Plan d'Études* (MENFP, 2011). For additional information on the available discussions on the Luxembourgish curriculum, Lenz et al. (2013) have explored it using the socio-historical lens, and Trigo (2023) has described the place of science in the curriculum, offering an overview.

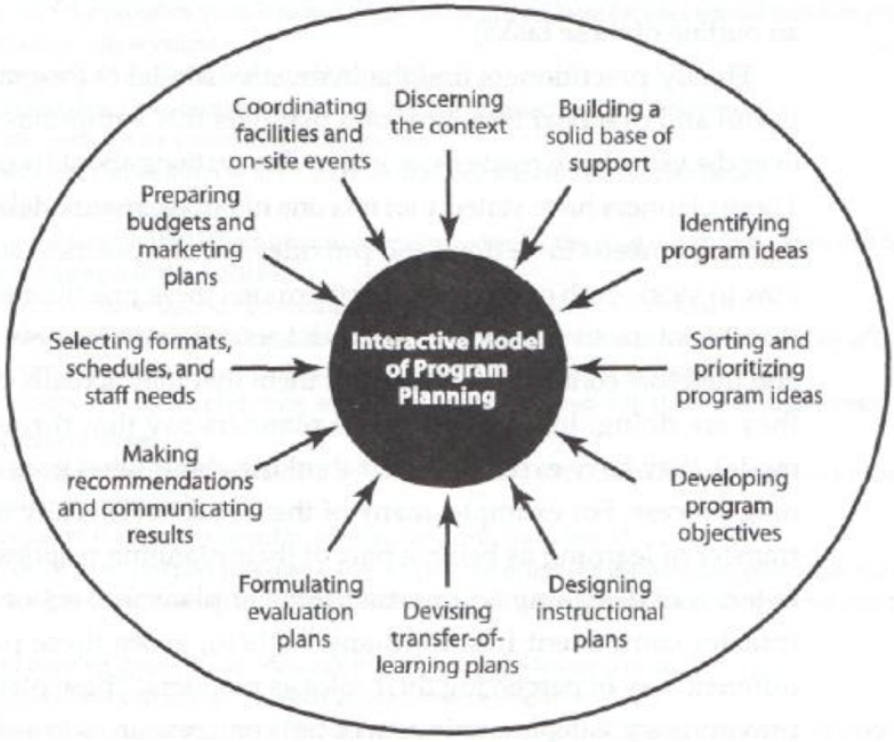
3. Planning professional development offerings

In order to offer professional development workshops (also referred to as professional learning opportunities in this dissertation), there is a need to understand that the process of planning can take place in different formats. For this research, planning is a comprehensive process that includes steps beyond and after the delivery of a workshop. The Interactive Program Planning Model is based on seven assumptions (Caffarella, 2002, pp. 25–29): Focus on learning and change; Recognize the non-sequential nature of the planning process; Discern the importance of context and negotiation; Pay attention to advance planning and last minute changes; Honor and consider diversity and cultural differences; Accept that program planners work in different ways; and, Understand that program planners are learners. Consequently, this comprehensive approach offers a solid base for planning teacher professional development offerings within collaborative structures.

It is important to note that Caffarella's model was designed for the development of training actions for adult learners and comprises 12 steps (Caffarella, 2002): Discerning the Context;

Building a Solid Base of Support; Identifying Program Ideas; Sorting and Prioritizing Program Ideas; Developing Program Objectives; Designing Instructional Plans; Devising Transfer-of-Learning Plans; Formulating Evaluation Plans; Making Recommendations and Communicating Results; Selecting Formats, Schedules, and Staff Needs; Preparing Budgets and Marketing Plans; Coordinating Facilities and On-Site Events (Figure 15).

Figure 15 – Interactive Program Planning Model



Source: Caffarella (2002, p. 21)

The steps can be used sequentially, or the program organizers can choose the needed steps to carry out their activity. It is essential to highlight two aspects that are often neglected when planning training programs, but are taken into account in this research: the transfer of skills (*Devising transfer-of-learning plans*) and in-depth evaluation (*Formulation evaluation plans*).

4. Evaluating professional development offerings

Usually, when providing professional development offerings, organizers are keen to ask feedback on the participants' reaction basis, but this represents only one level of evaluation when considering Kirkpatrick's Model (Kirkpatrick & Kirkpatrick, 2006). This model presents four levels to evaluate the effectiveness of training programs (in the context of this research, the focus is on teacher professional development offerings), consisting of:

- *Reaction* (level 1), which is characterized as feedback (commonly done with surveys), aims to gather the participants' immediate reaction based on their satisfaction and participation;

- *Learning* (level 2), that aims to assess the learning process, by verifying what knowledge and skills were acquired during the training (usually done through questioning and, more recently, digital polls; it can also include pre- and post-tests);
- *Behavior* (level 3), which offers evidence of transfer of knowledge (learning, or skills) as the participant changes his/her behavior by implementing what was learned during the training on the workplace;
- *Results* (level 4), the hardest level to achieve, should evaluate the impact of a training on an organizational level.

Levels 3 and 4 are the most relevant when considering teacher training programs. For this research, evaluating the effectiveness of a workshop is when it is considered that a change of one's behavior (level 3) can trigger a change in the school setting (level 4). In this research, the success of a workshop is based on a planning grounded on the possibility of immediate implementation, where the primary teacher (workshop participant) can go back to her/his classroom and replicate the activities from the workshop. This possibility of immediate implementation relates to the transfer of skills: part of the process of using Kirkpatrick's model for evaluating teacher professional learning opportunities also linked to the use of Caffarella's model for planning.

5. School-university partnership / Research-practice partnership

The literature provides an extensive list of types of partnerships and many of them can be found in the field of Education: *Public-Private Partnerships* (PPP) can emerge from stakeholders considering their financial status (Smith & Wohlstetter, 2006); *Industry partnerships* mainly promote the appointment of people from their trainings to the industry (see also this in research – European Commission, n.d.); *Research-practice partnerships* (RPP), liking research to practice through network community, design research and alliances (Coburn et al., 2013; Sjölund et al., 2023); and, *School-university partnerships* (SUP) that put together stakeholders involved in the process of providing education (Goodlad, 1991; Clark, 1991).

This research explores an "in-between" conceptualization of a research-practice partnership and a school-university partnership, considering the SciTeach Center as such partnership. This is because the addressed partnership is composed of researchers and teachers, working within their scopes of praxis, but coming together through the establishment of an agreement between the school and university sides of respective ministries. This relates to the reflections from Guerrero and Reiss (2020) and Kang and González-Howard, (2022), where both types of partnership are addressed, both using as working grounds the aspect of collaboration towards science education. Guerrero and Reiss (2020) focused on "the experience [of a research-practice partnership using an interdisciplinary approach] provided a rationale for more

collaborative-action work projects to foster curricular planning of outdoor science activities and in-service teacher education. RPPs benefit from collaborative learning in all the phases of an outdoor science activity" (p. 1538), and Kang and González-Howard (2022) narrated their own experience within two school-university partnerships, illustrating " the complexity of educational institutions working collaboratively towards transformative social changes in local contexts" (p. 15).

Three aspects within the partnership are explored in the core chapters of this dissertation: partnership as a *continuum* from networking (Fynn et al., 2022); collaborative partnership as responsible for *transformational and synergistic* learning process (Saltiel, 1998); and partnership as an *organization* structured in itself (Baker, 2011).

5.1. Collaboration

Even though the work "partnership" implies the concept of "collaboration", here collaboration is understood as a structure that allows *co-* processes (e.g., co-development, co-teaching etc.), *power sharing* (e.g., Patton, 2002), and *learning through interaction* (e.g., Engeström et al., 1995). Wilmes, te Heesen et al. (2018) have traced the foundational collaborative structure of the studied school-university partnership, grounded on the aspect of *reflectivity* (Schön, 1987) and *cogenerative dialogue* (Tobin & Roth, 2005; Tobin, 2006): ***Reflect – Dialogue – Act***.

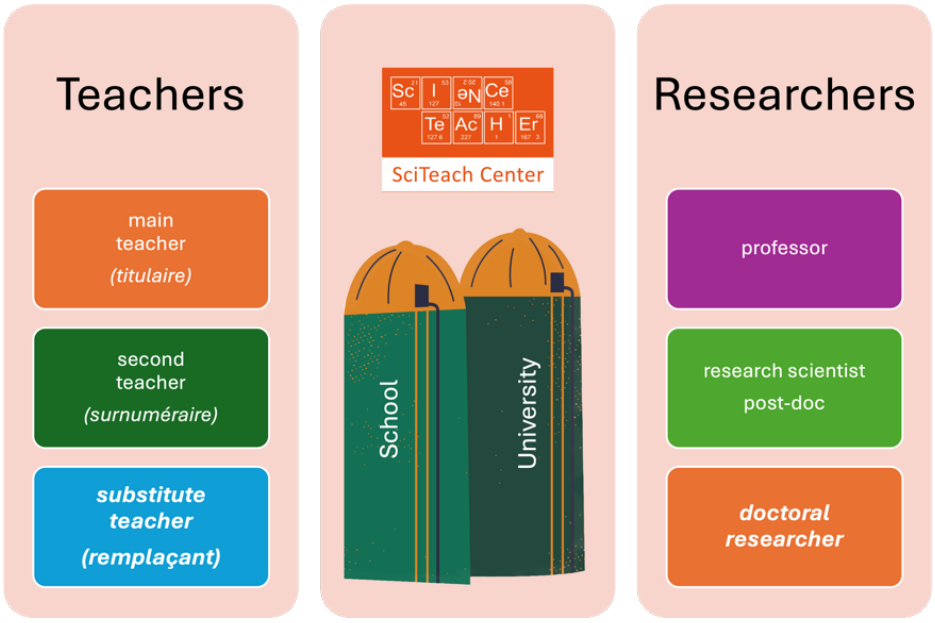
Collaboration can take place in different formats by the establishment of partnerships, but also through creating spaces for co-structures (e.g., co-teaching – Roth & Tobin, 2004; Silva et al., 2022), platforms for dissemination (e.g., use of journals for science teacher education – Martins & Barros, 2015), inclusion of informal education settings (e.g., Monteiro et al., 2016), and building close collaborative relationship (e.g., teacher-researcher collaboration – Manz et al., 2022).

5.2. Third space

Third space is a concept widely used to describe organizational and communicational settings. Bhabha (2004) argues about the third space in a (de)colonizing perspective, exploring the production of hybridity and moving away from the puristic perspective of cultures. Gutiérrez et al. (1999) present the idea of third spaces as "zones of development", emergent from "hybrid activities, roles and practices" (p. 286). Both studies are within the scope of language research, but both concepts are grounded in the hybridity aspect.

For this research, the SciTeach Center is the umbrella partnership positioned as a third space, emergent from the action of exiting the school and university silos (Figure 16), decolonizing from the original settings (Bhabha, 2004), and creating a new setting from negotiation based on the grounds of collaboration (Gutiérrez et al., 1999).

Figure 16 – Siloing within the school-university partnership



Considering the partnership's dimensions (organizational, cultural, relational, and historical – based on Wegemer & Renick, 2021), the SciTeach Center is a third space where the core partnership stakeholders (teachers and researchers) meet, negotiate working settings, work together, and span/cross their boundaries.

5.3. Boundary spanning

Within a school-university partnership, people can come together and work together, but not necessarily influence each other's work. The boundary spanning/crossing process is only possible when collaboration is nurtured by the permeability of the collaborators (Klein, 2021). This can be enabled by developing *communities of practice* (Wenger, 1998/2005) through *mutual engagement*, and cultivating *distributed leadership* (Woods et al., 2004) through the *openness of boundaries*. The spanning/crossing of boundaries enables a dialogical phenomenon where people acknowledge their differences as resources for learning (e.g., Akkerman & Bakker, 2011; Engeström et al., 1995).

This research was able to examine in detail the boundary spanning of a teacher and a researcher as they exit their silos (school and university, respectively) to come together in collaboration in a third space (Trigo et al., 2024), benefiting from the permeability of the silo-spaces and learning from each other, giving one step forward serving as an example of co-research and co-write (see also the work of Cowie et al., 2010).

5.4. Habitus

> Habitus is both a system of schemes of production of practices and a system of perception and appreciation of practices. And, in both of these dimensions, its operation expresses the social position in which it was elaborated. Consequently, habitus produces practices and representations

> which are available for classification, which are objectively differentiated; however, they are immediately perceived as such only by those agents who possess the code, the classificatory schemes necessary to understand their social meaning. Habitus thus implies a "sense of one's place" but also a "sense of the place of others" (Bourdieu, 1989, p. 19).

An education system can be perceived on the *field–habitus-doxa* conceptualization (Bourdieu, 1977). This specific school-university partnership (the SciTeach Center), built on the basis of a community of practice in a third space, where its stakeholders span their boundaries in order to come together and advocate for inquiry-based science education by offering professional learning opportunities for in-service teachers, serves as an example of how an existing *habitus* can be provoked towards a disruption of the *habitus* and *field* (see also the work, in this case with pre-service teachers, of McPherson, 2023).

6. Sociodynamic perspective

Research in education can be done based on different assumptions and research designs. Dewey (1939) has highlighted the importance of context and, considering the concepts of social dynamics (Moscovici, 1988/2005), sociodynamics (Moles, 1967; 1971), Pinto (2022; 2023) has proposed a framework grounded on the relevance of the context (not only as background – temporal and spatial) when conducting research with oral testimonies in the scope of History of Education.

As the framework uses the elements of time, space, and conditions and their effects when looking into social phenomena, this research (in the scope of Teacher Education) sees the value in its use, especially considering that the research includes the aspect of a partnership that is contextually-responsive in uncertain times. Therefore, it is assumed that the sociodynamic perspective provides the basis to explore phenomena, processes, and changes in society and its factors (Pinto & Trigo, in press).

Methodological groundings

This section presents the comprehensive grounds of the methodological choices on which this research was conducted. It covers the Research approach and philosophical assumptions, Research design and Datasets. Each chapter presents a section on the methodology and methods linked to the data used to explore the social phenomenon(a) particularity.

> One case study is enough, under certain not particularly limiting conditions. We can know a great deal about the general from the specific if we know where to look and the general can be hidden in a vast number of cases if we don't (Easton, 2010, n.p.).

1. Research approach and philosophical assumptions

The research paradigm is grounded on the work of Guba and Lincoln (2005), which is built from considering four philosophical assumptions about the nature of reality (ontology), of knowledge (epistemology), of ethics (axiology), and of the systematic form of inquiry (methodology). These assumptions are the foundations to the qualitative research done here (Table 3), where social phenomena are examined and ethical considerations have to be taken into account in order to consider one research with impact on social change (Mertens, 2010a; 2010b).

Table 3 – Choices of philosophical assumptions

Assumptions	Choices
ontology	constructivist relativist
epistemology	interpretivism, subjectivism
axiology	existence of bias (epistemic orientation), declared values
methodology	**qualitative**

While ontology focuses on the nature of reality, epistemology focuses on the nature of knowledge and axiology on the value of the knowing (Amado, 2014). Not contrary but complementary, the assumptions allow to position the researcher within the research and also point out the relationship between the researcher, the research participants and the research object/subject. For this study, it is important to acknowledge that these boundaries are flexible and permeable, considering the existence of proximity, collaboration and convenience (Creswell & Clark, 2007; Cohen et al., 2018), as the researcher takes part of the research as participant, being an active agent of the research object (i.e., the teacher-researcher collaboration).

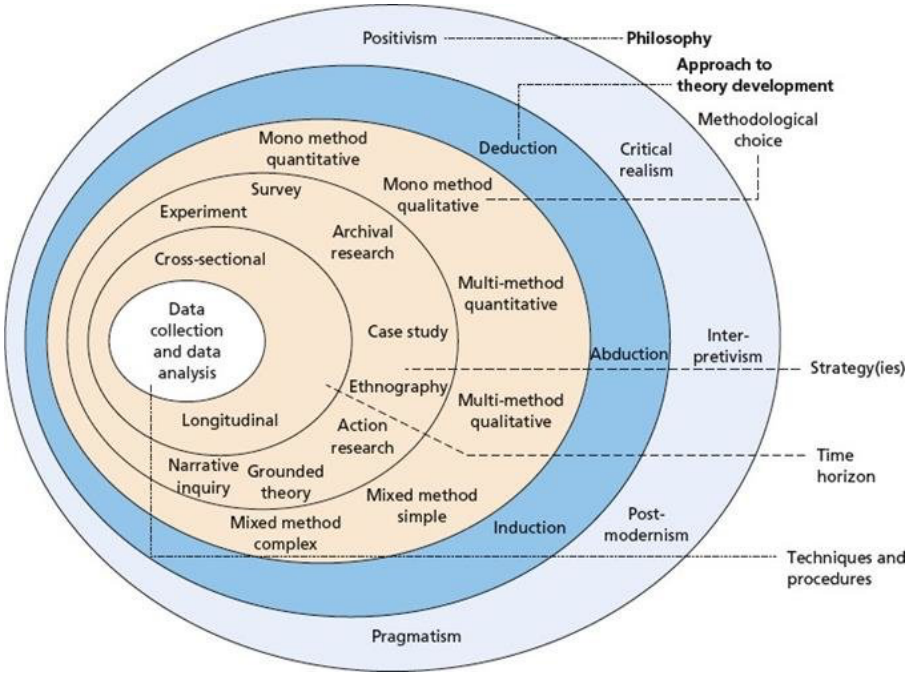
Considering the ontological assumption of the constructivist relativist type (Waring, 2012), the starting point is to accept the existence of multiple realities (Guba & Lincoln, 1982) and assume that the same phenomenon can be observed through different lenses: subjective and/or objective (Zanela Saccol, 2009; Tobin, 2015). The epistemological approach is based on interpretivism, in an effort to understand the phenomena through the beliefs on what was experienced and the shared

understanding of individuals in a social group, leading to an understanding of how the world is socially perceived and interpreted (Kuhn, 1996; Arthur et al., 2012).

Considering the axiological values (Biendenbach & Jacobsson, 2016), its foundations pursue to acknowledge the preservation of ethical and methodological procedures and participants' rights. Participants were invited to proceed with research findings checking, and the researcher was able to revisit the findings after the joint reflection. The research complies with the Ethics guidelines of the University of Luxembourg, through approved protocol ERP 21-050 SuperSci.

The research steps are taken based on the research philosophy, the approach to theory development, the methodological choice, the strategy, the time horizon, and the techniques and procedures (Figure 17).

Figure 17 – Research onion



Source: Melnikovas (2018, p. 33), based on Saunders et al. (2016).

This research has a multi-method qualitative approach, as datasets come from different sources and are treated under different analytical methods. This cross-sectional research is linked to the process of a school-university partnership to tackle issues of teaching science in a multilingual context, through the development of an in-service teacher education workshop (*Science and Language*), constituting it as a case study (Stake, 1995). Considering the different data sources, different collection techniques and analytical procedures were used, and they are described in the section "Datasets" of this chapter.

Understandings for research and researcher

Research here is understood from the perspective of exploring a phenomenon (a situation) through investigating it to understand the processes involved and how these impact the concerned

stakeholders (Abbagnano, 2007), considering a phenomenological approach, where lived experiences can be explored to understand the essence of the studied phenomenon (see Smith et al., 2009). Combining the views from research and metaphysics, the understanding of the research process is based on understanding that "Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole" (Dewey, 1939, pp. 104-105), especially when transformation happens through becoming aware of the phenomena.

The assumed position taken in this research as of the point of view of *What is research* and *What is the process of how to do qualitative research* is based on the perspective that:

> Qualitative research is a situated activity that locates the observer in the world. Qualitative research consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. (Denzin & Lincoln, 2011, p. 3)

A researcher is "someone who studies a subject, especially in order to discover new information or reach a new understanding" (Cambridge, n.d.). The consideration of "teacher as researchers" dates to the 1970s, when Stenhouse (1975) offered a differentiation on the concepts of "teacher researchers" and "professional researchers". Later in the 1990s, Hammersley (1993, p. 425) outlines "the development of the idea that educational research should be integrated with the work of teachers in schools, in the form of the teacher-as-researcher", indicating that "educational research should be an integral part of the work of teachers in schools rather than an activity carried out on schools by outsiders", while Hargreaves (1996, p. 111) implicates that

> Collaborative research between school teachers and university researchers is often advocated as a way of bridging theoretical knowledge and practical concerns in education, as a way of empowering teachers to be democratic participants and not merely objects of research, and as a way of guarding the ethical rights of teachers not to be exploited or demeaned by the ways in which researchers represent them,

offering a discussion on how to cross the borders (or blur them) between the knowledge of teaching and research. In the 2010s, Mills (2011) proposed a set of principles on the role of teacher-researcher, considering mainly one's role as reflective practitioners. Thus, this study considers that a researcher can take part of the phenomena that is being investigated, with the possibility of positioning oneself in different ways and sharing the research endeavor through the process of co-researching, considering that the process of co-researching between teachers and researchers as "a contribution towards building the relationship between research and practice" (Mariguddi, 2022, p. 87).

2. Research design

This research is to be considered a mosaic, where the pieces are layered together, both horizontally and vertically. As it emerged from the existing collaboration between teachers and researchers, little design was done on a basis *a priori*. As awareness of social phenomena emerged, research foci also emerged, and different research designs were implemented in order to understand the different phenomena studied.

For some phenomena, the research used triangulation (Flick, 2018b) to draw understandings, especially on structures in which the phenomena were observed as replicated, confirming its sustained aspect (such as the collaboration structure itself), and also used bricolage (Kincheloe, 2001), to comprehend one phenomenon based on the implications of other phenomena (such as boundary spanning being enabled in a third space setting, which is based on the building of a community of practice, which is governed by the principle of distributed leadership).

Research question(s) and aim(s)

As the research has different datasets, these bring to light different problems, and different research questions emerge. The overarching research question is ***How can we support primary education through science teaching in multilingual learning contexts?*** (represented in the title of this research). To do that, a two-fold question-set was developed:

1. What is available in the literature about primary science education in multilingual contexts?
2. What are the structures that can support teachers (science teachers) in primary education in multilingual contexts?

This research focuses on the educational sciences, and the phenomena studied are from different fields, mainly including theories from the social sciences: sociology, management, history, etc.. Therefore, the different datasets have different aims, goals, and objectives, but overarching ones are presented here (Table 4). Each chapter will present its research question and aim, based on the studied phenomenon.

Table 4 – Overarching aims, goals and objectives

Aims	Goals	Objectives
To investigate what has been researched about primary science education in multilingual contexts	To draw from studies and overlaps between language learning and science education	To conduct an exploratory mapping about "inquiry" and "language" and their overlaps
	To build a database of studies about primary science education in multilingual contexts	To conduct a systematic review about primary science education in multilingual contexts
To identify what structures support teachers (science teachers) in primary education for multilingual contexts	To understand the groundings of the multilingual context and the teacher profession	To outline the Luxembourgish context in terms of primary school and primary teacher profession
	To investigate existing structures that support primary science teachers for multilingual contexts	To list the existing structures that support primary science teachers for multilingual contexts
		To identify what sustain the structures that support primary science teachers for multilingual contexts

3. Datasets

This section aims to present the different datasets, considering data collection, treatment, and analysis procedures.

3.1. Systematic review

Considering the need to map the research field and identify research gaps, one systematic review was included in this investigation (of the scoping type) in order to address the following research question: *What has been published about teaching primary science education in multilingual learning contexts?*. During the final screening, a comprehensive analysis was conducted in order to also identify the place of inquiry-based learning, considering a secondary research question: *How is inquiry-based science education mentioned in these publications?*

Two different online databases were used as sources for the search to build the scoping review from a search considering all fields **EBSCO*host***, for which access was provided by the a-z.lu platform, comprises three education research databases (Education Research Complete, ERIC – Education Resource Information Center, and SocINDEX with Full) within the subject of Education; and, **Web-of-Science** databases, considering the Social Sciences collections and indexes (SSCI – Social Sciences Citation Index; SCIE – Science Citation Index Expanded; and ESCI – Emerging Sources Citation Index). Due to a limitation on the search form when the search was conducted on the database **Scopus**, the strings were used for search only on titles, keywords, and abstracts.

The search used validated descriptors from the ERIC Thesaurus, and the keywords referred to school levels (early childhood education and primary education), school subject (science

education), and school system language context (multilingual education). The search strings were chosen considering the core keywords and attributed synonyms, using *OR* within the scope and *AND* between them (Table 5).

Table 5 – Core concept keywords, and synonyms

Core concept keywords	Synonyms
early childhood education	kindergarten, preschool
primary education	elementary education, elementary school, primary school
science education	science curriculum, science education, science instruction, science learning
multilingual education	language diversity, language learning, multilingual learning

The search limiters included publication date (15 years, between 2008 and 2022), source type (academic journals – Article, Journal Article, Research Article), and language (English); only articles with full text access were included. The year 2008 was chosen due to the publication of the ***Science Now*** report in December 2007 (European Commission, 2007). The source type and language were added due to the limited time and resources (two researchers) to conduct a more open review. Therefore, inclusion eligibility statement is "academic articles written in English with full text available, focused on primary science education in multilingual contexts" and, by contrast, the exclusion statement is "any other type of publication, with full text not accessible online, which themes does not include science, focused on middle or secondary education, on monolingual contexts".

The screening report process was accompanied by the use of the new Preferred Reporting Items for Systematic reviews and Meta-Analyses – PRISMA flow diagram 2020 (Page, et al., 2021), and the publications were clustered by themes, and implications for research were drawn. This scoping review is presented in Chapter IV – Primary science education in multilingual contexts.

Besides this scoping review, other three exploratory mappings were conducted (although they do not constitute datasets themselves) in order to verify the existence of research gaps on the topics of: "primary science teacher education", for which a brief description is presented in Chapter III – *State of the Art*; the "overlaps between language and inquiry", a manuscript that outlines thematic tendencies for "language" and "inquiry" using lenses from comparative studies, also presented on Chapter III; and, "partnerships in primary science education", a search used for the manuscript on the topic of " School-university partnership in times of uncertainty", part of Chapter V – *SciTeach Center as an umbrella partnership*.

3.2. Workshop Science and Language

The research on how to support primary teachers for multilingual contexts using open science investigations had foreseen the development and offer of a workshop targeting primary teachers

in Luxembourg, with special focus on teachers of students with immigrant backgrounds. To accomplish this, there are three phases that constitute datasets for this research: *the co-development process,* which took place during the SciTeach Center team meetings; *the co-planning process*, when I (the Doctoral Researcher that authors this dissertation) and a teacher met to plan the workshop; and *the co-teaching process*, which took place three times in the school year 2022-2023; twice in the SciTeach Center atelier and once in a school in the North of Luxembourg.

Co-developing the workshop *Science and Language*

The co-development process constitutes a dataset from the brainstorming of how a workshop could be developed in order to address the multilingual context, which took place during team meetings. The data sources are the cuts of these team meetings' video recordings. The analytical memoing was used to code and analyze the dataset, guided by the research question ***What themes emerge from our discussion while co-developing the workshop Science and Language?***. From my research journal, field notes are included from teacher / researcher exchange (Table 6).

Table 6 – Description examples of dataset from the co-development process

Data focus description	Data sources		Data codes
Languages used by the team (after team meetings)	Field notes	researcher-teacher exchange	Nov21NLK Dec21DMM
Use of different languages in the workshop	Memos from videorecording	team meeting	20220125TMm
Reflection on personal language situation and the complexity of language use in Luxembourg schools			20220315TMm
Team discussion about the concepts of *interdisciplinarity* and *inquiry-based science*.			20220125TMm 20220322TMm 20220426TMm
Discussions on the need to find a common ground for "what is science?"			20220315TMm

Co-planning the workshop *Science and Language*

The co-planning process composes a dataset from the discussion on the possible structure of the workshop *Science and Language*, in which there were moments of discussion about the language to be used and what activities to be done. Other key moments include setting the common concept for *interdisciplinarity* to be discussed with the participants of the workshop, and a deep reflection about the teacher roles and professional profiles in Luxembourg. Content analysis was used to code and thematic analysis was used to cluster the indicators into themes, guided by the research question ***What themes emerge from our discussion and what decisions were made while co-planning the workshop Science and Language?*** (Table 7).

Table 7 – Description examples of dataset from the co-planning process

Data focus description	Data sources		Data codes
Researcher (1) and teacher (2) agreeing on the use of German	Indicators from video recording transcripts	workshop planning meeting	VT20220426
Researcher (1) and teacher (2) discussing about the need to use science as a universal language and include different forms of documentation			VT20220426
Discussion about the concept on *interdisciplinarity* and what was to approach it with teachers			VT20220823
Perceptions about the teacher profile, the separation of subjects and the lack of emphasis on science teaching in Luxembourg schools			VT20220823

Co-teaching the workshop *Science and Language*

The co-teaching process also constitutes a dataset from field notes from my research journal, based on my lived experience while delivering the workshop with the teacher and their debriefing and reflection moments, which took place after the workshop. The data sources are notes taken during and after the delivery of the workshop. Analytical memoing was used to code the event and data analysis was based on thematic clustering, guided by the research question ***What themes emerge from the teachers' reflections on the topics addressed during the co-teaching the workshop Science and Language?*** (Table 8).

Table 8 – Description examples of dataset from the co-teaching process

Data focus description	Data sources		Data codes
Participants' profiles and reflections on science teaching	Field notes	workshop co-teaching	Oct22W1-1 Dec22Wdf20 Feb23W2-1 Mar23W2-2 Apr23W3-1 Jun23W3-2
Awareness of linguistic diversity			
Implementation of inquiry-based science education to classroom practices			
Discussion of how to implement interdisciplinary activities when science and language are taught by two different teachers			

These different datasets were used for exploring different social phenomena, such as the boundary spanning of teachers and researchers within the school-university partnership (Chapter V), the conditions for a school-university partnership to be responsive to context and uncertainties (also Chapter V), and the organizational learning happening within the school-university partnership (Chapter VI).

3.3. What is science?

During the process of co-developing the workshop *Science and Language*, the SciTeach Center team decided to discuss the concept of science by asking ***What is science for us?***. The discussion takes place in different stages: the trigger for the discussion; the discussion of the concept itself; the coding of the poster in which the discussion was recorded in written form; and the reflection between me and the teacher on the coding of the poster (Table 9).

Table 9 – What is science dataset sources

Data focus description	Data sources		Data codes
Discussions on the need to set a common ground for concept of "what is science?"	Memos from video recordings	team meeting	20220315TMm
Discussion on the concept of "what is science?"			Jul22Sci
"What is Science?" poster	Coding with text highlighting stickers	flipchart	RcMTqca TcTFintlab
Reflection on the coding of the "What is Science?" poster	Memos from videorecording	teacher-researcher collaboration	Feb24Sci

The process that led to the discussion about "What is science?" and the discussion itself was video recorded during the team meetings, with analytical memoing used to code and analyze the data; this set was used as evidence of the school-university partnership being a safe place, which was established as a condition for the partnership to successfully exist and be responsive on Chapter V. The coding process of the "What is science?" poster done by the researcher and the teacher, and the reflection on it were used as evidence of organizational learning on individual level within the partnership, which was explored on Chapter VII.

3.4. Teacher-Researcher collaboration

The dataset based on teacher-researcher collaboration focuses on two aspects: team reflections on their roles and achievements; and the records of the process of boundary spanning of the teacher into teacher-researcher. (Table 10). The reflection pieces were collected after team meetings, and were used as direct citation to use as evidence of shifting roles and boundary spanning (used in Chapter V). As the observation notes consist of the researcher's interpretation of what was observed (after being confirmed through open conversation with the teacher), they were used as evidence of the foundation of the teacher-research collaboration, as one condition for a partnership to be successful while trying to be responsive (Chapter V).

Table 10 – Examples of data records for the teacher-researcher collaboration

Data focus description	Data sources		Data codes
Reflection on what roles each team member sees oneself in	Paper pieces	team reflection	Oct23Sdc
Reflection on what shifts in their roles team members observe	Digital pieces	team reflection	May23Concept
Individual reflection of team's achievement during 2022-2023	Video recording	team reflection	VT20230712
Shift on the teacher's posture during the interviews	Observation notes	interview Case Sdc	Oct23Sdc
Teacher's posture while presenting in an academic event	Observation notes	conference session	May24Berg
Teacher's input using academic language	Observation notes	team meeting	June24FNRfund

3.5. Workshop participants' perceptions

The workshop *Science and Language* was fully attended by 16 participants, across the three times it was offered through the SciTeach Center. All participants were invited to follow-up interviews to share their perceptions on the workshop, on the dialogue between science and language, and on the implementation of the inquiry-based approach. Five teachers accepted and took part in the interview. Each interview was conducted by me and the teacher (both involved on the workshop co-teaching). Interviews have a duration average of 1h10min, they took place between October 2023 and May 2024, always inside a closed room (either the researcher's office, the SciTeach Center or in the participants' school). All participants agreed to the audio recording (received the information sheet and signed the consent form). The recording was done using an Olympus recorder.

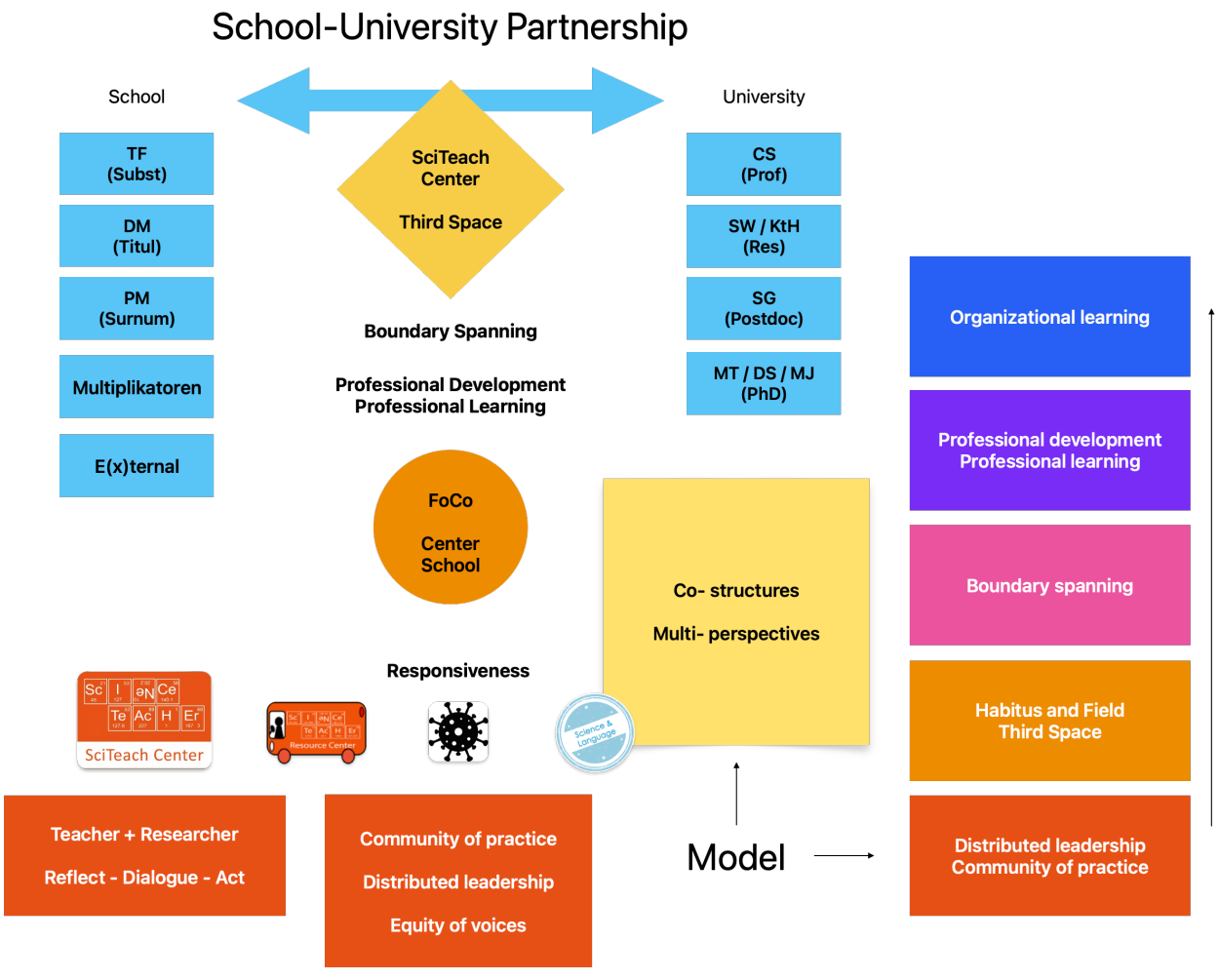
The participants were pseudonymized and allocated a Case code, in accordance with the microanalysis approach (Lejeune, 2019). The participants are Sheldon (Case Sdc), Quinn (Case Qsn), Gemma (Case Gdc), Denise (Case Dtt), Nick (Case Nsn), named here in order of data collection. One teacher is a main teacher (*titulaire*), two teachers work as second teachers (*surnuméraire*), and the other two are detached from teaching tasks to work in other educational structures. Their personal data (such as gender, age, or workplace) is not used to characterize them nor to establish correlations between their perceptions. Three main themes emerged from their narratives: their perceptions about the teacher profile in Luxembourg and the impact on schooling; the separation of subjects; and the lack of emphasis on science teaching in schools. This data was used in Chapters V (partnership in uncertain times) and VII (workshop participants' perceptions).

3.6. The SciTeach Center history timeline

The SciTeach Center became a key piece of this research, not only for providing the space for the workshop *Science and Language* to be do-developed and co-taught, but the space to navigate the

teacher-researcher collaboration. As learning was identified at individual level within the teacher-researcher collaboration and at the project level mainly on the concerns from the field, the need to examine the history of the school-university partnership emerged as to identify the events from the organization and how the organization changed, learning from these events (Chapter VI). Therefore, the three senior researchers (Christina Siry, Kerstin te Heesen and Sara Wilmes) made themselves available to produce a timeline of the organization's events. Data was produced using timeline interview (Adriansen, 2012), using paper support (two A0 sheets) and digital support (Conceptboard online app). The videos were coded per researcher (CSti240425; KtHti240424; SWti240426), and anonymization was not needed as the researchers are co-authoring the manuscript on organizational learning. Data underwent microanalysis procedure (Lejeune, 2019). All interviews were recorded using the Webex (Cisco Systems' tool for web/video conferencing), and consent was given verbally at the beginning of the interview, as all three researchers have signed consent for research done within the SciTeach Center.

4. Research design visual representation



Chapter III –
State of the Art

This chapter aims to present exploratory mappings that were conducted to examine the existence of research gaps on the different intersections of the research fields, always considering the setting of primary science education in multilingual contexts. Here, you will find a search on the topic of "Primary science teacher education" and a more extensive mapping on the "Tendency for 'language' and 'inquiry' in seven key journals in science education" (this manuscript is single authored – Maiza Trigo, and it has been accepted for publication in the *Revista Brasileira de Educação Comparada* [Brazilian Journal of Comparative Education]). Finally, this chapter serves as the basis for the systematic review conducted and presented in the next chapter, Chapter IV.

So, if you are the researcher with the children,
you don't need to be the expert.

[A direct quotation from Sheldon's interview]

Primary science teacher education

Using EBSCOhost as a search database, choosing the database by the subject "Education Research Databases" (which includes "Education Research Complete", "ERIC", "SocINDEX with Full Text"), a search was conducted to establish the scope of the research field of "primary science teacher education". In order to have a glance, the search was conducted in three levels of strings: 1. characterizing the school level by using "primary education" or "elementary education" or "primary school" or "elementary school"; 2. narrowing the subject scope to "science education" or "science teaching" or "science learning" or "science instruction"; 3. addressing the need to form interesting science learning settings by considering the variable of "teacher education" or "teacher training" or "teacher preparation". The strings used are derived from the database suggestion menu from the search box field and considering no selection of a field search.

Using the first string ("primary education" or "elementary education" or "primary school" or "elementary school"), 360.962 results are retrieved, with no screening duplicity nor inclusion of search limiters. The search comprehends documents since 1837, being the book "First Lessons about Natural Philosophy, for Children. Part First " by Mary A. Swift, until the year of 2024. The documents are classified by source types[12], which include Academic Journals (n=205.409), Reports (n=193.895), Magazines (n=43.246), Electronic Resources (n=29.225), Conference Materials (n=15.989), Reviews (n=12.307), Dissertations (n=10.963), Books (n=8.480), Trade Publications (n=839), News (n=809), and Government Documents (n=582). English is the language used on the majority of the documents (n=318.571), followed by major European languages, such as Spanish (n=1.314), French (n=572), German (n=470), Castilian (n=467), and Portuguese (n=439), one Euro-Asian language (Turkish, with n=2.458) and one major Asian one, Chinese (n=436).

By adding the second string ("science education" or "science teaching" or "science learning" or "science instruction"), results retrieved count 28.412 documents also from the different sources and mainly in English. However, there is a need to recognize that the addition of the subject scope of *science education* represents only 7,87% of the results from the school level (primary education). This decrease already points to the need to explore more the field of *primary science education*, especially considering the recommendations for starting to teach science as early as possible (Rocard report – European Commission, 2007) and developing the interest to study the field of science (European Commission, 2004). And, of course, to develop the field of

[12] Consider that each result is a document that can be classified (or integrated) in more than one source type.

primary science education, there is a need to engage teachers in different training opportunities, especially those linked to their professional development/learning.

Therefore, considering the variable of "teacher education" or "teacher training" or "teacher preparation" (third string), the results (*n*=4.701) represent 0,00013% of the first set of results (school level), and 16,55% of the second set (subject scope). There is no statistical significance if the second and third string are switched, as results end to be 32.774 documents when the school level (first string) and the teacher education (third string) are put together, representing 9,08% compared to the first set. Setting all three strings, the results symbolize 14,34% to the switched search.

Just out of curiosity, "Europe" was added to the search, which returned only 26 results (after exclusion of duplicates, *n*=24), distributed in five types of publication (Table 11). It is relevant to point out that, from the 10 articles, four refer to research done on pre-service teachers (Lindemann-Matthies et al., 2011; Avraamidou, 2016a, 2016b; Evagorou & Mauriz, 2017), one on in-service teachers (Kokkotas et al., 2009), one on teacher preparation (Avraamidou, 2015), and four addressing contexts or topics (Stavy & Tirosh, 1996; Kilic, 2003; Türkmen, 2015; Casadellà et al., 2022). Lucy Avraamidou is the only repeated author, presenting her research on preservice primary teachers with the focus on life stories and identity(ies) in science (Avraamidou, 2015, 2016a), and primary teacher preparation for cases of informal science experiences (Avraamidou, 2016b).

Table 11 – Distribution of results per type of publication

Type of publication	n
Articles/paper	10
Proceedings	5
Historical documents	4
Research reports	4
Book	1

Lastly, it is important to acknowledge that this does not consist of a review, the search is limited to the results retrieved from EBSCOhost (provided by the Consortium of Luxembourg), which may differ from other providers, and the search strings are not retrieved from any available Thesaurus.

What tendency for “inquiry” and “language”: examining key journals in science education[13]

Conducting a review of the literature can provide a foundation for understanding research trajectories in a given field, and this article aims to present how the words “inquiry” and “language” emerge in seven science education journals, mapping the themes to guide a PhD research project relating primary science education and multilingual learning contexts. The search for the words “inquiry” and “language” can draw a huge number of results in a general search engine, such as Google. A first generic search with the terms “teacher education”, “primary education”, “science education”, “inquiry” and “language” led to an overwhelmingly high number of publications to be gathered and analyzed. So, the path of searching articles in the main scope of the research (science education) was chosen, towards the elaboration of an analytic review map. This mapping consists of a database that was built with articles retrieved from seven key journals’ official website (identified through JCR/Scimago ranking), funneling the scope to “teacher education” in primary level (and elementary, for the USA context), and focusing on how the words “inquiry” and “language” emerge in these publications starting from 2008 (after the Rocard report, from 2007). This type of data is presented by the frequency of occurrences and analyzed by theme cluster for tendency construct, using content analysis. In order to tackle how the implications and overlaps between language learning and science education (focusing on the inquiry-based method) are presented in published articles, the qualitative analysis exposes two set of results: 1. Occurrence and thematic mapping from a social-cultural perspective; 2. A set of meanings and its relevance to the topics as relations between the use of the words “inquiry” and “language” are drawn.

Keywords
teacher education
primary education
science education
exploratory mapping
comparative studies

The research takes place under an umbrella project, portrayed as a resource center for primary teachers, which its team of teachers and researchers advocate for open-ended science investigations). The design of the state of the art, within the PhD project, integrates different searches on academic databases, mainly using the access provided by the Consortium of Luxembourg through the a-z platform, and the search presented here is related to journals in the scope of science education looking into articles where “inquiry” overlaps with “language”. The analysis includes the term search on Cultural Studies of Science Education (CSSE), International Journal of Science Education (IJSE), Journal of Research in Science Teaching (JRST), Journal of Science Teacher Education (JSTE), Research in Science Education (RISE), Science Education (SE), and Studies in Science Education (SSE). The choice is based on the journal’s scope within science instruction, reflecting on the diversity in the study of science education in different contexts.

This kind of study serves the purpose to strengthen the field of the science education research by reflecting on the existing fields in order to promote the design of new research areas. (Zawacki-Richter et al., 2020). The national education report for Luxembourg (LUCET &

[13] This manuscript has served as a basis for an article accepted for publication at the *Revista Brasileira de Educação Comparada* [Brazilian Journal of Comparative Education] in its Volume 6 (2024), e024008.

SCRIPT, 2022) outlines the highly diverse student population, especially when confronting data about the languages spoken at home and the languages of instruction. The use of inquiry-based science education is advocated for as a pedagogical approach that supports science teaching/learning in multilingual contexts. Therefore, this exploratory mapping will enable teachers and researchers to be exposed to the literature that overlaps "inquiry" and "language", as the analysis outlines two sets of results: 1. frequency of occurrences and thematic mapping; 2. set of meanings and its relevance to the topics as relations between the use of the words "inquiry" and "language" are drawn.

1. Grounding "inquiry" and "language"

In Luxembourg, the education system is trilingual (Luxembourgish, German and French) and the languages of instruction have different roles when linked to science (Trigo, 2023). Rocard and colleagues' starting point is that inquiry-based science education (IBSE) is a more effective teaching approach, yet not largely implemented in European countries (European Commission, 2007). They indicate that children should be exposed to the "inquiry-based" approach as early as possible, reporting it as recommendation

> The earlier the better: science teaching at primary school has a strong long-term impact. Primary school corresponds to the time of construction of intrinsic motivation, associated with long-lasting effects
>
> (...)
>
> Priority given to initiatives that include a large diversity of practices in science teaching to respond to the diverse needs of children: problem based inquiry process; hands-on/minds-on activities; teamwork; independent work on open-ended questions; trans-disciplinary activities; showing relevance of science content. (European Commission, 2007, p. 11)

There is the need to consider that science teaching has been in the spotlight since the beginning of the century. In its first decade, the European Commission (2004) prepared a report on the need to nurture young people's engagement in science, in order to fight against the decrease of number of scientists or the interest in careers in science. Following this initiative and considering that the cause of the decrease might be directly linked to the ways science is taught in school, a group of science experts examine several initiatives "to draw from them elements of know-how and good practice that could bring about a radical change in young people's interest in science studies - and to identify the necessary pre-conditions" (European Commission, 2007, p. 2).

To establish the grounds for the research based on a professional learning opportunity for primary teachers where Science and Language are put into dialogue, the search done on the journals helps to outline the meanings linked to "inquiry" and "language". Even though these words can generically be associated to "questioning" and "verbality", for this contribution

implicates the use of "inquiry" to the pedagogical approach to teaching/learning science (e.g., Bybee, 2014). On the other hand, the word "language" is treated using axial codes, based on indicators such as "language of science", "language of instruction", "bilingualism", "multilingualism", "translanguaging", considering both verbal and non-verbal approaches.

2. Research design

When searching for the first reads in a generic search engine, the desired expressions can be put together (such as "teacher education", "primary education" and "science education"), but the number of resources is overwhelmingly high to be gathered and analyzed (approx. 722,000 results through Google Search). Google Books Ngram Viewer can give another visual perspective, however, choosing the path of searching into articles in the main scope of research eases the data gathering and treatment.

This exploratory mapping aims to build a database of articles in science education, considering the scope of "teacher education" at the primary/elementary level. Therefore, the descriptive search path taken is to determine the sources to use (journals in science education) and pose the questions for data treatment:

- How are "teacher education" and "primary education" positioned in the overall publications?
- Amongst these results, what are the occurrences of "language" and "inquiry"? How relevant are the overlaps?
- What tendency can be withdrawn from the dataset?

Gathering this kind of data requires a specific search in each journal's official website, use of the expression(s) intended and download of the articles (whenever possible). Once those articles are collected and classified, a tendency construct will emerge from the data, several approaches for data treatment can take place, but this mapping review opts to present frequency of occurrences and content analysis (Bardin, 2011), grounded as bricolage (Kincheloe, 2001) for the tendency construct. This qualitative approach allows the researcher to reflect on the tendency of the expressions searched, considering specifically here the overlaps of "inquiry" and "language". It is important to underline that after several journals are treated, the intra-analysis will allow an inter-analysis, and the comparative education methodology will be used for the discussion.

3. Key journals

This mapping consists of a database that was built with articles retrieved from seven key journals' official website, funneling the scope to "teacher education" in primary level (and elementary, for the USA context), and focusing on how the words "inquiry" and "language" emerge in these

publications starting from 2008 (after the Rocard report, from 2007). This type of data is presented descriptively by the frequency of occurrences and analyzed by theme cluster for a tendency construct.

Therefore, data collection was conducted on seven journals within the scope on science education, identified through JCR/Scimago ranking as the key journals in the field: Cultural Studies of Science Education (CSSE); International Journal of Science Education (IJSE); Journal of Research in Science Teaching (JRST); Journal of Science Teacher Education (JSTE); Research in Science Education (RISE); Science Education (SE); and Studies in Science Education (SSE).

All seven journals have provided material to conduct this exploratory mapping. This serves as the basis for an open systematic review, as it became evident that there is a research gap on studies conducted about "teacher education" in "primary" school level in the scope of "science education". Table 12 presents the key features of the journals examined in the scope of "science education".

Table 12 – Characterization of the journals included

	Found. year	Scope	Genre	Publisher
SE	1916	all in science education	all	Wiley
JRST	1963	science teaching and learning and science education policy	all	Wiley [NARST]
RISE	1971	science education research	empirical	Springer [ASERA]
SSE	1974	key topics and issues in science education	reviews	Taylor&Francis
IJSE	1979	science teaching and learning	all	Taylor&Francis
JSTE	1989	science teacher education	empirical and position	Taylor&Francis [ASTE]
CSSE	2006	cultural studies	all and new	Springer

All journals tackle issues relating ***science teaching and learning*** and/or ***science teacher education*** (including initial and continuous education), with CSSE giving a focus on sociocultural aspects. Four journals accept different types of manuscripts (CSSE, IJSE, JRST, and SE), while RISE and JSTE focus on empirical articles, and SSE only publishes reviews. All seven journals are edited and managed by publishing companies, and three of them are related to associations: JRST, being the official journal of NARST (A global organization for improving science education through research); JSTE, the flagship journal of ASTE (Association for Science Teacher Education); and RISE, to ASERA (Australasian Science Education Research Association).

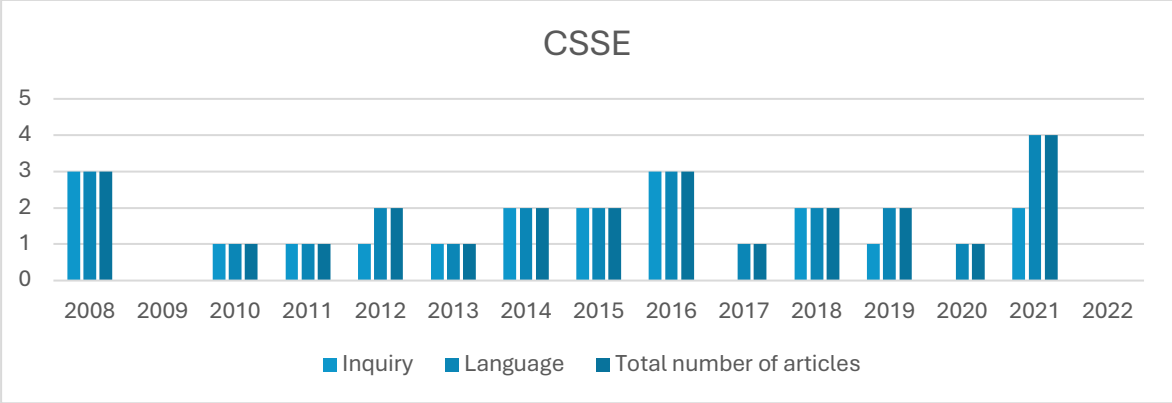
4. Data collection, treatment and results

This exploratory mapping enables teachers and researchers to be exposed to the literature that overlaps "inquiry" and "language", considering the occurrences of the overlaps and thematic mapping of the datasets. Through clustering the topics, a set of meanings and its relevance to the as relations between the use of the words "inquiry" and "language" are drawn.

4.1. Cultural Studies of Science Education (CSSE)

Through the search on CSSE, the expressions "teacher education" and "primary education" lead to a total of 14 results, while elementary result into 21. These results only overlap on one article, which uses both expressions "primary education" and "elementary education" throughout the text. When looking into the words "inquiry" and "language" and applying the time limiter (2008–2022), seven articles emerge for "teacher education", "primary education", "inquiry" and "language", and 12 for the change of "primary education" and the usage of "elementary education" (Chart 1).

Chart 1 – Occurrences of "inquiry" and "language" per year in CSSE



Source: CSSE (n.d.).

This first screened set of data shows that the "language" appears in 25 documents, while "inquiry" in 19 results; "inquiry" occurrences always overlap with "language", but the number decreases to one result (overlapping "inquiry" and "language") when its appearance in publication titles is taken into account; no relevance in terms of historical context was identified as occurrences were too part in time and two years lack publications that include any of these words. Due to the scope of the journal, socio-cultural aspects are present, and *Ubunifu*, *Māori*, *indigenous*, *multiculturalism*, *cross-cultural*, *urban*, *rural*, and so many others are words that emerge in articles.

The theme ***identity*** appears in four documents, considering three on research about teacher identity around teaching science (Dominguez et al., 2015; Avraamidou, 2019; Ibourk, 2021) and one about female teachers' positionalities (Teo, 2015). Results about the relationship between science and culture (linked only to language) emerge around the ***hegemony of English*** as language of science instruction (Bansal, 2022) and ***cultural factors influences*** (e.g., home culture, faith) on science learning (Alghamdi & Malekan, 2020). Two documents refer to ***reform in science***

education, both linked to teacher preparedness, one about sociocultural issues (gender, culture and social factors) within teacher preparation (Zapata, 2013) and one related to the implementation of inquiry-based approach (Avraamidou, 2017). And, finally, four articles tackle the relationship between ***science education and indigenous aspects*** (Ryan, 2008; Wood & Lewthwaite, 2008; Semali et al., 2015; Gallegos-Cázares, et al., 2020).

4.2. International Journal of Science Education (IJSE)[14]

The IJSE retrieves 61 results on the search with the expressions "teacher education" and "primary education", while when changes to the USA context result into 66 documents, being eight of those overlap for the use of both school-level expressions. When looking into the words "inquiry" and "language" and applying the time limiter (2008–2022) in the journal's platform, 22 articles emerge for "Teacher education", "Primary education", "Inquiry" and "Language", and 34 for the change of "Primary education" and the usage of "Elementary education". However, after screening for duplicates and overlaps, it is evident that this journal is more focused on the scope of teaching practices, as "inquiry" is more present than "language" in the single-theme articles (Table 13).

Table 13 – Occurrences per combination of topics in IJSE

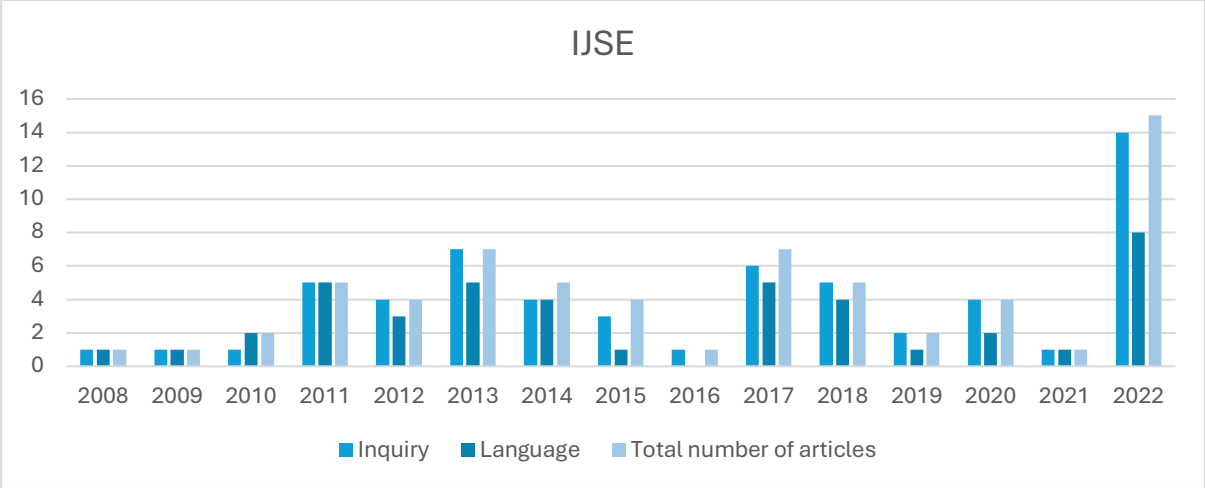
Topics	*n*
Teacher Education – Elementary education – Inquiry	12
Teacher Education – Elementary education – Language	4
Teacher Education – Elementary education – overlap	24
Teacher Education – Primary education – Inquiry	12
Teacher Education – Primary education – Language	1
Teacher Education – Primary education – overlap	16

Note: 3 articles for "inquiry" and 2 articles for "inquiry" and "language" overlap the school level.

This screened set of data shows that the sole term "language" appears in five documents while "inquiry" in 21, and "inquiry" overlaps with "language" 38 times. "Inquiry" is more frequent than "language", with the exception 2010, when "language" appears in two documents, being one overlapping with "inquiry" (Chart 2).

[14] This journal used to be European and, as it became International, this shift also reflects on it focus, as just over 60% of the articles target the "elementary education". Also, IJSE is the journal in science education with the highest number of issued published per year (18), which explains the higher number of occurrences.

Chart 2 – Occurrences of "inquiry" and "language" per year in IJSE



Source: IJSE (n.d.).

Amongst the identified themes, four thematic clusters emerge (*Table 14*), being three clusters related directly to the ***teaching scope*** (*Teacher Development and Professional Identity*, *Science Teaching Approaches*, and *Student Learning and Engagement*). The two largest categories are ***Teacher Development and Professional Identity*** (*n*=13) and ***Science Teaching Approaches (IBSE included)*** (*n*=9), under which other subcategories were clustered.

Table 14 – Thematic clusters in IJSE

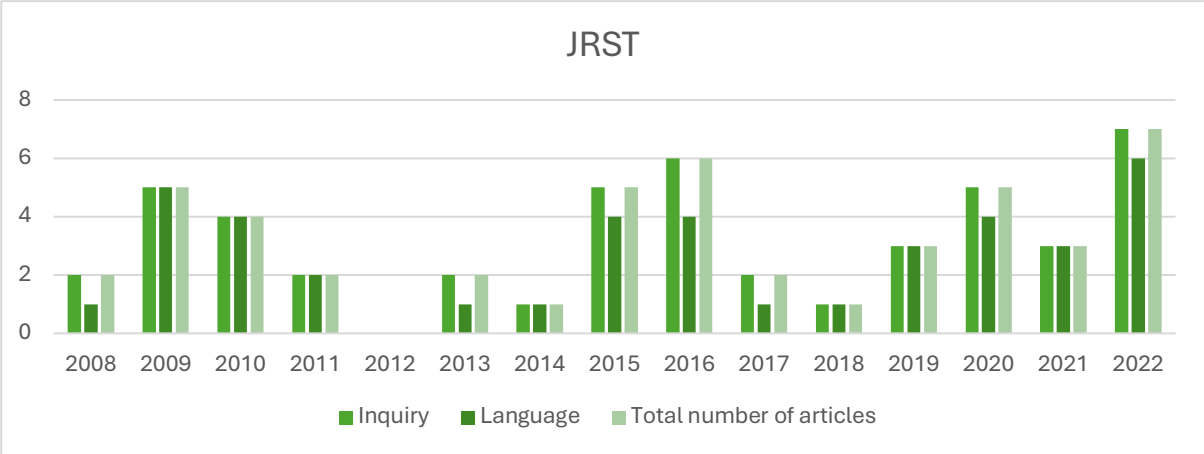
Clustered themes	*n*
Teacher Development and Professional Identity	**26**
Teacher Development and Professional Identity	13
Teachers' Views, Attitudes and Beliefs	7
Teacher Experiences and Development	5
Addressing Challenges in Teaching Practice	1
Science Teaching Approaches	**18**
Science Teaching Approaches (IBSE included)	9
Effectiveness of Teaching Approaches	6
Collaboration and Co-teaching	2
Supporting Science Education Implementation	1
Student Learning and Engagement	**15**
Student Understanding and Attitudes	7
Environmental Education and Science Instruction	5
Assessment and Understanding	3
Research and Methodologies	**5**
Science Education Research	3
Science Education Challenges	2

The identification of thematic clusters has enabled to understand that the scope of the journal is reflected in the emergent themes. Considering the research being conducted in Luxembourg to support teachers for multilingual contexts, there is a match of the research interests: ***teacher professional development*** and ***use of inquiry-based approaches to science education***. Even though the item "language" is not spotlighted in the titles, it occurrences in the texts still relevant, taking into account that different articles tackle contexts that are country specific – Erden and Sönmez (2010); Sharp et al. (2011); Childs et al. (2011); Oh and Kim (2012); Quigley et al. (2014); Casanoves et al. (2015), and that emerge from comparative studies, such as Forbes et al. (2014), Sharma and Yarlagadda (2018), and Ustun et al. (2022). In the interest of teaching science with different languages, special attention could be given to the contribution about "Coteaching in a science-CLIL classroom" by Valdés-Sánchez and Espinet (2020).

4.3. Journal of Research in Science Teaching (JRST)

JRST is the journal linked to NARST, which has a long tradition of promoting research in science education in the United States of America, and publishes 10 issues per year. The search terms "teacher education" and "primary education" retrieved 24 results whilst 188 documents come as result for "elementary education". Applying the same 15-year timeframe (2008–2022), the results per school level decrease to 13 for "primary" and 42 for "elementary". Even though the label "inquiry-based science education" fades away from the daily use in the USA (most likely due to the crescent criticism in the early 2000s – Gross, 2005; Kirschner et al., 2006), its occurrences maintain attention (Chart 3). The term "language" is always overlapping with "inquiry" in 40 occurrences, but "inquiry" is the sole protagonist in other eight documents.

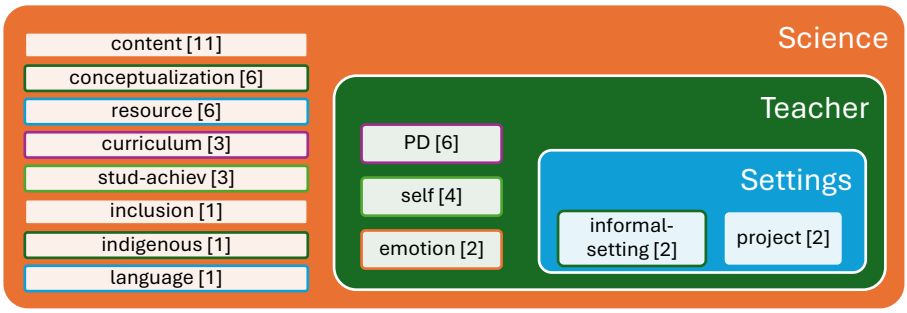
Chart 3 – Occurrences of "inquiry" and "language" per year in JRST



Source: JRST (n.d.).

The audience of JRST includes researchers and practitioners, which led to a different grouping of the indicators. Three thematic clusters emerged from the mapping of the journal, with special attention to the topic of "Science" itself (Figure 18).

Figure 18 – Thematic clustering in JRST

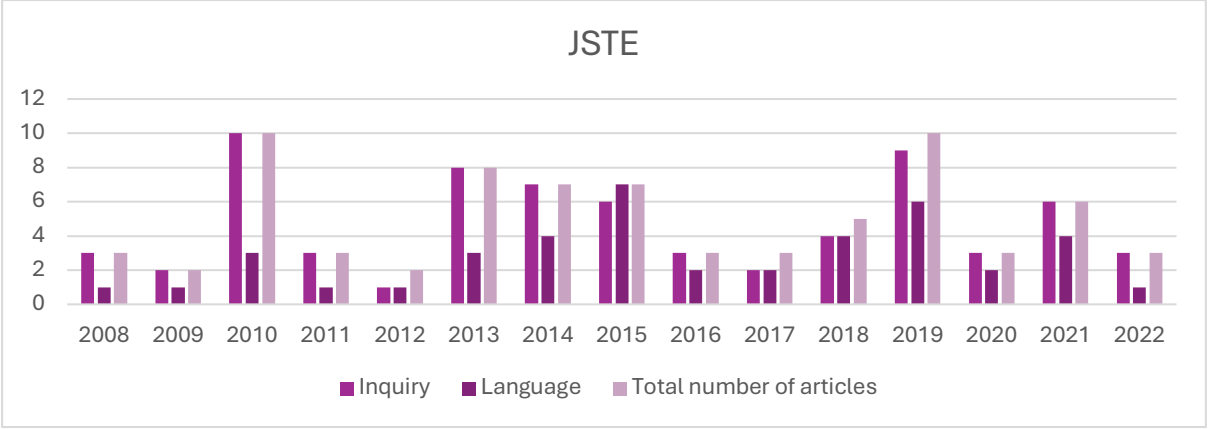


Two publications are highlighted here due to its discussion about the conceptualization on "inquiry", which is key to bring to reflection as there are challenges to overcome when implementing open-ended science investigation: Demir and Abell (2010); and Bartels et al. (2019). The first one addresses mismatching views of inquiry in higher education, and the second one is based on promoting students' understanding of inquiry. Interestingly enough is the fact that several documents for "inquiry-based science education" (IBSE) were not included under just "inquiry", such as: Ramnarain (2016), that looks into the factors influencing the implementation of IBSE; Brown (2017), about the relationship between "culturally responsive" and IBSE towards equitable science teaching and learning; and Akuma and Callaghan (2019a; 2019b), who explored in two articles the challenges to implement the IBSE.

4.4. Journal of Science Teacher Education (JSTE)

JSTE has the focus on publishing manuscripts concerning pre-service and in-service education of science teachers. A total of 1.205 results were retrieved from the search using "teacher education", 157 of which are linked to "elementary education" and 17 to "primary education". The first observation needed is the existing research gap when the school level is considered *per ratio*. Limiting the results by publication date (2008–2022), the screening enabled to find 70 documents with reference to "inquiry" and 42 to "language", considering the existing overlap of 37 results (Chart 4).

Chart 4 – Occurrences of "inquiry" and "language" per year in JSTE



Source: JSTE (n.d.).

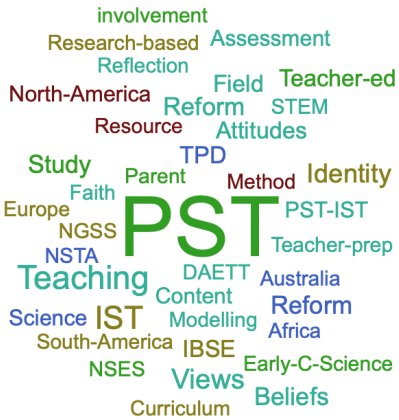
Even though the search terms are frequent in the documents from JSTE (*n*=75), the occurrence in the title is limited to less than 10% for "inquiry" (*n*=6) and null for "language". These articles that highlight "inquiry" in the title are all linked to research done with pre-service teachers, being four articles related to the (self)reflectiveness of the profession (Table 15).

Table 15 – Occurrences of "inquiry" on the title

Title	Reference
The Influence of an Extensive Inquiry-Based Field Experience on Pre-Service Elementary Student Teachers' Science Teaching Beliefs	Bhattacharyya, Volk and Lumpe (2009)
The Impact of an Inquiry-Based Geoscience Field Course on Pre-service Teachers	Nugent et al. (2012)
Student-Generated Scientific Inquiry for Elementary Education Undergraduates: Course Development, Outcomes and Implications	Salter and Atkins (2013)
Elementary Preservice Teachers' Authentic Inquiry Experiences and Reflections: A Multicase Study	Kazempour (2018)
The Impact of a Summer Camp-Based Science Methods Course on Preservice Teachers' Self-Efficacy in Teaching Science as Inquiry	Seung, Park and Lee (2019)
"They Were Teaching Me!": Reimagining Collaborative Inquiry with Elementary Students in Science Teacher Education	Macias, Shin and Bennett (2021)

Applying thematic content analysis, by identifying two indicators for each article (considering the titles as register units and the abstracts as context units), themes were clustered by frequency (weight) to create a wordcloud (Figure 19). The most evident theme is **pre-service teacher** (PST), especially linked to **attitudes**, **beliefs**, **views**, and **identity**. Other evident themes ***include in-service teacher*** (IST), ***reform***, ***teaching practices*** (teaching), and ***curriculum*** (curriculum, STEM, NSES, NGSS, NSTA). Geographical references are associated with the special issue on Global Perspectives on Preservice Science Teacher Education, edited by Norman G. Lederman and Judith S. Lederman. The issue consists of six articles, representing ***North America*** (Olson et al., 2015); ***South America*** (Cofré et al., 2015); ***Europe*** (Evagorou et al., 2015); ***Africa*** (Ogunniyi & Rollnick, 2015); ***China*** (Liu, Liu & Wang, 2015); and ***Australia*** (Treagust et al., 2015).

Figure 19 – Emergent themes from articles in JSTE



The publication *Orientations to Science Teacher Professional Development: An Exploratory Study* (Park Rogers et al., 2010) needs to be highlighted due to the nature of the study. Examining how orientations to teaching and learning are directly linked to practice, Park Rogers and colleagues' study shows this relationship in the metalevel of professional development, under the construct of "PD Project Orientation". The authors investigated nine PD projects and were able to identify five PD project orientations and how the orientations were emphasized in the projects. This connection between orientations and practice serves as a basis for reflection when designing and implementing PD offers.

This study has a direct implication to the PhD research that triggered this mapping of the literature (examining the development and implementation of a PD course on the dialogue between science and language), as the team involved advocates for inquiry-based approaches that draw on interdisciplinarity concepts, with these serving as orientations to teaching approaches, which implicates directly how the PD Science and Language was designed and implemented.

4.5. Research in Science Education (RISE)

Since its foundation in 1971, the journal RISE has published 2.188 manuscripts. The search for "teacher education" and "primary education" has retrieved 50 results and 30 articles when using "elementary education" for the school level. The scope of RISE includes publications from all levels of education, and these retrieval results point to a possible research gap for the level of primary(elementary) education, as results (n=50) represent less the 3% of the total of articles published (Table 16).

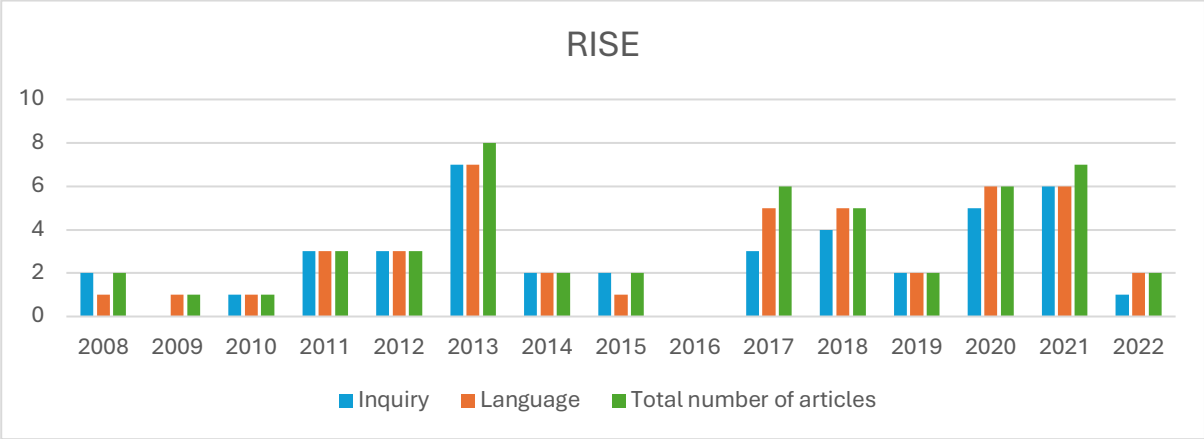
Table 16 – Occurrences per topic in RISE

Topics	*n*	*n*-title
Inquiry	41	6
Language	45	1
overlap	36	-
total	**50**	**7**

With the exception of 2008 and 2015, the term "language" either matched or passed the number of occurrences of the term "inquiry", concluding that this journal has the term "language" more frequently than "inquiry" on the overall (Chart 5). The screening of the articles per title led to the discovery of one article with "language", where Fazio and Gallagher (2019) examined how five elementary teachers integrated language and science to their science lessons with the goal to outline what impact could be seen on the students' achievements for both science and language. Six articles present "inquiry" on the title, but only four relate the search term "inquiry" to the IBSE approach with primary(elementary) teachers: Meyer et al. (2013), whose research looked into

intrinsic barriers for implementing IBSE; Seung et al. (2014), who examined data about the understandings of the essential features of IBSE and the reflection about the implementation; García-Carmona et al. (2017) investigated how pre-service teachers plan the use of scientific inquiry, and their study concluded that there is a need to rethink course on science teaching in order to provide the tools to future teachers implement IBSE; lastly, Lee et al. (2020) compare the context of Hong Kong and the USA about the pre-service teachers' conceptions and attitudes towards IBSE.

Chart 5 – Occurrences of "inquiry" and "language" per year in RISE



Source: RISE (n.d.).

It is important to point out that, in 2019, RISE published a special issue about **Practitioner Learning About Science and Language in Classrooms**, with 13 articles being included and two of these addressing the level of primary/elementary education: *Science and Language Integration in Elementary Classrooms: Instructional Enactments and Student Learning Outcomes* (Fazio & Gallagher, 2019); and *Science in Silence: How Educators of the Deaf and Hard-of-Hearing Teach Science* (Raven & Whitman, 2019).

From the same special issue, there is an interesting article that has as participants one primary teacher and one secondary teacher and looks at their work as "as they engaged with their students in constructing science explanations", *Constructing Explanations in Science: Informal Formative Assessment Practices Among Science Teachers of English Learners* (Román et al., 2019, p. 1055), and another article that addresses secondary level and relates to the Luxembourg context on the "challenges of linguistically diverse science classrooms", *Meeting the Challenges of English Learners by Pairing Science and Language Educators* (Meskill & Oliveira, 2019, p. 1025).

4.6. Science Education (SE)

Science Education is one of the oldest journals in the scope of science education. Besides having a General Section and Book Reviews, this journal has thematic sections in its issues, such as:

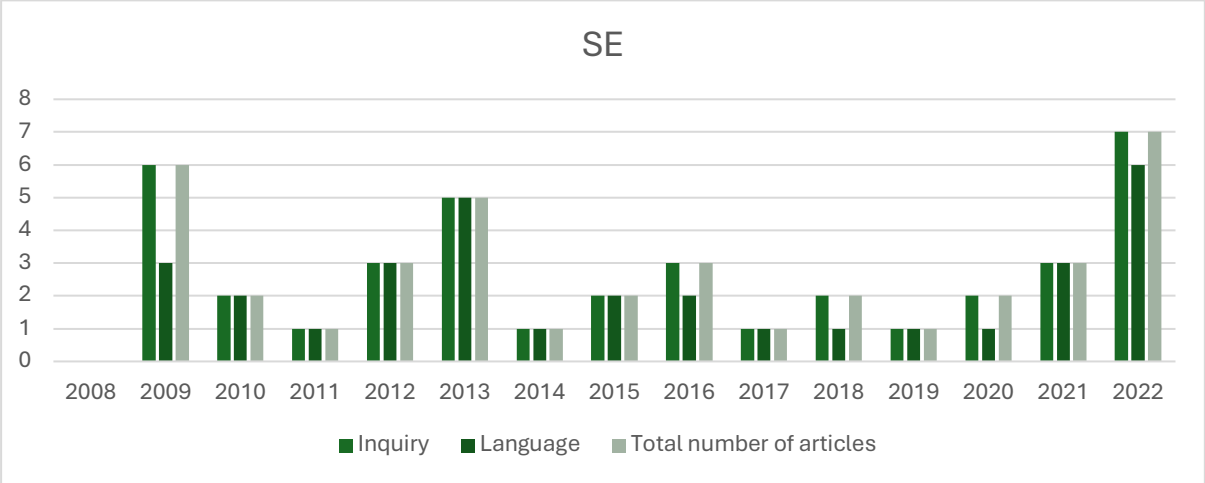
"Issues and Trends", "Science Education Policy", "Science Studies and Science Education", "Science Learning in Everyday Life", "Science Teacher Education", and "Learning". For this mapping, 10.792 results are found for the term "teacher education" and, adding "elementary education", results decrease to 1.790, while with "primary education", the results drop to 56 documents. Again, with the timeframe limiter, results drop significantly (*n*=39) (Table 17).

Table 17 – Occurrences per combination of topics in SE

Topics	*n*
Teacher Education - Elementary education - Inquiry	26
Teacher Education - Elementary education - Language	22
Teacher Education - Elementary education - overlap	**22**
Teacher Education - Primary education - Inquiry	13
Teacher Education - Primary education - Language	10
Teacher Education - Primary education - overlap	**10**
Documents to be screened	**39**

Inquiry is more frequent than language in this journal (Chart 6). With the goal to create big thematic groupings, from the screening of these articles emerged five themes: ***Content*** (*n*=12), to articles that explicitly reported a content (e.g., evolution, ecology, chemistry); ***Teacher education*** (*n*=11), referring to articles about teacher preparation, professional development, and field experiences; the articles about attitudes, beliefs, motivation and emotions were put together under ***Views*** (*n*=9); ***IBSE*** (*n*=5) refers to the teaching approach itself; and an article about the Exploratorium was categorized as ***Structure*** (*n*=1).

Chart 6 – Occurrences of "inquiry" and "language" per year in SE



Source: SE (n.d.).

Amongst the different titles, three documents explore the dialogue between science and language, being two linked to assessment: *Navigating the language demands of an inquiry-based science performance assessment: Classroom challenges and opportunities for English learners* (Lyon et

al., 2012); and *Mitigating the effect of language in the assessment of science: A study of English-language learners in primary classrooms in the United Kingdom* (Afitska, & Heaton, 2019). The third article advocates for the use of engineering to help overcome the challenges faced by students learning the language of instruction at the same time as a subject in that language (Cunningham et al., 2021). Finally, it's important to outline that only two articles explicitly target the school level of early childhood: *The collective construction of a science unit: Framing curricula as emergent from kindergarteners' wonderings*, from Siry and Max (2013); and *Analysis of prospective early childhood education teachers' proposals of nature field trips: An educational experience to bring nature close during this stage*, by Bravo et al. (2021).

4.7. Studies in Science Education (SSE)

Publishing review articles is the central aim of the journal SSE, and the search on it retrieves overall 162 results for the term "teacher education" and 22 documents containing "primary education" within and only six for "elementary education". Limiting the publication date to the 15-year timeframe after the Rocard report (European Commission, 2007) and searching with the terms "inquiry" and "language", seven results are recovered for the years 2012 (*n*=2), 2015 (*n*=2), 2019 (*n*=1), 2021 (*n*=1), and 2022 (*n*=1).

Giving relevance by taking part in the title, the term "inquiry" appears in the document authored by Herranen and Aksela (2019), which consists of a review of 30 articles about "the use of students' questions as a starting point for inquiry-based science education". For the term "language", Ardasheva et al. (2015) explore teaching science and language under three themes (negotiation, embeddedness, and non-threatening learning environments).

The reviews screened include one on ***teacher professional development*** (van Driel et al., 2012), one on the ***content*** of evolution in early childhood science (Bruckermann et al., 2020), one on ***science teaching*** (Deehan et al., 2022) and two articles approaching the topic of ***media literacy***: McClune and Jarman (2012), looking into science and news; and Belova et al. (2015), working on science and advertising.

5. Discussion and final remarks

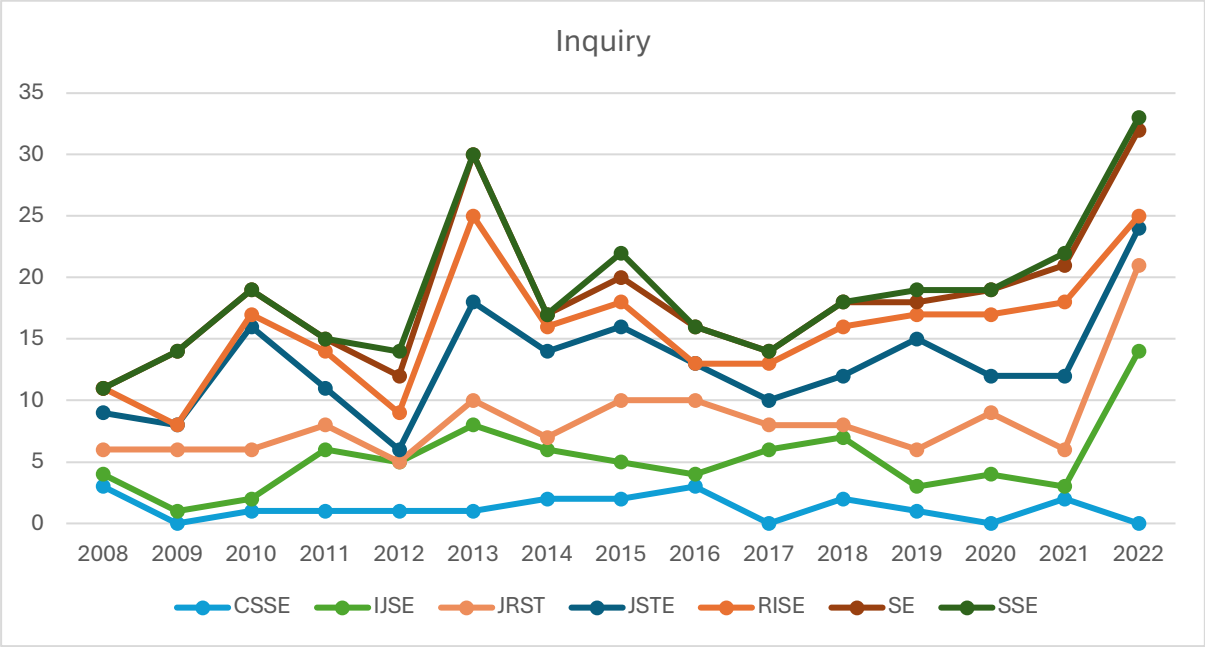
It was not possible to establish a connection between the age of the journal and the results retrieved, nor was the number of publications proportional when including the search terms (Table 18).

Table 18 – Search results per term

		CSSE	IJSE	JRST	JSTE	RISE	SE	SSE
"teacher education"		346	842	4336	1205	666	10792	162
+ "primary education"		14	61	24	17	50	56	22
+ "elementary education"		21	66	188	157	30	476	6
2008–2022	+ inquiry	19	59	48	70	41	39	7
	+ language	25	43	40	42	45	32	7
	+ overlaps	19	38	40	37	36	32	7
total screened		**25**	**64**	**48**	**75**	**50**	**39**	**7**

In most journals (except for CSSE and RISE), the frequency for "inquiry" is higher than for "language". Regarding the tendency for "inquiry", many manuscripts address the curricular guidelines from the US context (National Science Education Standards – NSES, 1996; and Next Generation Science Standards – NGSS, 2013), which is possibly shown through the peak on the trend in the year of 2013 (Chart 7). However, there is no divergence in the conceptual use of the term "inquiry" comparing the EU to the US contexts. "Inquiry" is linked mainly to three conceptions: the approach to teaching and learning (IBSE; open inquiry); the perception of posing questions (or enabling the space for it); and the notion linked to the scientific method (from formulating hypotheses to drawing conclusions and sharing).

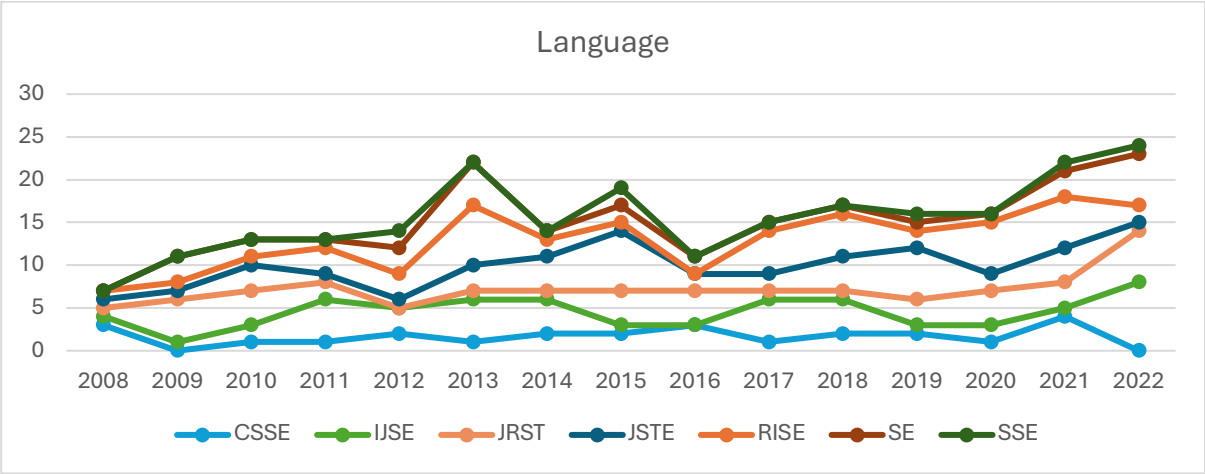
Chart 7 – Tendency for "inquiry" by stacking occurrences



As the different guidelines for inquiry (European Commission, 2007; NGSS, 2013) establish a link to "language", either to use science as a means or to explore scientific processes as to enhance linguistic skills, the dialogue between science and language emerges as a need in the classroom, as many articles outlined to science in student diverse contexts and within minority communities.

Therefore, there might be a connection between the peak from "inquiry" and "language" in 2013 (Chart 8). "Language" is much linked to English learners and inclusion of minority language in science education (considering cultural heritage).

Chart 8 – Tendency for "language" by stacking occurrences



After going down in 2016, the tendency for "language" starts to grow back the tendency as this possibly matches a language policy initiative in Europe. In 2017, the European Union hosted a Social Summit for Fair Jobs and Growth, where there was a major discussion about the use of different languages in different settings. The Language Policy (European Parliament, 2017, n.p.) opens with this statement:

> As part of its efforts to promote mobility and intercultural understanding, the European Union (EU) has designated language learning as an important priority, and funds numerous programmes and projects in this area. Multilingualism, in the EU's view, is an important element of Europe's competitiveness. One of the objectives of the EU's language policy is therefore for every EU citizen to master two languages in addition to their mother tongue.

Besides building a database with articles from the seven key journals in science education that were chosen to be screened (CSSE, IJSE, JRST, JSTE, RISE, SE and SSE), this mapping has enabled a better understanding of how "inquiry" and "language" are placed within the research in "teacher education" in primary school level (elementary, included). However, this constitutes an exploratory mapping, which has served as a basis for a scoping review about primary science education in multilingual contexts.

This contribution has limitations linked to not using strings from any Thesaurus and the restricted use of the Boolean system (only AND was used). As the search was done on each of the journals' websites (each platform had its own "way" of searching; yet, whenever it was possible, the advance search key was used), the results were provided in different formats, and the overlaps were treated manually.

Finally, the dialogue between "inquiry" and "language" (i.e., science and language) has become even more important to research and practice in science education as the world

experiences more and more mobility and (forced-)migration fluxes. This dialogue becomes also a bigger trend in the classroom, especially in primary education when children enter literacy processes. Not speaking the language of instruction can pose classroom challenges and opportunities, and science can be the means to create a safe space for interaction and language immersion.

Chapter IV –
Primary science education in multilingual contexts

This chapter presents a systematic scoping review about primary science education in multilingual learning contexts. The aim of the review is to identify what research has been conducted that included the subject of "science" in the school level of "primary education" and "elementary education" in education systems that are multilingual. For this scoping review to take place, an external expert was included in the process of screening and analyzing the database.

If only we spoke German at home, I would get more things right...

[6-year-old boy, being alphabetized in German]

Primary science education in multilingual contexts: a scoping review

Reviews have been used consistently to identify existing research gaps and to find researchers with common research interests to build collaborative networks. Conducting systematic reviews in Education is becoming more recurrent as the methodology is spreading amongst social science researchers. This chapter presents a briefing of a systematic scoping review about primary science education in multilingual contexts. The aim of the review is to identify what research has been conducted that included the subject of "science" in the school level of "primary education" ("elementary education") in education systems that are multilingual. The search was done using the databases EBSCOhost, Web of Science and Scopus, and two researchers verified the search results and proceeded to the screening. Limiters used included type of publication (academic article), language (English) and publication date (from 2008). The search retrieved 286 results and 24 were excluded for being duplicates. The process of conducting this systematic review has suffered methodological turns as issues from the database collection were identified and, most of the studies, were rejected at first screening. With the goal to understand how the themes of "science education", "primary education" and "multilingual context" were being used and crossed, the two researchers re-screened the abstracts, and 182 manuscripts were excluded. Amongst the 80 manuscripts that had the full text screened, 41 were included in the analysis. Data is presented here in different formats (e.g., year, journal, thematic clustering), and the analysis shows a predominance of the studies about children learning English in school with the use of science (e.g., vocabulary learning). This chapter ends with a reflection on the process of conducting a systematic review.

Keywords
primary education
science education,
multilingual context,
inquiry-based learning
systematic review

This chapter presents a systematic scoping review focused on primary science education within multilingual contexts. The review aimed to identify and analyze the existing body of research that addresses the intersection of science education (scope), primary education (school level) and multilingual contexts (context), by conducting a comprehensive search across major academic databases such as EBSCOhost, Web of Science, and Scopus, and thereby mapping the research landscape to highlight significant trends, gaps, and areas of focus since 2008.

The review followed rigorous methodological procedures to ensure the inclusion of relevant studies, using specific criteria to filter and analysed the 286 results retrieved. After the abstract and full text screening, 41 records were included in the research, emphasising the challenges and opportunities of teaching science in multilingual classrooms, where linguistic diversity intersects with educational practices. Key themes identified in the literature include the role of inquiry-based learning, the development of instructional materials for English Learners (ELs), and the integration of science and language education.

By synthesising the findings, this chapter contributes to a deeper understanding of how multilingualism influences primary science education and offers insights into effective strategies

for teaching in diverse linguistic environments. The outcomes of this review not only inform current educational practices but also highlight the need for further research to address the complexities of science education in multilingual settings, with particular emphasis on the role of inquiry-based and practice-oriented approaches.

1. Conceptual framework

The school can be seen as a microcosm of society, reflecting the national context, and cultural, political, and economic dynamics (Bourdieu, 2022; Wedlock, 2023), and as such, schooling and school communities typically reflect transformations of the social macrocosm in which it is situated. As such, the cultural and linguistic diversity (CLD) of a society affects the dynamics of teaching and learning at different levels, which calls for educational policies aimed at meeting the challenges arising from this context. This has particular relevance to societies in which CLD is experiencing shifts and changes, such as the national context in Europe, in which our work is situated.

1.1. Diversity and multilingual context

CLD brings numerous positive aspects to learning contexts, such as the development of intercultural and communicative competences (Byram, 2021) and increased cognitive development and focus (Bialystok, 2017), yet it also brings some challenges that are reflected in the school microcosm such lack of appropriate resources and support for students and teachers (Cummins, 2007; García, 2009) and limited proficiency in the language of instruction which can lead to achievement gaps compared to their monolingual peers (Collier & Thomas, 2017). Although these challenges have different characteristics and dimensions depending on the country or the region, a considerable positive change can be observed since the second half of the last century regarding educational policies related to CLD.

The first step towards change in the European Community (EC) is the recognition in 1995 of the importance of a multilingual learning context and the need for appropriate educational policies to meet the challenges of CLD. In this sense, language teaching and proficiency in the language of instruction have become relevant issues in the educational policies and the national strategies for equity and social mobility policies (Bonacina-Pugh & Helot, 2023). To promote further ethnolinguistic integration in the face of European cultural plurality, the context of multilingual learning has considered part of European educational policies.

The white paper “Towards the learning society”, published by the European Commission in 1995, advocated about the mother tongue/first language-plus-two principle, stimulating the communication in the mother tongue (Nikula & Mård-Miettinen, 2014). According to this

document, “Multilingualism is part and parcel of both European identity/citizenship and the learning society” (European Commission, 1995 p. 67). According to Jessner (2008), although the document is based on multilingualism as a characteristic of the European identity and stresses the importance of mastering one’s mother tongue, three European languages and two other Community languages, it is not clear on the issue of managing bilingual or multilingual learning contexts.

1.2. Language policies

Several countries have implemented policies that aim to promote and support multilingual education, while addressing the specific needs of multilingual learners. In the Italian context, the Ministry of Education launched, along with the 1985 reform, the project *Insegnamento della Lingua Straniera nella Scuola elementare* (ILSSE), stimulating the foreign language teaching in primary schools (Minardi, 2014). In Finland, the “Language Shower” model promoted multilingualism by exposing students to a variety of languages throughout their education (Mård-Miettinen et al., 2023), and in Sweden, the *modersmålsundervining* and the *Modersmålslärare* program provided some support, such as specialized training for teachers working with multilingual learners (Roux Sparreskog, 2023).

In Sweden, the Language Act of 2009 laid the foundations for strengthening and protecting the Swedish language in schools, establishing it as the main language of instruction. The Swedish case is particularly interesting, especially as it adopts the students’ mother tongues to provide teaching and learning support (Paulsrud, Juvonen, & Schalley, 2023). In the same way, in 1984, Luxembourgish was recognized as a national language and was then listed as a language of instruction alongside French and German. Rohstock and Lenz (2011) state that schools reflect the cultural and identity aspects of societies, highlighting Luxembourg’s multicultural and multilingual context as an element reflected both in schools’ social dynamics and educational policies developed throughout history. The context of cultural plurality is compounded by migration, which increases the challenges of the learning process at school.

The study of Knudsen et al. (2021) in a Danish context suggests that migrant pupils have more difficulties in learning school content in a multilingual learning context. A frequently employed strategy is to regard a language that has already been acquired (such as the mother tongue) as a foundation for the acquisition of other languages. As previously indicated by the study conducted by Knudsen et al., this approach becomes more challenging when the language of instruction differs from the native language and remains unknown to the learner. In addition to teacher support, one potential avenue for progress may be the implementation of interdisciplinary

initiatives that engage the entire school community in the teaching and learning process (Haukås, 2016).

1.3. Science teaching in multilingual learning contexts

As previously stated, the multilingual learning context can be evidenced by certain constraints on the students' learning process. In countries such as Luxembourg, characterized by a cultural and linguistic diversity (CLD) in schools, it is evident that effective learning may be hindered (Gomez Fernández & Siry, 2017). Therefore, it is of paramount importance to be aware of semantic and social resources that facilitate the comprehension of subject matter taught by the teachers. A study by Wilmes and Siry (2020), conducted in Luxembourg, examining the notebooks of students learning science (in this case, the topic of condensation and evaporation), demonstrated that the notebooks functioned as an informal semiotic-social space that promoted both interaction and learning, particularly when the language of instruction was not their mother tongue.

The expansion of pedagogical approaches to teaching and learning can facilitate more efficacious learning in science, especially in a multilingual learning context. In that sense, scientific reflection, engagement through asking scientific questions and formulating possible answers, and sharing findings and perceptions with other students can be fostered through the implementation of inquiry-based in science teaching – IBST (Minner et al., 2010; Strat et al., 2023). The focus of this review on IBST is emergent from our national context, in which the curriculum works towards students' competences in science and builds from an inquiry-oriented approach. In order to ensure the effective implementation of IBST in multilingual learning contexts, teachers need to draw on related pedagogical knowledge and skills. This includes understanding the linguistic backgrounds of their students and implementing language scaffolding strategies that support content learning and language development. Nevertheless, it is important to highlight that in a multilingual context, pupils should be encouraged to go beyond the written and spoken language in order to express their understanding in the science classroom.

Although the theme of inquiry-based education goes back to Dewey's approaches (1910), its application in several European schools is still hesitant. In 2007, the European Commission published the report "Science Education Now: A Renewed Pedagogy for the Future of Europe" (European Commission, 2007), which served as a milestone for the inclusion of inquiry-based approach in the field of science education in European schools.

2. Study purpose

The purpose of this study is to see what has been published between 2008 and 2023 on the topic of primary science teaching in multilingual learning contexts, exploring what has been published

on the theme in the last 15 years. The choice of this time frame is justified by the fact some events serve as milestones for the field of science teaching, such as the publication of the Rocard' report.

In this sense, the study also aims to see how inquiry teaching is referred to in the publications and the contexts in which it is evoked, mapping the articles published in peer-review journals (Booth et al., 2012) and to answer the following research questions: 1. *What has been published about teaching primary science education in multilingual learning contexts?* 2. *How is inquiry-based mentioned in these publications?*. While the first question is general, focusing on mapping, categorizing, and analyzing publications, the second question focuses on checking for gaps in publications regarding the inquiry-based approach in the European educational context.

3. Method

> *Reviews that follow a broadly configurative synthesis logic approach usually investigate research questions about meaning and interpretation to explore and develop theory. They tend to use exploratory and iterative review methods that emerge throughout the process of the review.* (Newman & Gough, 2020, p. 4–5)

3.1. Research Design

The study was conducted in two parts using a descriptive approach with qualitative methods to analyze the results, in order to synthesise the results (Gough, 2007; Zawacki-Richter et al., 2020) and provide a comprehensive understanding about what has been published on the topic of primary science teaching in multilingual learning contexts. Likewise, the aim is to see how studies approach inquiry-based research and in what contexts it is applied. Thus, this systematic review is intended to answer two research questions:

1. What has been published about teaching primary science education in multilingual learning contexts?
2. How is inquiry-based mentioned in these publications?

Based on these research questions, the first part of the study aimed to verify what has been published in the field of primary education in contexts of multilingualism, while the second part aimed to examine, within the results, what is mentioned about "inquiry-based" and how this topic is approached in the context of science education.

3.2. Search procedures

The search was conducted online in three different database collections: 1. Web-of-Science databases in the Social Sciences collections Citation Index (SSCI), Social Sciences Citation Index Expanded (SCI-Expanded), and Emerging Sources Citation Index (ESCI); 2. EBSCOhost; 3.

Scopus. The keywords were chosen with the thesaurus of validated descriptors from the Education Resources Information Center (ERIC), considering in the structure of the search, screening and analysis of the results their core concepts and synonyms (Table 19).

Table 19 – Core concepts keywords and synonyms

Core concepts keywords	Synonyms
early childhood education	kindergarten, preschool
primary education	elementary education, elementary school, primary school
science education	science curriculum, science education, science instruction, science learning
multilingual education	language diversity, language learning, multilingual learning

The following search strings were chosen in line with the core concepts keywords and their synonyms: ("multilingual education" OR "multilingual learning" OR "language diversity" OR "language learning") AND ("primary education" OR "elementary education" OR "primary school" OR "elementary school" OR "early childhood education" OR "preschool" OR "kindergarten") AND ("science education" OR "science teaching" OR "science learning" OR "science instruction" OR "STEM education" OR "science curriculum").

3.3. Eligibility Criteria

Searches in the databases considered the results in the titles, keywords, and abstracts. In this sense by refining the results, studies were selected that were more in line with the research objectives, in terms of their type, language, and year of publication. With the aim of guaranteeing a systematic and transparent procedure in the process of choosing which studies would be included in the review, the following inclusion and exclusion criteria were drawn up:

- Inclusion criteria: Academic articles written in English with full text available, focused on the themes of science education in multilingual contexts.
- Exclusion criteria: Other types of publication with full text not accessible online, focused on middle or secondary education in monolingual contexts with themes that science is not included.

4. Review process – findings

The search results were downloaded in BibTeX, RIS, and CSV formats, checked for information, and then entered into the Parsifal literature review platform version. 2.2 (Kitchenham, 2007). The search yielded a total of 286 results (Table 20), with a total of 24 results removed before screening. The largest number of results (n=250) was found in the EBSCOhost database, while Web of Science (n=20) and Scopus (n=16) together had the lowest number of results. This might be due to the fact that the filters were more restrictive in the Web of Science and Scopus, and perhaps

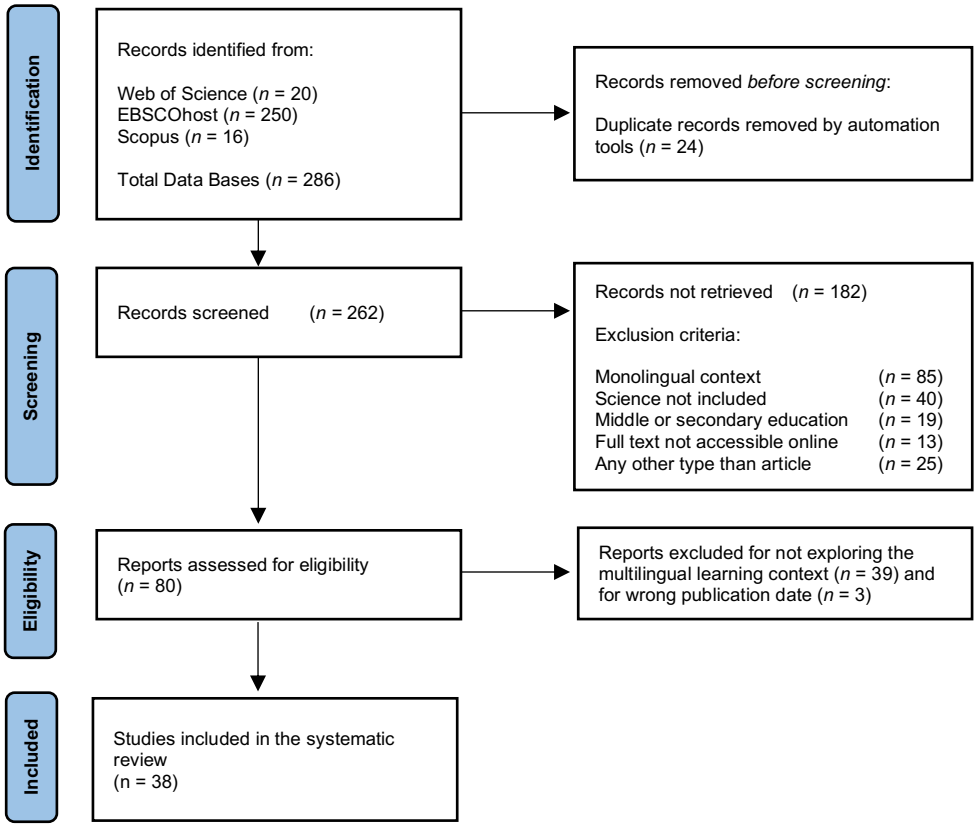
because the EBSCOhost collected more results in the Education Resources Information Center (ERIC) collection.

Table 20 – Systematic review stages

Data Source	Identification	Screening	Eligibility	Studies included
Web of Science	20	7	2	1
EBSCOhost	250	250	76	39
Scopus	16	5	2	1
Totals	**286**	**262**	**80**	**41**

In the process of screening the articles, duplicate articles (*n*=24) were checked both automatically (using Parsifal platform) and manually (using Excel sheets) and excluded from the review. The review followed the inclusion and exclusion criteria established for eligibility, excluding articles whose studies were in a monolingual context (*n*=85), science not included (*n*=40), middle or secondary education (*n*=19), full text not accessible online (*n*=13), and any other type than article (*n*=25). In this phase of the review, the titles, abstracts, authors' keywords, and the keywords generated by the database were checked. A total of 182 articles were excluded, and a total of 80 articles were selected as eligible for a review of full text (Figure 20).

Figure 20 – PRISMA Flow Diagram – Review Process



The representation of the screening and selection process for the publications that progressed to full text analysis was inserted in the new Preferred Reporting Items for Systematic reviews and

Meta-Analyses – PRISMA flow diagram 2020 (Page, et al., 2021) as it is a recognised visualisation tool for recording the systematic review process.

5. Results

After the review of full texts of 80 articles considered eligible, 39 were excluded because they did not explore multilingual learning contexts, and a total of 41 studies were included in the systematic review for a qualitative synthesis. The eligible studies were analyzed in the light of the research questions: What has been published about teaching primary science in multilingual learning contexts. How is inquiry mentioned in these publications? The contents of the articles were classified and organized in an Excel table to enable a qualitative synthesis of the selected studies (Table 21).

Table 21 – Articles included in the systematic review after full text review

Nº	Author(s)	Title	Year	Journal
1	Grapin et al	Developing Instructional Materials for English Learners in the Content Areas: An Illustration of Traditional and Contemporary Materials in Science Education.	2023	TESOL
2	Mercuri & Ebe	Developing Academic Language and Content for Emergent Bilinguals through a Science Inquiry Unit.	2011	Journal of Multilingual Education Research
3	Fine & Furtak	A Framework for Science Classroom Assessment Task Design for Emergent Bilingual Learners.	2020	Science Education
4	Busse et al	Addressing Linguistic Diversity in the Language Classroom in a Resource-Oriented Way: An Intervention Study with Primary School Children.	2020	Language Learning
5	Lyon et al	Navigating the Language Demands of an Inquiry-Based Science Performance Assessment: Classroom Challenges and Opportunities for English Learners.	2012	Science Education
6	Martínez-Álvarez	Multigenerational Learning for Expanding the Educational Involvement of Bilinguals Experiencing Academic Difficulties.	2017	Curriculum Inquiry
7	Esquinca et al	Meaning Making and Translanguaging in a Two-Way Dual-Language Program on the U.S.-Mexico Border.	2014	Bilingual Research Journal
8	Spycher	Learning Academic Language through Science in Two Linguistically Diverse Kindergarten Classes.	2009	Elementary School Journal
9	Ralston et al	"We're Actually Teaching Science!": A Partnership Approach to Investigating a New Model for Embedding Language in Science.	2021	School-University Partnerships
10	Fine, Caitlin G. McC.	Translanguaging Interpretive Power in Formative Assessment Co-Design: A Catalyst for Science Teacher Agentive Shifts.	2022	Journal of Language, Identity, and Education
11	Virdia, Simone	The (Heterogeneous) Effect of CLIL on Content-Subject and Cognitive Acquisition in Primary Education: Evidence from a Counterfactual Analysis in Italy.	2022	International Journal of Bilingual Education and Bilingualism
12	Lee et al	Teacher Professional Development Programs Integrating Science and Language with Multilingual Learners: A Conceptual Framework.	2023	Science Education
13	Roper et al	Teacher Approaches to Writing in Science in Bilingual Elementary Classrooms.	2021	International Journal of Bilingual Education and Bilingualism

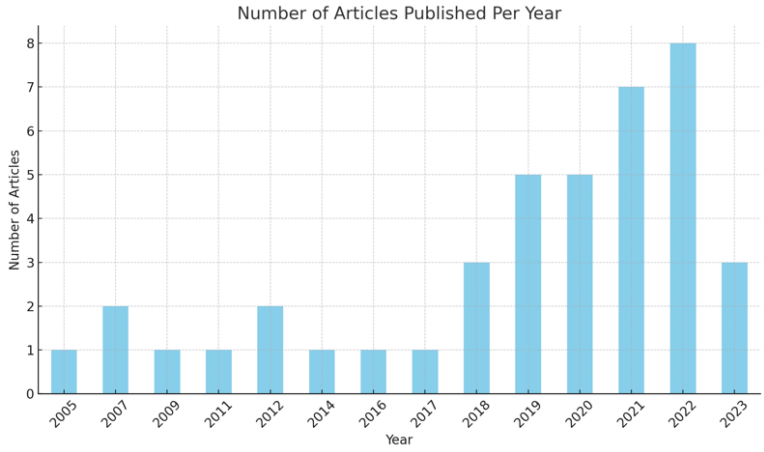
14	Pierson et al	Scientific Modeling and Translanguaging: A Multilingual and Multimodal Approach to Support Science Learning and Engagement.	2021	Science Education
15	Esquinca et al	Hegemonic Language Practices in Engineering Design and Dual Language Education.	2018	Association of Mexican American Educators Journal
16	Lan & de Oliveira	English language learners' participation in the discourse of a multilingual science classroom.	2019	International Journal of Science Education
17	Valdés-Sánchez & Espinet	Coteaching in a Science-CLIL Classroom: Changes in Discursive Interaction as Evidence of an English Teacher's Science-CLIL Professional Identity Development.	2020	International Journal of Science Education
18	Gómez Ramos et al	CLIL: Graphic Organisers and Concept Maps for Noun Identification within Bilingual Primary Education Natural Science Subject Textbooks.	2022	International Journal of Bilingual Education and Bilingualism
19	Leal	Assessment in CLIL: Test Development at Content and Language for Teaching Natural Science in English as a Foreign Language.	2016	Latin American Journal of Content and Language Integrated Learning
20	Martinez-Alvarez	What counts as science? Expansive learning actions for teaching and learning science with bilingual children	2019	Cultural Studies of Science Education
21	Quintero et al	Cross-disciplinary lessons in an elementary public institution; [Lecciones interdisciplinarias en una institución pública de básica primaria]	2021	Profile: Issues in Teachers' Professional Development
22	Navarro Martell	"Ciencias bilingües": How Dual Language Teachers Cultivate Equity in Dual Language Classrooms.	2022	International Journal of Bilingual Education and Bilingualism
23	de Larios et al	The Effects of Using Cognitive Discourse Functions to Instruct 4th-Year Children on Report Writing in a CLIL Science Class.	2022	Studies in Second Language Learning and Teaching
24	Williams & Tang	The Outcomes of Fifth-Grade Emergent Bi/Multilinguals' Introduction to a Visual Metalanguage When Constructing Scientific Explanations in Hong Kong.	2021	Asia-Pacific Science Education
25	Kiramba & Harris	Navigating Authoritative Discourses in a Multilingual Classroom: Conversations with Policy and Practice.	2019	TESOL Quarterly
26	Siry & Wilmes	Working toward Equitable Research Practices: The Value of Highlighting Complexity and Respecting Context.	2020	Cultural Studies of Science Education
27	Poza	The Language of "Ciencia": Translanguaging and Learning in a Bilingual Science Classroom.	2018	International Journal of Bilingual Education and Bilingualism
28	Alvarez	Reconsidering Academic Language in Practice: The Demands of Spanish Expository Reading and Students' Bilingual Resources.	2012	Bilingual Research Journal
29	Lee et al	The Challenge of Altering Elementary School Teachers' Beliefs and Practices Regarding Linguistic and Cultural Diversity in Science Instruction.	2007	Journal of Research in Science Teaching
30	Luykx et al	Cultural and Home Language Influences on Children's Responses to Science Assessments.	2007	Teachers College Record
31	Di Stefano et al	Exploring Bilingual and Dual Language Teachers' Perspectives on Asset-Based Professional Development in Science and Engineering.	2022	Bilingual Research Journal
32	Kiramba	Heteroglossic Practices in a Multilingual Science Classroom.	2019	International Journal of Bilingual Education and Bilingualism
33	Harden et al	Influences on Teachers' Use of the Prescribed Language of Instruction: Evidence from Four Language Groups in the Philippines.	2022	Education Quarterly Reviews

34	Symons	Instructional Practices for Scaffolding Emergent Bilinguals' Comprehension of Informational Science Texts.	2021	Pedagogies: An International Journal
35	Ünsal et al	Jumping Pepper and Electrons in the Shoe: Using Physical Artefacts in a Multilingual Science Class.	2020	International Journal of Science Education
36	Ünsal et al	Language Use in a Multilingual Class: a Study of the Relation Between Bilingual Students' Languages and Their Meaning-Making in Science.	2018	Research in Science Education
37	Karlsson et al	Multilingual Students' Use of Translanguaging in Science Classrooms.	2019	International Journal of Science Education
38	Tian	Challenging the 'Dual': Designing Translanguaging Spaces in a Mandarin-English Dual Language Bilingual Education Program.	2022	Journal of Multilingual and Multicultural Development
39	Grapin et al	Science Education with Multilingual Learners: Equity as Access and Equity as Transformation.	2023	Science Education
40	Mohan & Slater	A Functional Perspective on the Critical "Theory/Practice" Relation in Teaching Language and Science.	2005	Linguistics and Education: An International Research Journal
41	Pierson & Grapin	A Disciplinary Perspective on Translanguaging.	2021	Bilingual Research Journal

Note: during the creation of this table, a final verification was conducted, and three articles were identified as being out of the publication date range, for the reason for existing divergent information between journal and database from where they were retrieved. Therefore, they were kept in the table as they were included in the analysis.

Figure 21 shows the selected articles included in the systematic review distributed per year, with three-quarters of the publications distributed between 2018 and 2023 (31 articles). The majority of the articles were published in recent years, particularly in 2022 (eight articles) and 2021 (seven articles). It is also noteworthy to mention the years of 2019 and 2020 with five articles each, indicating a growing focus on the themes covered by these accepted articles in the past few years.

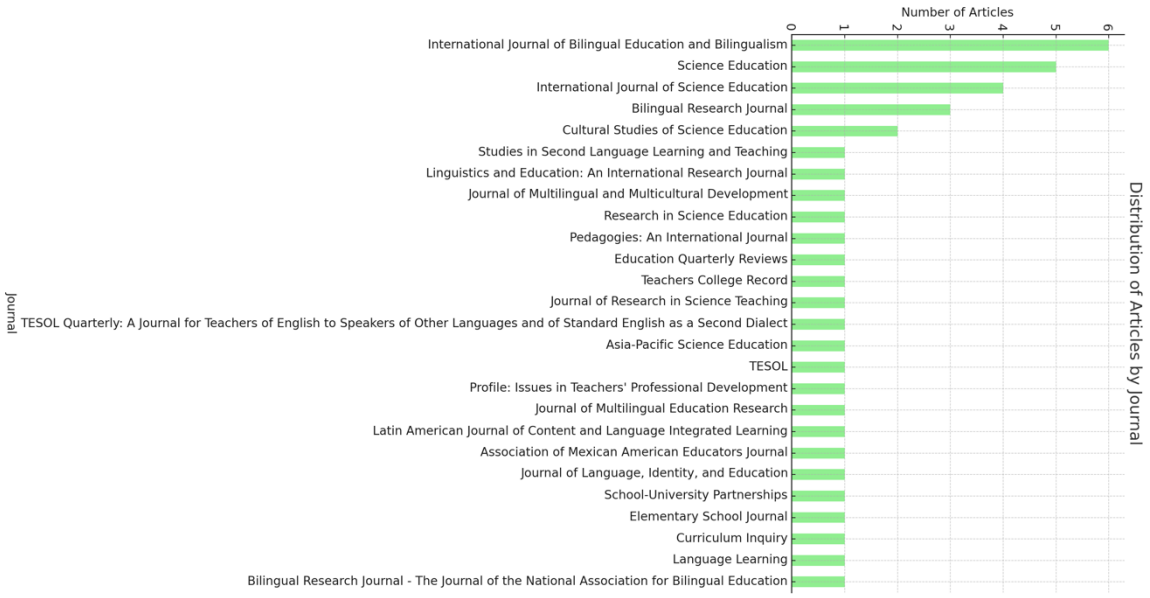
Figure 21 – Distribution by year of included studies



The set of articles included in the systematic review (n=41) is distributed across 26 different journals (Figure 22). 21 articles included in the systematic review are distributed across five journals: "International Journal of Bilingual Education and Bilingualism" (six articles), "Science Education" (five articles), "International Journal of Science Education" (four articles), "Bilingual

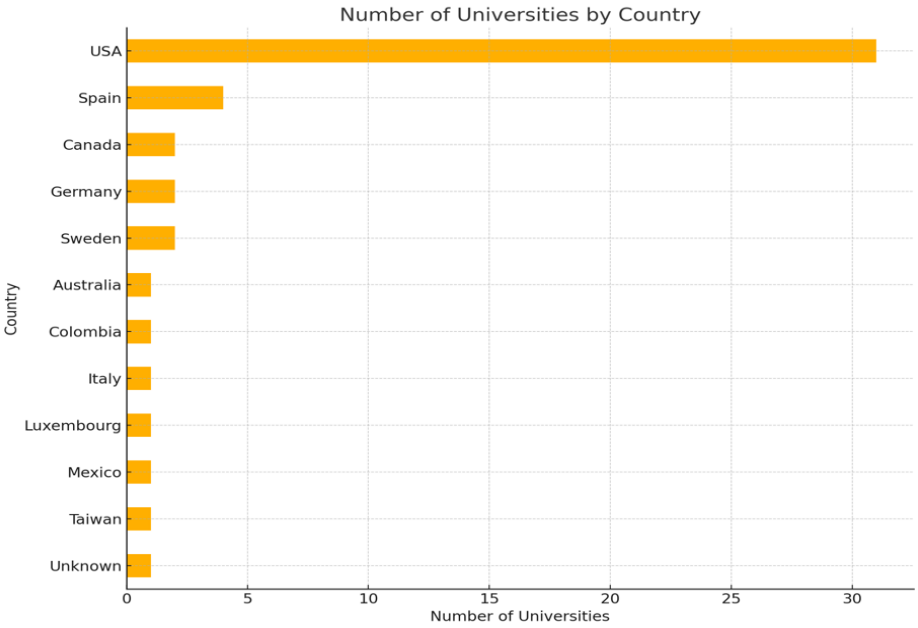
Research Journal" (three articles) and "Cultural Studies of Science Education" (two articles). The remaining 21 journals have a single publication each.

Figure 22 – Distribution by journal of included studies



In the course of examining the articles to be included in the systematic review, it was observed that the distinct systems employed differences in classifying educational cycles in Europe and the United States (primary and/or elementary education; or middle school for grade 6); the age range 4-12 of children was used as a standardising reference. Figure 23 illustrates that, of the 41 studies included in the review, a greater proportion of authors are affiliated with universities in the United States of America. With regard to European universities, Spain, Germany and Sweden are particularly prominent in the graph. Nevertheless, in the latter case, there were fewer than five authors affiliated with each.

Figure 23 – Distribution by universities and countries of included studies



The set of accepted articles concentrates the research focus primarily on the interconnection of language learning and science content instruction, particularly within the context of English learners (ELs). A significant focus of these articles is the creation of instructional materials that facilitate the simultaneous acquisition of academic content and ELs skills, reflecting the current shifts in educational standards. Themes will be discussed in the next final section.

5. Discussion

The included studies share several key aspects identified in the theoretical framework, and/or in the context of the research. In this sense, we verify that some studies address educational strategies and frameworks designed to support students from multilingual or bilingual backgrounds, particularly in science education or academic language development.

Science Assessment and Language Learning

The existing body of research in the field of science assessment and language learning investigates potential avenues for enhancing the academic performance of students who encounter challenges in comprehending scientific concepts due to linguistic constraints. In this sense, the study by Grapin et al. (2023) analyses the production of educational materials designed for English Language Learners (ELLs) within the context of science education. The study places an emphasis on the integration of language and content objectives, with the objective of facilitating the comprehension of scientific concepts by ELLs. The principal objective of the study is to develop instructional materials that are aligned with both language and science standards, with the aim of enhancing learning outcomes for ELLs.

Similarly, Mercuri and Ebe (2011) examine the potential of inquiry-based learning as a means of developing academic language and content knowledge in ELLs. The study employs a qualitative descriptive approach to assess the efficacy of inquiry-based methods in facilitating the academic advancement of ELLs across a range of subject areas. The article highlights the challenges and benefits of this approach in multilingual classrooms.

Fine and Furtak (2020) proposed a framework for science assessment designed to support ELLs in K-12 classrooms. The objective of this study was to align assessment practices with the specific requirements of ELLs, with a dual focus on language acquisition and content learning. The study is notable for its development of bespoke assessment tools and strategies that address the linguistic and cognitive demands of science education.

Multilingual Discourse and Dual (Trans)Languaging

In their study, Busse et al. (2020) investigate the impact of a multilingual approach in language classrooms. This quasi-experimental study examines the impact of integrating students' diverse linguistic backgrounds into the curriculum on language learning outcomes. The study highlights the benefits of a multilingual approach in promoting inclusivity and enhancing language proficiency in a variety of classroom contexts.

The article by Lyon et al. (2012) examines the potential for adapting science performance assessments (SPAs) to better meet the language demands of ELLs. The study focuses on the challenges faced by ELLs in the context of inquiry-based assessments and proposes recommendations for improving the accessibility of such assessments. The research underscores the imperative for assessments that are responsive to linguistic diversity while upholding academic standards.

Virdia (2022) presents evidence that CLIL (content and language integrated learning) has a detrimental effect on the acquisition of content knowledge in primary science education, particularly among students with lower language proficiency and from disadvantaged backgrounds. The findings of the study indicate that while CLIL may facilitate the development of higher-order cognitive abilities, it presented difficulties in the retention of content knowledge, particularly when students were engaged in the simultaneous acquisition of both language and subject matter. The study focuses on primary education (fourth grade), thereby directly aligning with the research questions pertaining to the teaching of primary science education in multilingual learning contexts. The study addresses the issue of multilingualism through the implementation of CLIL, whereby science is taught in either English or German. Although inquiry-based learning is not explicitly identified as a core element, the cognitive domains assessed (applying and reasoning) align with critical thinking and problem-solving skills frequently emphasised in inquiry-based education. Nevertheless, the principal objective of the study is to examine the cognitive load and content retention in a multilingual context, rather than to investigate the specific aspects of inquiry-based learning.

In a contrary vein, Leal (2016) verifies in his study that results showed that the assessment grid was a valid tool for categorising test items, providing insights into students' performance in terms of both content and language. Most of the test items focused on high content demands and low language demands, highlighting the challenge of creating test items that balance the two. It also showed that more emphasis was placed on content knowledge, with a gap in addressing higher language demands, particularly in more complex items.

The study conducted by Pierson et al. (2021) revealed that the utilisation of translanguaging enabled students to draw upon their comprehensive linguistic repertoires, thereby facilitating more

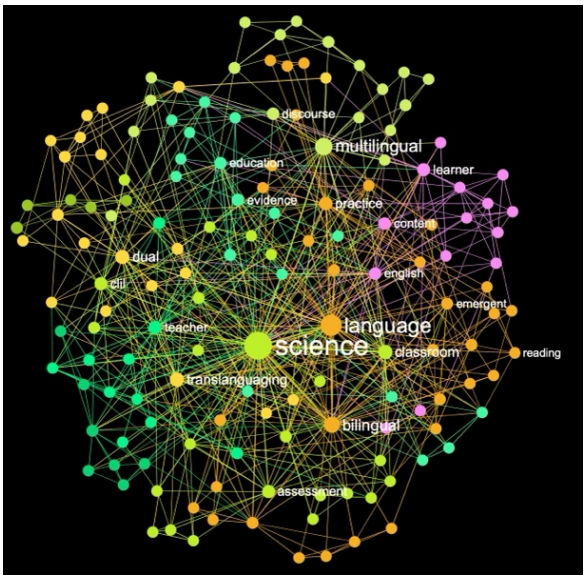
profound engagement and comprehension of STEM (science, technology, engineering and mathematics) subjects. The students employed a range of modes and languages to represent and process the scientific concepts under study. However, the study also revealed the continued prevalence of monolingual ideologies in English-dominant educational settings, which posed a significant obstacle to the full realisation of the transformative potential of translanguaging.

Although the selected studies can be categorised as research into the linguistic challenges of teaching science in primary schools, it was difficult to identify studies carried out in multilingual contexts. In many cases, the study took place in a predominantly monolingual environment where English is not only the language of instruction but also the language of everyday school life. In these cases, a second language spoken at home acts as a limiting factor in understanding science content. In other cases, English is taught as a foreign language in conjunction with science content.

Main topics

The analysis revealed that the topics 'Science Assessment", "Language Learning", "Multilingual Discourse", "Dual (Trans)Languaging", "Science Classroom", "Bilingual Practice", "Multimodal Discourse", "Translanguaging equity", and "Learner Development" exhibited the greatest number of connections across the texts (Table 22).

Table 22 – Included studies – Cluster distribution by topics

Network of clusters of topics in the included studies	Topical Cluster	Cluster Code	Influence	Total Nodes	Percentage of Entries	Category
	**1**	1	36%	24	24%	1. Science Assessment
	2	3	28%	34	27%	2. Language Learning
	3	7	13%	19	12%	3. Multilingual Discourse
	4	5	10%	20	17%	4. Dual (Trans)Languaging
	5	0	5%	14	2%	5. Science Classroom
	6	2	3%	17	7%	6. Bilingual Practice
	7	4	3%	10	5%	7. Multimodal Discourse
	8	8	1%	5	2%	8. Translanguaging Equity
	9	6	1%	7	2%	9. Learner Development

Note: Each topical cluster represents a distinct subject or theme, identified by a number and related to different areas of research or topics based on the dataset of included studies in the Systematic Review. The influence of each cluster is shown as a percentage, which signifies the relative importance or prominence of that cluster in the overall dataset. A higher percentage suggests that the particular cluster has a stronger presence or relevance within the system review topics.

As illustrated in Table 22, *Cluster 1* [science] has the most significant influence, accounting for 36% of the total. This indicates that it has the most substantial impact with the most frequently

connected cluster within the dataset. It may be the area that has been the subject of the greatest amount of discussion in the included studies. Subsequently, *Clusters 2* [language] and *3* [multilingual] account for 28% and 13% of the influence, respectively. Although they remain relatively prominent, their influence is considerably less than that of *Cluster 1*. The influence of *Clusters 4* [translanguaging] and *5* [classroom] is considerably less significant, with a respective influence of 10% and 5%. This suggests that these clusters are less central or exert less influence than the others in the set of included studies.

The analysis of the nine clusters of topics with the greatest influence on the texts of the studies included in the systematic review demonstrates that the inclusion and exclusion criteria of the studies enabled the gathering of a set of articles that most closely matched the objectives and thematic framework of the review.

Main explored concepts

It was found that the set of articles concentrates the research focus primarily on the interconnection of language learning and science content instruction, particularly within the context of ELLs (Álvarez, 2017; Leal, 2016; Virdia, 2022; Lyon et al., 2012; Pierson et al., 2021; Di Stefano et al., 2022).

In some of these articles, the researchers conducted their studies in contexts where the language of instruction differed from the language spoken by the child at home. In the majority of cases, the language of instruction was English, while the language spoken at home was Spanish, and there were instances where the home language was Arabic or Italian. The studies demonstrated the significance of language in the cognitive processes of the students.

The research by Quintero et al. (2021) investigates the effectiveness of implementing an interdisciplinary approach that integrates English language teaching with science curricula in a Colombian public primary school context. The findings suggest that this pedagogical strategy has the potential to increase student engagement and foster the development of communicative skills. This effect is particularly pronounced when instructional content is contextualised to students' lived experiences, such as through the incorporation of environmental education and basic science concepts. The study's focus on fourth-grade students places it firmly within the domain of primary education, making it highly relevant to inquiries into science education at the elementary level. The primary theoretical constructs underpinning this research are content-based instruction (CBI), cross-curricular pedagogical approaches, and the integration of foreign language acquisition with science education. Of particular importance is the study's emphasis on the synergistic relationship between science content knowledge and language learning in the public school environment.

A significant focus of these articles is the creation of instructional materials that facilitate the simultaneous acquisition of academic content and ELs skills, reflecting the current shifts in educational standards. The authors underscore the increasing necessity to accommodate the linguistic diversity of students, emphasising innovative approaches to integrating language and subject matter, such as science and STE[A]M (science, technology, engineering, [arts] and mathematics). The evolution of TESOL (teachers of English to speakers of other languages) materials illustrates a transition from traditional methods to new frameworks that have a better response to the challenges faced by ELs in achieving academic success (Grapin et al., 2023). These studies emphasise the importance of aligning language learning strategies with content education to foster more effective learning outcomes for linguistically diverse students.

Exploring aspects of inquiry-based learning, Luykx et al. (2007) examine how students from different linguistic and cultural backgrounds affect their performance in science assessments, particularly in a multilingual context. By analysing students' written responses in an inquiry-based science curriculum, the research highlights the challenges that ELLs face in understanding and responding to science test items due to linguistic interference and cultural beliefs. The findings highlight the need for culturally and linguistically sensitive assessment practices in science education. The study was conducted in primary education, specifically with third and fourth graders, which fits well with the research question focusing on primary science education. It addresses how students' prior linguistic and cultural knowledge affects their engagement with scientific inquiry, particularly through their written assessments. Although the term 'inquiry' is not extensively explored in terms of direct inquiry-based methods, it is central to the instructional approach used in the study.

Also, in the domain of inquiry and inquiry-based learning, Esquinca de la Piedra and Rocha (2018) investigate the implementation of the STEM curriculum, which did not follow the principles of bilingual education, with English dominating as the language of instruction in the engineering design modules. Teachers, especially the Dual Language (DL) teacher, faced significant challenges such as lack of resources, time constraints and limited familiarity with inquiry-based learning and engineering design. As a result, the inquiry-based curriculum reproduced hegemonic practices by marginalising Spanish and treating it as a secondary language of instruction, contrary to the aims of the DL programmes.

The concept of co-teaching in a science CLIL classroom is explored by Valdés-Sánchez and Espinet (2020). The study analyses the effectiveness of graphic organisers and concept maps in teaching noun identification in a bilingual primary science classroom. They found that although these tools helped students to improve noun identification, especially for verbs, they were not sufficient to completely prevent errors. The short intervention period and the non-randomised

sample were limitations. Despite these challenges, the use of graphic organisers showed promise as a tool for improving science vocabulary comprehension in a bilingual context. This study focuses on primary education (grade 5, ages 9-11) in a bilingual science context, making it directly relevant to the research question of primary science education in multilingual contexts. It addresses some aspects of multilingualism and science education in bilingual contexts, with a particular focus on the identification of lexical categories in science texts. However, it does not deal extensively with inquiry-based science teaching but focuses on vocabulary acquisition and recognition.

6. Final remarks

The aim of this systematic review was to identify what has been published between 2008 and 2023 on the topic of primary science education in multilingual learning contexts and to answer the following research questions 1. What has been published on primary science education in multilingual learning contexts? 2. How is inquiry mentioned in these publications?

The database search identified a total of 286 studies, of which 24 duplicates were excluded before screening. Of the 262 studies that were screened, 182 were excluded because they did not meet the inclusion criteria, while 80 studies proceeded to the eligibility phase. At this stage, the selected studies were read and analysed, and a total of 39 studies were excluded. The 41 articles selected for inclusion in the review were analysed according to the research objectives.

It was found that the articles analysed shared some common characteristics regarding the central topics of the studies. In this sense, the most common topics were categorised and the articles were organized into clusters [topics: ‘Science Assessment”, “Language Learning”, “Multilingual Discourse”, “Dual (Trans)Languaging”, “Science Classroom”, “Bilingual Practice”, “Multimodal Discourse”, “Translanguaging equity”, and “Learner Development”]. The clusters highlighted the dominant content of the studies and, at the same time, made it possible to see that the review was able to answer its first research question. All 41 of the selected studies addressed issues related to primary science education in (multi)(bi)lingual learning.

The analysis of the texts made it possible to answer the second research question, and it was found that, in some studies, the issue of inquiry teaching was explored in dialogue with strategies for teaching science. In other studies, it appears as a teaching and learning strategy. In this sense, the review can be said to have answered the two research questions by identifying what has been published on science teaching in a multilingual context and by examining how these studies have incorporated the theme of inquiry or inquiry-based approaches.

However, the analysis of the texts revealed different understandings of science teaching in a multilingual context, in most cases mixed with bilingual approaches. This finding highlights

some aspects that need to be highlighted in this conclusion. The first is the need to question the procedures used to search the databases, and the second is the criteria for inclusion and exclusion of studies set out in the review protocol.

Limitations and future works

Although the filters applied to the Scopus and Web of Science platforms excluded several studies from the results, it was noted that the EBSCO*host* platform had a much higher number than the other two. In addition, many of the results were linked to the ERIC repository, so it was necessary to exclude from the screening some publications that did not meet the established criteria (e.g. non-articles). In the same sense, the different perceptions of the concept of multilingual context had a strong influence on the analysis of the texts, since it was not enough to exclude it from the review, but to confuse it in terms of the research context (bilingual and multilingual) or the sociocultural aspects involved. It is recommended that future work take these limitations into account.

The review also showed that, although a holistic view of the studies is interesting in some aspects, more targeted research, such as 'How is inquiry-based research explored in science education in contexts of linguistic diversity' or 'What is the relevance of context in the development of teaching and learning strategies in science' might be relevant topics for further literature reviews.

Chapter V –
The school-university partnership

This chapter presents the SciTeach Center as an umbrella partnership, where the teacher-researcher collaboration happens, and consists of two manuscripts:

- ***Exploring boundary-spanning in teacher education: supporting elementary science education through a school-university partnership***, a book chapter accepted in 2024 for publication, authored by Maiza Trigo, Christina Siry and Thierry Frentz, which outlines the authors' boundary-spanning process within the school-university partnership.
- ***Examining a school-university partnership in Luxembourg: supporting primary science education in times of uncertainty***, an article accepted for review in 2024, authored by Maiza Trigo and Christina Siry, which explores the conditions in which the school-university partnership can be responsive in uncertain times.

How can we incorporate in the **formation continue**
our approach for **Forschend-entdeckendes Lernen*?***

[An example of translanguaging happening during a team meeting]

Exploring boundary-spanning in teacher education: supporting elementary science education through a school-university partnership[15]

Luxembourg is known for its diversity whilst a multilingual country with a rapidly changing context. The use of different languages in the school system elicits challenges and opportunities for both students and teachers and, consequently, teacher education. This chapter presents data from the development of a workshop focusing on Science and Language, which takes place in a school-university partnership that supports elementary science teacher education in Luxembourg – the SciTeach Center. Through exploring the dynamics of the team of researchers and teachers, it is revealed how its collaborative structure based on co-developing and co-teaching professional learning opportunities can create spaces for boundary-spanning. Therefore, grounded in sociocultural perspectives and using tools from critical ethnography and participatory research lenses, this contribution presents a case study of boundary-spanning within a school-university partnership as we analyze our own boundary-spanning as a professor, a doctoral researcher and an elementary teacher.

Keywords
collaborative structures
school-university partnership
boundary-spanning
elementary science teacher education
sociocultural perspectives
Luxembourg
multilingual context

This chapter introduces a partnership focused on science teacher education, with the goal of elaborating the structures that mediate the boundary-spanning of the participating elementary teachers and researchers that collaborate through a school-university partnership (e.g., Guerrero & Reiss, 2020; Kang & González-Howard, 2022; Penuel et al., 2015). Situated within a teacher education resource center, the SciTeach Center at the University of Luxembourg, the research presented in this chapter emerges from a study of the SciTeach team's collaboration, focusing on the co-development and co-teaching of professional learning opportunities for other teachers. We, the authors, are each members of this team, together with currently nine other colleagues, and our collective overarching objective is to support inquiry-based elementary science education as recommended by the European Commission (Fibonacci Project, 2012; Rocard report 2007), through open-ended, practice-oriented pedagogical approaches (e.g., NASEM, 2022) and aligned with the Luxembourgish national competency-based curriculum (MENFP, 2011).

Our work is grounded in sociocultural perspectives, and we use participatory research (Bang & Vossoughi, 2016) and critical ethnography (Carspecken, 1996) in our work with teachers. Here we explore analysis of data drawn from participants' reflections on their roles as part of a case study (Stake, 1995) to explore boundary-spanning within the school-university partnership by focusing on three boundary-spanners (the authors). The analysis layers thematic data from team meeting video recordings together with written reflection pieces (i.e., using bricolage – Kincheloe, 2001) with the aim of retracing a collaborative structure focused on a process of Reflect-Dialogue-

[15] This manuscript has served as a basis for a book-chapter in the book *Boundary-Spanning in School-University Partnerships*, edited by K. Zenkov, D. Polly and L. Rudder, and published by Emerald (Information Age Publishing).

Act (Wilmes, te Heesen et al., 2018). The goal of this chapter is to elaborate the research into the ways in which the collaborative structures of the Center create spaces for boundary-spanning, first beginning with an introduction to the national context, the structures of the Center, and the frameworks that guide our work within the school-university partnership.

1. The Luxembourgish context and its trilingual elementary school system

Luxembourg is a trilingual nation state in Europe, a European country with a long history of migration (Trausch, 2007; also see Trigo, 2023), where several ethnolinguistic communities coexist (Gómez Fernández & Quintus, 2020), with foreign residents making up almost 50% of the total population (Statec, 2021). Aligned with the population's changing demographics, the student population has consequently increased its numbers of foreign students or students with migration background (MENJE, 2022), creating a rapidly changing context with over 170 nationalities represented in Luxembourg's relatively small population of just over 630,000 residents. The cultural and linguistic complexity is also evident in elementary school (LUCET & SCRIPT, 2016, 2019, 2022), where approximately half of schoolchildren speak languages at home other than the curricular languages of instruction (MENJE, 2022).

Luxembourg's school policy is multilingual, and at elementary school, Luxembourgish is used as the first language of instruction (Kindergarten; Cycle 1 – ISCED 0[16], ages 4-6). From 1st grade on (Cycle 2 – ISCED 1), children are taught basic literacy in German, and French is later introduced as a third school language. However, science instruction shifts from Luxembourgish to German at this time, presenting teachers and children with challenges towards language expression in science, as children are learning the language of instruction for science simultaneously as they are learning science content. In the current curriculum guidelines (MENFP, 2011), after alphabetization, language instruction makes up almost half of the overall number of lessons, while science instruction undergoes a counter path of a progressive decrease of lessons while the program of instruction increases its complexity (Trigo, 2023).

This scenario can pose challenges to students and teachers (Weth, 2015), with science lessons resultantly often focusing on vocabulary learning (Siry, 2017). The contradictions for many students between the language(s) of instruction and the language(s) spoken at home play a critical role in this context where challenges and opportunities for learning surface as related to students' expression of science understandings, and critical reflection on equality, equity, and justice is much needed (Loureiro et al., 2019). Within this highly complex, super-diverse context

[16] ISCED stands for *International Standard Classification of Education*. More specifically, ISCED 2011 is an international reference for how education programs and qualifications are organized by levels of education (UNESCO, 2012).

(Vertovec, 2007), the most recent national curriculum reform focused on developing students' competencies to engage in science practices (Andersen et al., 2015) and the need to support elementary teachers with related curricular materials and professional learning (PL) opportunities[17] emerged. The SciTeach Center was created to respond to this need, with the goal of advocating for the role of science education in the elementary years (Wilmes, Siry et al., 2018).

2. The SciTeach Center and Its Purposes

The SciTeach Center was founded in 2016 as a resource center for teachers in Luxembourg, dedicated to supporting the teaching and learning of science education at the elementary school levels by providing a range of resources for in-service and pre-service teachers. Elementary teachers in Luxembourg are required to complete 48 hours of continuous education for each 3-year period (Luxembourg, 2017), and thus alongside materials available for loan, the main resource that the Center provides is teacher professional development (PD) courses (called in Luxembourg, *formation continue*), all accredited by the Institute for National Education Training (IFEN – *Institut de Formation de l'Éducation Nationale*), a service of the Ministry of Education (MENJE – *Ministère de l'Education nationale, de l'Enfance et de la Jeunesse*). The teacher education courses are offered on the university campus as well as within schools upon request, and these aim to support the Luxembourgish competency-based elementary science curriculum (MENFP, 2011), guided by an inquiry-based teaching approach (Bybee, 2014; te Heesen et al., 2022).

The purpose of the SciTeach Center is to design and facilitate professional learning opportunities that emerge from teachers' localized needs while addressing the national curricular context with a specific focus on supporting teachers in learning pedagogical strategies for facilitating open-ended science investigations within their multilingual classroom contexts. A wide range of teacher education initiatives and related research projects have emerged and evolved within the context of the Center, and current offerings for PD include foci that are topic-based (e.g., trees and leaves, temperature, playground physics), resource-based (e.g., digital microscopes, school gardens, makerspace) or method-based (e.g., inquiry-based science education, science & language, read science with me).

On the overall, the SciTeach Center is not only a physical space that was created to provide resources that support elementary inquiry-based science education, but it is the space where teachers and researchers come together to work on developing initiatives to support teachers' professional learning, including our own, considering our organizational learning through

[17] Throughout this chapter, the expression "professional development" will be used interchangeably with "professional learning". The "development" will be more linked to the "offerings" whilst "learning" more to "opportunities".

collaboration and boundary crossing (Engeström et al., 1995). The configuration of the SciTeach Center can be situated as a multi-level umbrella school-university partnership, guided by the continuum motto "Teaching grounded in Research. Research grounded in Teaching", a partnership which is elaborated further next.

3. The team members coming together across differences

The SciTeach Center is a comprehensive structure at the University of Luxembourg that has been developed in collaboration with the Ministry of Education (MENJE), the National Research Fund (FNR – *Fonds National de la Recherche*), and, and The Ministry of Research and Higher Education (MESR – *Ministère de l'Enseignement supérieur et de la Recherche*) to support elementary science instruction in Luxembourg. The overarching collaboration with the ministry supports an innovative team configuration in which researchers and in-service elementary teachers work together in different levels of partnership over time. Currently, the members in the teacher education team include seven researchers (one professor, two research specialists, one post-doctoral researcher, and three doctoral researchers) and eleven in-service elementary teachers, all of whom collaborate to co-develop, co-teach, and co-research professional learning initiatives for other elementary school teachers. The in-service teachers on the team are supported by the ministry to engage with the SciTeach Center as "Teacher-Leaders" –three teachers who are freed from their classroom teaching duties one day per week to work at the Center– and "Multipliers" – seven teachers who co-plan with the team for specific PD offerings that they later are paid by the Ministry for co-teaching with other team members.

Current team members' age range from 30 to 55 years old, and their backgrounds include different cultures (American, Latina and European), different nationalities (including Luxembourgish, German, French, American, Portuguese and Finnish), different education tracks (e.g., majors in Biology, Education, Educational Management, Languages, Media Education and Science Education), different professional paths (experiences in elementary school, secondary school, school leadership, museum education, and educational research). The working languages within the SciTeach Center are English, German, and Luxembourgish, and all team members are plurilingual in different ways (languages spoken include Luxembourgish, French, German, English, Dutch, Portuguese, Spanish, Italian, Finnish and Russian), enabling for a consistent and fluent translanguaging to occur during most of the team's interactions. This diversity in terms of spoken languages, cultures, and nationalities amongst the team also matches well the diversity of the country itself.

4. Data sources and analytical framework

This chapter uses data from different sources in order to trace the boundary spanning of the teacher and the researchers, authors of this manuscript. Excerpts from video recordings are transcribed and used to reconstruct the discussion about the existing types of primary teachers, how team members dialogue about the need to set a common ground for science as a concept, and our positionalities as we reflect on our roles within the team and the center (Table 23). These thread-line stories serve as background for the evidence of the process of boundary spanning.

Table 23 – Data sources and themes

Data sources	Themes
Team discussion recordings	Types of teacher in Luxembourg
	Languages used within the primary education context
Field notes	Types of teacher in Luxembourg
	Observation of posture
	Positionality within the team
Reflection pieces	Positionality on roles in the team
	Changes in the roles taken within the team

Team recordings underwent coding and analysis through the use of memoing (Saldaña, 2016), which allowed data to be put together across the different meetings. Field notes and reflection pieces were coded using content analysis (Bardin, 1977/1979), enabling codes to be crossed into themes. Data used was drawn up using the principle of bricolage (e.g., Kincheloe, 2001) to tell the story of teachers and researchers coming together and influencing their each other's work.

5. A Collaborative Structure for Teacher Education

The SciTeach Center is presented as an overarching case, illustrating how a team of researchers and teachers worked together in a school-university partnership to explore how different initiatives have emerged from – and responded to – elementary science professional learning needs. There is an agreement in the form of a legal convention between the University of Luxembourg and the Ministry of Education (IFEN), wherein each partner commits resources to support the SciTeach Center's PD offerings. This process solidifies and guides a partnership between the university and the ministry in which both the university researchers as well as the classroom teachers are supported to collaborate through the SciTeach Center to co-develop, co-plan, and co-teach the Center's professional development offerings.

At the core of this collaborative structure is the fact that all in-service workshops are facilitated by at least one teacher and one researcher coming together as teacher educators that share responsibility for the success of the workshop development and implementation. Co-

teaching and co-development support "learning at the elbow of others" (Roth & Tobin, 2004), as co-teachers engage in ongoing dialogue around the success, challenges, and surprises that emerge during the PD offerings, a process which serves as a form of reflexive praxis for the collaborating teacher educators, as they learn from the different perspectives and experiences of the others.

The partnership between these institutions has enabled the development of a structure for collaboration – Reflect-Dialogue-Act – which guides the team's interactions (Wilmes, te Heesen et al., 2018). Through this ongoing process, individual written reflections are used as basis for reflective practice (Schön, 1987) and collective dialogue, as a process from which future actions become emergent in discussion. The main data source for this study are recordings of team meetings, and video-based analysis (Schnettler & Knoblauch, 2009) was used to "zoom in" (Roth, 2005) to the data to identify patterns and contradictions that emerged (Sewell, 1992). In the sections that follow, excerpts are presented from a weekly team meeting in which team members discussed the connections between science and language in science instruction related to the development of a new workshop initiative intended to focus on integrating science and language, with particular relevance to the multilingual context, to emphasize the applicability of science education for developing language competencies.

These excerpts illustrate two important points that come into focus, including the positionalities of those teaching science and, relatedly, considerations for how the team can support teachers for multilingual contexts using science.

> Thierry: if we say teachers...I might say [there are] two main groups of teachers...those who teach science and those who don't teach science… the first problematics will, which will come up is, [imitating potential replies from participants] but I only teach science,...but I have no access to those German, French, mathematics lessons, and vice-versa too
>
> Maiza: but…within the process of doing science, we actually have a part of sharing…doing that, we are, we have to use some kind of language and that can be pointed out is the development of competences linked to language, because we are talking about argumentation, evidence, showing evidence, explaining the process. So we are talking about a lot of things that are important within the process of doing science being…But then again, we fall into the gap that you were talking [about], you know, if the teacher is teaching both language and science or not, because otherwise they will focus only on their own domain, the competences linked to their own domain

In Luxembourg, children attend elementary school for 26/28 hours per week (depending on the cycle), while teachers' workload includes fewer contact hours with students (Luxembourg, 2009a, 2009b). Therefore, a school grade classroom will have a main teacher (*Titulaire*), who usually will focus on the language and math instructions, and a second teacher (*Surnuméraire*), who will teach the class subjects such as science, arts, and sports. These differing teacher profiles in elementary schools in Luxembourg emerged in this discussion as a structural challenge, as it became evident that there were classroom teachers that designate their students' science lessons to be taught by other colleagues, a situation which Thierry elaborated as a problematic to be addressed by the

team, “but I only teach science, or I have no access to those [other] lessons.” This excerpt served as an example of how the team shared a commitment to better understand the context, a commitment which unfolded into an ongoing questioning of fundamental concepts through dialogue related to the teaching of science in our context. This team’s work dynamics facilitated the development of a community of practice (Wenger, 1998/2005), and reflecting on the team dynamics that are visible in this interaction reinforced how the dimensions of mutual engagement, joint enterprise, and shared repertoire (Wenger, 1998/2005) are present in the team’s interactions.

The conversation about how to bridge science and language in an in-service professional development workshop triggered a discussion on how national exams can put gaps between science and language or use science topics as a pretext. Throughout the discussion, Olga, another team member and also an elementary science teacher, posed the question as to whether or not science could be seen at all as she asked, *“*but what is science then, actually? Is science only the *forschend-entdeckendes* [inquiry-based], or is science everything that is related to science? Is science not a big big word?”, which then led into a reflection on the central question of “What is science?” that Chris, the second author of this chapter, underscored:

> I think that this question about what we mean by science is a fascinating question and I would like to strongly encourage us to think about this some more and pick it up in our next conversation as well because there are many definitions of science.

After this conversation, during a later team meeting, this emergent prompt of *What is science?* turned into a group reflection and related dialogue that focused on unpacking different perspectives on science, with an outcome of working towards a group perspective on science as a way of discovering the world, one which emerged from practices, processes, meanings and experiences.

These vignettes also exemplify the features of distributed leadership (identified by Woods et al., 2004), especially considering the Emergent Property one “where people work together in such a way that they pool their initiative and expertise, the outcome is a product or energy which is greater than the sum of their individual actions” (p. 441). Due to this community of practice being organized under a distributed leadership approach, the partnership was successful in being contextually responsive (see also Barbu et al., in press). This work revealed that as individuals are brought together with the explicit purpose of cogenerating plans for collective action, and their diversity enabled them to both lead and contribute to new initiatives according to their expertise (Woods et al., 2004), these other two features of distributed leadership (Openness of Boundaries and Leadership According to Expertise) were the ones that created permeable spaces for the individuals to span across their boundaries (Klein, 2021).

6. Boundary-Spanning: from Concepts to Challenges

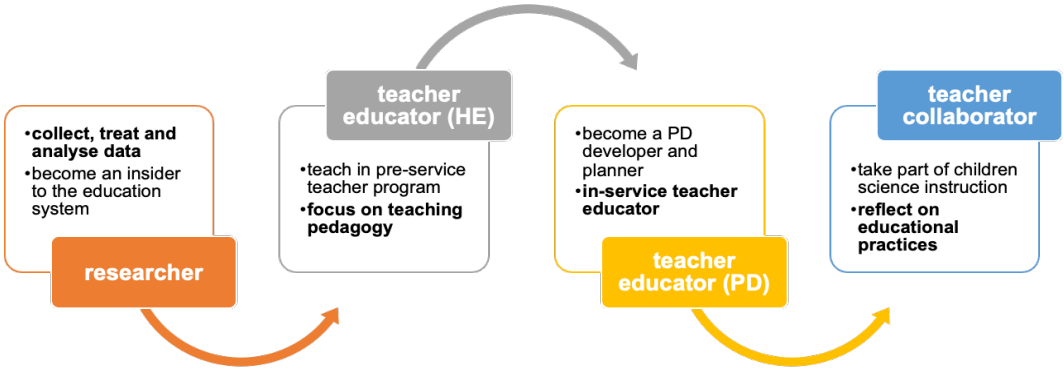
Boundaries and boundary-crossing through interaction can be understood as dialogical phenomena in which differences can serve as resources for learning (see Akkerman & Bakker, 2011; Engeström et al., 1995). In the sections that follow, we draw upon data resources from written reflections and team dialogue layered together with theoretical perspectives as well as those gleaned from research literature to narratively unfold illustrative moments of our boundary-spanning. We move between speaking about ourselves in first person, to taking a view on the data resources and narrating vignettes from a third person voice, to enable a broad perspective on the data and our experiences.

From the University side, the spanners are a Doctoral Researcher and first author (Maiza), a Full Professor and second author (Chris), and, from the Ministry side, a Center Teacher-Leader and third author (Thierry). Chris has research, higher education teaching and administrative duties, and within this role, she can position her team in a collaborative structure that enables boundary-spanning such as encouraging and facilitating co-teaching (both in pre- and in-service education courses) for Maiza, whose primary duties are oriented towards her PhD research, and Thierry, whose primary duties are teaching elementary school students. Co-teaching creates a context for boundary-spanning, as we each come together across a range of differences to cogenerate learning opportunities for pre- and in-service teachers.

In examining the case of the co-development of the workshop on science and language, the ways in which Maiza and Thierry came together across differences to span boundaries become evident. Maiza is a trained secondary school language teacher, and her current role as teacher educator (for pre-service and in-service elementary teachers) spans both her current duties as researcher and her previous experiences as a school teacher. Even though the process of teaching in all levels is concerned with the learning process itself, the activities within teaching (development, planning and delivering courses) differ when considering the school, the higher education and the continuous education (adult education) contexts. For example, one key aspect of being involved in teacher education (both pre-service and in-service) is the need to plan the transfer of skills and foresee impact (Caffarella, 2002; Kirkpatrick & Kirkpatrick, 2006), which is not typically part of teaching in school context. Figure 24 illustrates the evolution of boundary-spanning activities[18] that emerged over time through Maiza's co-development and co-teaching of the *Science and Language* workshops with Thierry.

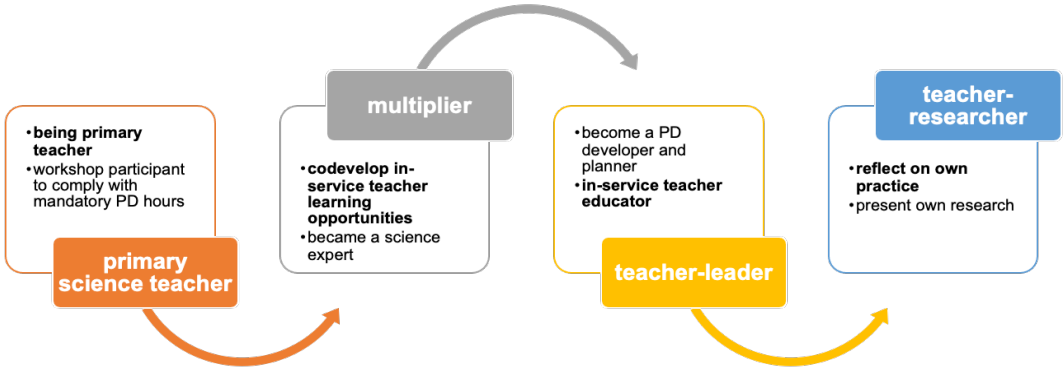
[18] The actions that the spanners are engaged in to facilitate the boundary-spanning are bolded in Figures 24 and 25.

Figure 24 – Boundary-spanning case of the researcher



Boundary-spanning through the SciTeach Center as a teacher educator creates a space for Thierry to transition from elementary science teacher to Teacher-Leader. He is an elementary teacher with duties of substituting colleagues and taking part in the leadership of a program that brings technology education activities to elementary classes. When he first attended a workshop in the SciTeach Center, he was complying with the requirement of the ministry that teachers attend professional development workshops each school year, yet, over time, he moved into taking part of the SciTeach Center's Multiplier initiative (*Multiplikatoren Netzwerk*), which enabled his transitioning from workshop participant to workshop co-developer/planner/deliverer. Through these boundary-spanning activities, he also spanned further over time to become a SciTeach Center team member, through the collaboration with the Ministry in which he has detached hours from his teaching duties to work at the SciTeach Center (Figure 25). It is within this space where the boundary spanning-happened, as he came to the Center and took the role as Teacher-Leader.

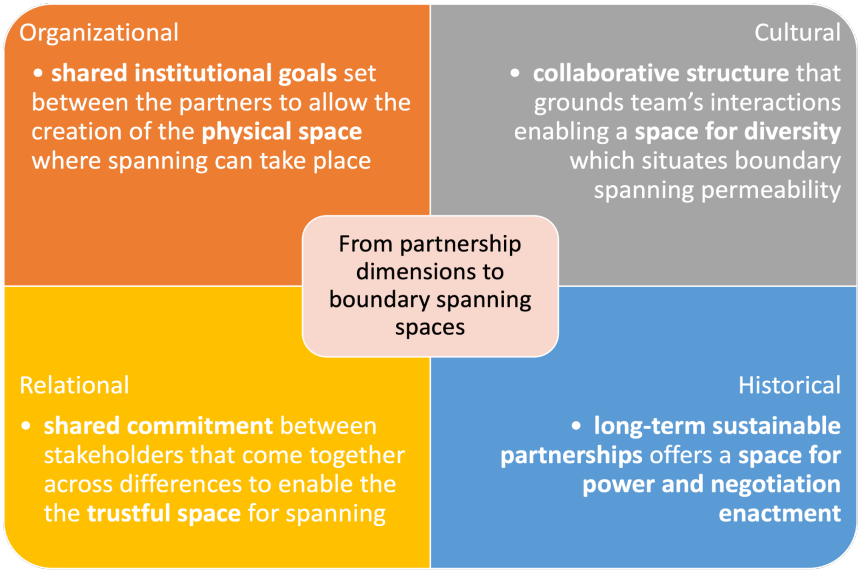
Figure 25 – Boundary-spanning case of the teacher



We position the SciTeach Center as a third space that mediates boundary-spanning in a process that is facilitated over time and through dialogue (see Gutiérrez et al., 1999). As both the researchers and the teacher are spanning boundaries through the collaborative co-construction and co-teaching of professional learning opportunities, they have to negotiate with colleagues their availability and workload as they enter this third space, the school-university partnership itself. Considering the partnership's organizational, cultural, relational and historical dimensions

(Wegemer & Renick, 2021), the SciTeach Center is a third space where the core partnership stakeholders met and could span a range of boundaries (Figure 26). This was enabled by the spanning of the senior researcher to create this space, a structure which evolved through the ongoing spanning of the members that dialogically led to new structures over time and through collaboration. The Center's physical space created a space for discourse where trust and learning permeability emerged as key features within the team's interactions, and, due to a long-term sustainable partnership structure, power and negotiation enacted together with distributed leadership to lead to the ongoing evolution of spaces that facilitated boundary-spanning.

Figure 26 – Boundary-spanning related to the partnership dimensions



Note: adapted from Wegemer and Renick (2021)

Through the process of Reflect-Dialogue-Act, the SciTeach team had an ongoing process of writing individual reflections that were used in dialogue to unpack a range of issues related to our work with teachers and our own professional learning. Themes related to boundary-spanning were visible in these, as they revealed reflections on our roles and positionalities. For example, Chris referred directly to the work within the school-university partnership: "I have several roles in the SciTeach Center. First and foremost is that I am one of the teacher educator members of the team," while the two other spanners referred to their own experience as teachers: Maiza noted "I'm a school teacher with experience within international context but still an outsider as of Luxembourg"; and Thierry, stated, "I'm a substitute teacher (officially)." All three boundary-spanners related directly to their roles within the SciTeach Center to the goal of this third space: to support science teacher continuous education, through co-planning and co-teaching of teacher education workshops as well as the co-development of different Center initiatives (Chris), by researching how to support teachers for multilingual contexts (Maiza), and accessing a multitude of aspects and levels of educational system throughout the involvement in its many areas (Thierry).

When reflecting on shifting roles, all participants referred to their boundary-spanning and -crossing as a continuum on their own professional learning process as Maiza listed her shifts within the circle of being colleague>leader>teacher>researcher>colleague and Thierry acknowledged directly the spanning *"*by acquiring new skills over time and by exchanging constantly with a team of such diversely skilled members, one can for sure say that his field of this very own role is expanding." Chris reflected on needing to shift and reach out as a part of her learning process:

> My role as researcher often encompasses being a teacher educator, and, in that role, I need to shift to reach back to my experiences as a classroom teacher while, at the same time, reaching out collaboratively (through co-teaching) to learn from the experiences of the people I am co-teaching with.

By addressing the team dynamics, Chris was able to connect with a previous research (Wilmes, te Heesen et al., 2018), which reflected the collaborative structure of Reflect-Dialogue-Act as fundamental for enabling the boundary-spanning in the spaces created within the school-university partnership.

The three boundary-spanners reported here as participants of the case study within a school-university partnership reflected on their boundary-spanning when writing reflection pieces on the roles taken and role shifting. Equally important to these reflections, we need to acknowledge that the space (the SciTeach Center as third space) and the conditions (the team functioning as a community of practice and under distributed leadership, and the school-university partnership being a sustainable structure) are key elements to enable this boundary-spanning.

7. Discussion and Final Remarks

The vignette presented above is from a group dialogue that contributed to the identification of a critical structural challenge, one which has become key to trying to understand how to balance the struggles between the instructions of languages and science: the profile of the teacher, as language teachers are mainly the classroom teachers (*Titulaires*), while science is more often taught by teachers who might teach in different classes (*Surnuméraires*). Important to note is that this is only one piece of data from a longitudinal study which confirms that through dialogue, team discussions emerge as relevant data that reveals that the approach of reflect-dialogue-act as situated within a structure of co-teaching plays a key role in boundary-spanning in the school-university partnership.

Considering the SciTeach Center at the macro-level (as the umbrella school-university partnership that hosts several initiatives) and its work on professional learning offerings as a meso-level activity, this chapter explored the development of an in-service professional learning course

about science and language as a micro-level activity, to unfold a structure grounded in collaboration and dialogue that enables boundary-spanning. The school-university partnership emerged as a third space created by community and leadership, where the SciTeach Center is not only a physical place that created to support elementary inquiry-based science education, but it is the space where teachers and researchers came together, interacted, spanned and learned, in a process that was enabled through the permeability of their traditional siloing.

School-university partnerships can become structures that facilitate transformation, and, in this case, through boundary-spanning. We note interpretively that such structures often are not easily fit within the institutional contexts of universities, and creating and developing opportunities for teachers and researchers to work together is a boundary-spanning process in and of itself. It is from the movement between Chris' research and teaching duties that the negotiation needed between the institutions for the school-university partnership to be established and continued can take place, in a process which also exposed her own boundary-spanning, through the continuous education initiatives created through the SciTeach Center. The work done within the partnership has enabled a continuum to be opened to establish the grounds for the work of the Center, as being *Teaching grounded in research and Research grounded in teaching*.

Through the diverse perspectives of the team and the structures based on co-actions (co- being a prefix indicating the meaning of together, joint), co-teaching creates a space for teaching, learning, and learning to teach to come together (Roth & Tobin, 2004) as co-teachers engage in ongoing reflective dialogue to further their own praxis. This is built upon the objective of facilitating professional learning opportunities for elementary teachers that are as close to participants' needs as possible, to support inclusive and equity-oriented school practices. In working towards such contextually-responsive professional learning opportunities, the importance of the team structures focused on co-developing and co-teaching PD offers becomes clear, alongside the relevance of developing long-term sustainable and transformative school-university partnerships.

Examining a school-university partnership in Luxembourg: supporting primary science education in times of uncertainty[19]

This article examines a school-university partnership at the SciTeach Center in Luxembourg that supports elementary teacher professional development in science education. The partnership operates as a third space, enabling collaboration and boundary spanning between researchers and teachers. The article explores the conditions that sustain the partnership and allow it to address emergent uncertainties. It highlights the importance of the partnership to be a community of practice, fostering collaboration and shared responsibility. The partnership also embraces distributed leadership, allowing for the negotiation of roles and expertise. The article discusses the contextual complexities and uncertainties faced by teachers in Luxembourg, including language diversity, teacher profile and changing curricula. It demonstrates how the partnership navigates these uncertainties by creating a safe and trusting space for dialogue and reflection. The article also emphasizes the longitudinal nature of the partnership, which enables the development of structures and initiatives to be contextually responsive. Overall, the article argues that the partnership's collaborative structure and responsiveness to uncertainty contribute to its sustainability and effectiveness in supporting teacher professional development in science education.

Keywords
school-university partnership
collaborative structures
responsiveness
uncertainties

This contribution presents research that focuses on a school-university partnership that supports primary teacher professional development in science education in Luxembourg. The research aims to explore the collaborative structure of the partnership, the contexts in which it operates, and the conditions that contribute to its success in responding to emergent uncertainties. This partnership is based at the SciTeach Center at the University of Luxembourg (hereafter The Center), a teacher education resource centre that is dedicated to supporting the teaching and learning of science at the primary levels in Luxembourg. The Center can be viewed as a third space (e.g., Bhabha, 2004; Gutiérrez et al., 1999) that enables boundary spanning of its team members Trigo et al. (in press), through a collaboration between researchers and teachers that focuses on co-developing and co-teaching professional learning opportunities for other teachers in Luxembourg, a collaboration which creates a space for our own professional development (Wilmes, te Heesen et al., 2018.

In this manuscript, we look across different levels of the partnership to consider the guiding research question: What features sustain a school-university partnership that allows it to address emergent uncertainties? We propose that a partnership can be seen as a third space, both physically and relationally. It is a collaborative structure that brings together researchers and teachers to co-develop and co-teach professional learning initiatives for other primary science teachers in , and the analysis that follows will explore the ways in which the features of the partnership mediate responding to emerging uncertainties in our context.

[19] This manuscript has been submitted and accepted for review.

1. Establishing a background

When sectors join forces to respond to challenges or concerns, partnerships can emerge, and different sectors have different types of partnerships that can be established between institutions. Some examples within Education include Public-Private Partnerships (see Smith and Wohlstetter, 2006), Research-practice partnerships (see Coburn et al., 2013; Sjölund et al., 2023), and School-university partnerships (see Goodlad, 1991; Clark, 1991). In our national context, many of these partnerships are established involving different educational sectors and stakeholders, including non-profit organizations, university departments, and formal and informal schooling structures, among others. This manuscript explores a school-university partnership behind The Center by outlining its collaborative structure and building a case study as a continuum from networking and our work drawing on collaborative *co-structures* (e.g., co-development, co-teaching) (see also Fynn et al., 2022) to understand the ways in which these structures mediate possibilities to navigate uncertainty in our practice as teacher educators.

To identify and verify the existence of a research gap about "partnerships in primary science education", we conducted an exploratory search using the Education research databases (ERIC, Education Research Complete, and SocINDEX with Full Text) from EBSCO*host* (provided by our institutional consortium). We looked into papers from "Academic journal" within the "21st century" (as limit parameters) using three lines of strings. For the first string ["school-university" OR "research-practice" AND "partner*"], the generic search found 18.516 results. When adding the second string ["primary education" OR "elementary education" OR "primary school" OR "elementary school"], 838 results were reported. By adding a third string ["science education" or "science teaching" or "science learning" or "science instruction"], 32 results were retrieved and screened. Many of these results were excluded for being off-scope (n = 18).

The final screening excluded three other papers and identified 11 relevant studies. Three studies relate directly to working with in-service teachers on providing tools for their practice (Leslie, 2011; Norman and Nordine, 2016; Attorps and Kellner, 2017) and four papers report research done on different ways of collaboration between pre-service teachers, in-service teachers and researchers (Cozza, 2010; Kenny, 2010; Kittleson, Dresden and Wenner, 2013; Gilbert et al., 2020). Lastly, the other four studies connect with this work, through their focus on: two partnerships that deal with concepts of boundaries and framing (Penuel, Coburn and Gallagher, 2013); a partnership as an encounter of communities of practice from school and university (Hamza et al., 2018); a school-university intersection as a professional learning arena (Kellner and Attorps, 2020); and, a partnership that puts science and language in dialogue (Ralston et al., 2021). This exploratory search provided evidence of a research gap, to which we aim to contribute regarding the role of partnerships for primary science education.

As introduced above, the particular school-university partnership highlighted in this manuscript is structured around the co-design and co-teaching of in-service professional learning opportunities, focused on reform-oriented science education for primary teachers. We build on studies exploring processes and practices of science education through relational and collaborative structures, such as: Dare, Ellis and Roehrig (2018), who explore how educational reforms come into implementation (showing the case of integrated STEM curricular units) by pointing out how policies meet classroom challenges; and, relatedly, Manz and Suárez (2018), who address how to help primary science teachers to overcome the fear faced by the uncertainty of science through inquiry. Both studies make it evident that classroom challenges can turn into opportunities.

The gap between curricular reforms and its implementation relies on how teachers take action, and a support network can be valuable through providing learning and exchange opportunities. In this sense, Lowell (2023) argues that effective teacher professional development is based on the need to create a safe environment to be wrong (by building trust and community) and to build epistemic empathy for their students (by using metacognitive reflection through *the student hat* approach). Weaving teacher professional development with school-university partnership, Saltiel (1998) provides a foundation to understand collaborative partnerships and starts by stating that "There is magic in a collaborative partnership. It provides the power to transform ordinary learning experiences into dynamic relationships, resulting in a synergistic process of accomplishment" (Saltiel, 1998, p. 5). It is precisely this possibility of transformation that emerges from relational and collaborative partnerships that is of interest in our work, which is situated in a complex and rapidly changing context, as elaborated next.

2. Outlining the contexts

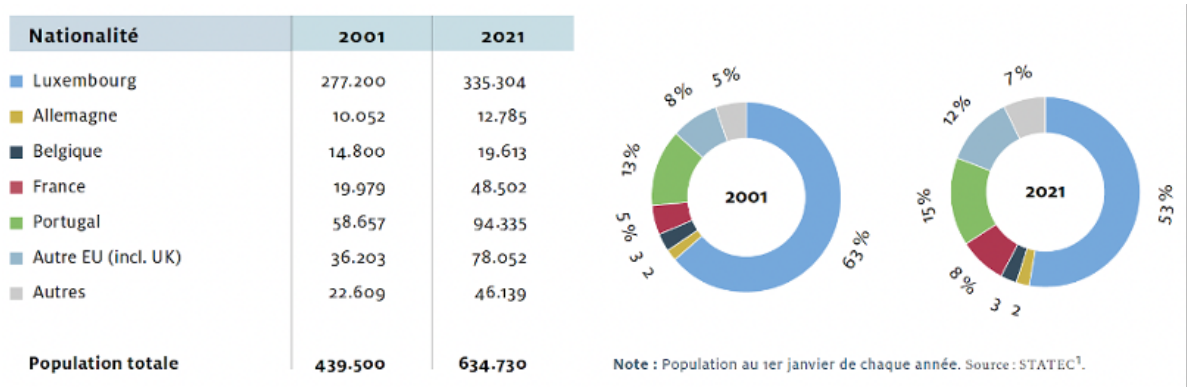
Several contextual considerations are important for understanding the research that follows, including the cultural diversity of the national context and complexities of a multilingual school system, as well as the guiding structures of the SciTeach Center, each of which come together to create a context for navigating uncertainty.

2.1. Luxembourg: a trilingual state where several ethnolinguistic communities co-exist

Luxembourg is a trilingual state, where Luxembourgish, French, and German are used in everyday life (Luxembourg, 1984). The country has a complex migration history due to its own history of borders being shifted as a result of different occupations over time (Thewes, 2017), and the population diversity was enabled by the waves of immigration to cover the labour market needs (Trausch, 2007), leading to the existence of different communities in Luxembourg. Foreign residents constitute almost 50% of the population (Statec, n.d.), and, as it can be seen below (Figure

27) the biggest ethnolinguistic minority is Portuguese speakers (e.g., Gómez Fernández and Quintus, 2020).

Figure 27 – Population by nationality in 2001 and 2021

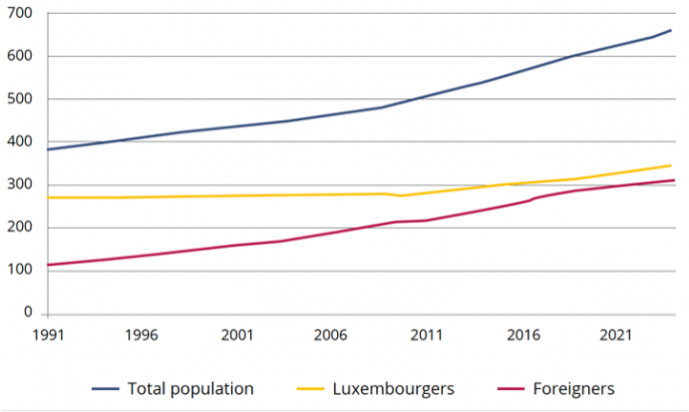


Nationalité	2001	2021
Luxembourg	277.200	335.304
Allemagne	10.052	12.785
Belgique	14.800	19.613
France	19.979	48.502
Portugal	58.657	94.335
Autre EU (incl. UK)	36.203	78.052
Autres	22.609	46.139
Population totale	**439.500**	**634.730**

Source: LUCET and SCRIPT (2022, P. 28)

Luxembourg's population has changed rapidly, both regarding the number of residents as well as the diversity (Figure 28). Aligned with the population's changing demographics, the student population has consequently increased its numbers of foreign students or students with a migration background (MENJE, 2022), creating a rapidly changing context with around 180 nationalities (out of the 223 nationalities worldwide) represented in Luxembourg's relatively small population of just over 660,000 residents (Statec, n.d.; Statec, 2023).

Figure 28 – Evolution of the population in 1.000 inhabitants

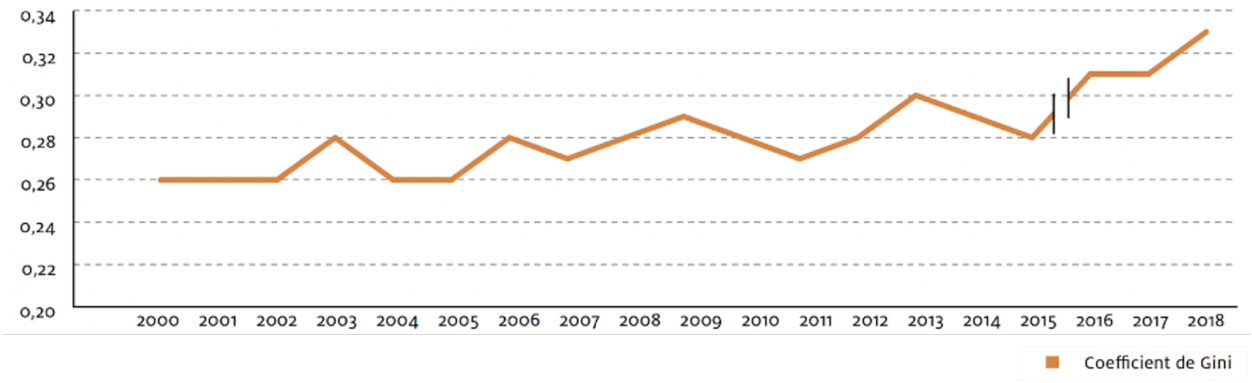


Source: Statec (2023, p. 13).

The cultural and linguistic complexity is also evident in elementary school (LUCET and SCRIPT, 2016, 2019, 2022), where approximately half of school children speak languages at home other than the curricular languages of instruction (MENJE, 2022). The most recent national report for education highlights that the socio-economic situation of families is also significant to student success and that "the increase in the risk of poverty and inequalities in Luxembourg could therefore also generate new challenges for the education system" (LUCET and SCRIPT, 2022, p. 31). The graph below shows the increase in the rate of socio-economic inequalities overtime (2000-2018,

Figure 29) by highlighting the Gini coefficient, which represents "the extent to which the distribution of income among individuals and households within an economy deviates from a perfectly equal distribution (...). Thus, a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality" (World Bank, n.d.).

Figure 29 – Inequality in Luxembourg



Source: LUCET and SCRIPT (2022, P. 31).

In addition to the crescent rate of socio-economic inequalities (Figure 29), languages play a key role in any migration scenario and, in education, the tension between the language(s) of instruction and the language(s) spoken at home can pose both learning challenges and opportunities for teachers and students.

2.2. Contextual complexities and uncertainties

Layering the student diversity with the fact that currently we are in a period of curriculum reform (the development of a new curriculum in Luxembourg is based on the *Project Plan d'Études 2025*), consisting of implementing even further competences (SCRIPT, 2023), and confronted with a changing world (post-pandemic, climate change crisis, emergent wars, etc.), changing practices set up a context of uncertainty and teachers in Luxembourg are facing these two contextual issues: a rapidly changing national context; and a changing national curriculum.

Colombo (2022) analyses the connections between social experience and its socio-historical context through looking into people's discourses about their experiences. He highlights that

> In general terms, we may say that uncertainty is connected to the social character of human experience, to the fact that our ability to relate to experience is always relational: it is always a being-with-others within a material context.
> (...)
> However, the growing centrality assumed by the question of uncertainty cannot be fully understood from only an existential point of view. If it is plausible that uncertainty can be considered a constitutive aspect of human experience, it is probably equally plausible that the meaning that it assumes in experience is linked to historical and social conditions. (139-140)

The rapidly changing context sets up uncertainty for teachers, as the diversity of cultural backgrounds of their students shifts and complexifies with each new school year. Our Center was created to respond to a need that emerged from a national curriculum reform back in 2011 (publishing of the curriculum – *Plan d'Études* – following education reform in 2009; see Luxembourg, 2009a), from which competencies were included in the curriculum (MENFP, 2011), outlining disciplinary as well as transversal competencies, which required teachers to change their practices across the disciplines, and in science to work towards inquiry-oriented approaches with children (European Commission, 2007). The uncertainty of a new curriculum reform is layered with the contextual ones, which can be seen through documents (such as reports) but also through stakeholders' shared perceptions, outlining what is happening in our context. This uncertainty scenario grounds the empirical interpretations that follow, from which we draw implications for teacher education practices and how we are addressing these uncertainties, while working to support teachers in reform-oriented instruction.

2.3. The partnership itself: the SciTeach Center

The SciTeach Center is a resource centre for both pre-service and in-service teachers dedicated to supporting the teaching and learning of science at the primary school levels. Located on the University of Luxembourg Belval campus, the Center provides teachers with access to educational resources in forms of both materials available for loan as well as teacher workshops offered as Ministry accredited professional learning opportunities (see Trigo et al., 2024). The work done at the Center towards teacher professional development is based on an agreement established between the University of Luxembourg (through the Institute for Teaching and Learning) and the Ministry of Education (through the Institute for National Education Training – IFEN), both committing to provide human capital as resources for offering these workshops (through the process of co-development and co-teaching). The SciTeach Center is at its core a living lab, dedicated to exploring the processes of teaching, learning, and learning to teach science at the early childhood and primary school levels. Through numerous research projects, researchers engage with teachers who are freed from their teaching duties one day each week, thereby being "detached" from their teaching tasks through IFEN to collaborate on the Center team and support professional development for other primary teachers through co-development, co-design, and co-teaching. The part from the university brings reflective analytical lenses from research, and the part from the school brings reflective field lenses from practice to come together through collaboration in an ongoing and evolving partnership.

This particular partnership can be viewed as both a school-university partnership (see Clark, 1991) as well as a research-practice partnership (Coburn et al., 2013), as the partnership not

only relies on putting stakeholders from the school and the university settings to work together but is oriented towards using the dialogue between research and practice as foundational (with the motto *Research grounded in teaching. Teaching grounded in research*). The main reason behind is that the partnership aim is to support the Luxembourgish competency-based elementary science curriculum (MENFP, 2011) and its transition to the new curriculum (in development and to be put in place within two school years), using an inquiry-based teaching approach (Bybee, 2014) and offering workshops based on topics, resources or teaching approaches. From the university side, the researchers commit with different percentage of our working hours to the Center (20-40% – professor; 30-60% – doctoral researchers; 60-100% – researchers) and, from the school side, the teachers have roughly 20% of their work dedicated to the Center's initiatives (through having detached hours from their classrooms).

Currently, the partnership members consist of eight researchers (one professor, two research scientists, one post-doctoral researcher, three doctoral researchers, and one pre-doctoral researcher), eight in-service primary teachers (three "Teacher-Leaders", the ones that have the detached hours detached; and five "Multipliers", who take part in a professional teacher learning program as participants, towards building a network of teacher educators and later offer their own workshops in a co-teaching format with a researcher), and two administrative staff. The teacher education team members collaborate to co-develop and co-teach professional learning initiatives provided by the SciTeach Center for other primary school teachers; and, in some cases, the Teacher-Leader team members also engage in co-research.

This manuscript explores the work done within a professional development course dedicated to connecting science and language. The processes of co-development and co-teaching included the dialogue between five researchers and three detached teachers (2022) and one researcher (Maiza) and one teacher (school year 2022-2023), respectively. The workshop has served as the basis for a doctoral study research, enabling the examination of the team's work as a school-university/research-practice partnership, drawing some conditions to why it sustains over time, which will be explored later.

3. Grounding perspectives of the school-university partnership to support science education in times of uncertainty

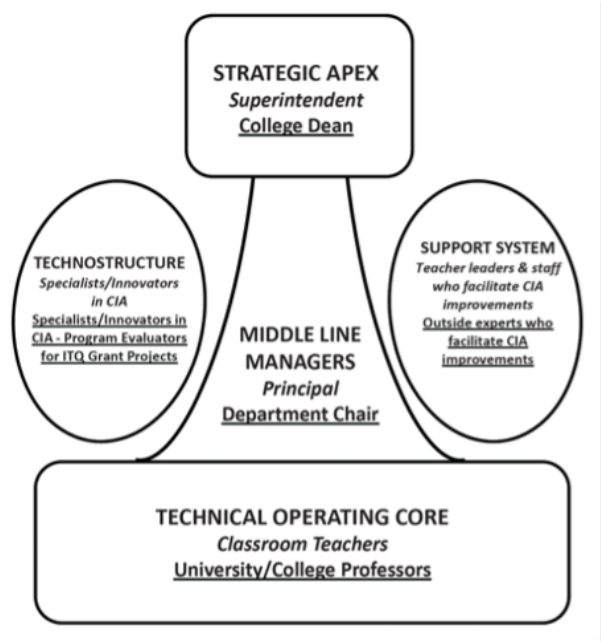
3.1. The partnership as an organizational third space

When talking about the partnership itself, we must think of it as partners coming together for a common goal. In the case of the SciTeach Center, which brings professionals from schools and the university together, the partnership can be positioned as a third space, both physical and relational. As a resource centre for teachers, it consists of an independent physical space, created

with resources provided by the University and funders (yet, not a school nor a university organizational structure in literal functional terms – Bhabha, 2004), but also a relational space as the constituting members are constantly reflecting together about the purpose of the space (not static, but a negotiated space – Gutiérrez et al., 1999; Gutiérrez, 2008).

Considering the framework presented by Mintzberg (1983) for organizations (the five parts are: strategic apex; middle line; technical operating core; technostructure; and support), Baker (2011) explored it to analyse **school-university partnerships** by, firstly, fitting both schools and universities into Mintzberg's framework (Figure 30).

Figure 30 – Mintzberg's 5-part framework adapted for schools and universities



Note: Baker (2011) adapted from Mintzberg (1983).

As this partnership emerges to respond to the educational context needs as an independent third space, we have to consider that it is a comprehensive organization positioned as a third space. By establishing that teachers and professors/researchers are considered the technical operating core of each organization (Baker, 2011), you need to consider that each core (from the schools, the teachers; from the universities, the professors and/or the researchers) is responsible for the outputs of its organization. However, these outputs are not always emerging from them (bottom-up) as other intra-structures (mainly the strategic apex) and external influences (e.g., government, agencies, policies) can directly affect their work (Mintzberg, 1983).

The essential work of university professors and primary teachers is linked to teaching duties, yet for different public targets (respectively, adults and children). In our case, our target group is teachers (mainly in-service teachers) and our work is based on dealing with educational tasks (e.g., curriculum, teaching method, student assessment, resources) at a metalevel (making

the teaching about the teaching), through creating space for sharing and exchange, focusing on teacher continuous professional learning opportunities.

Whilst the partnership is grounded on where the technical operational cores of these educational structures meet, the members of this third organization (the SciTeach Center) go back to their own organizations, shifting back to their primary roles. Nonetheless, each member goes back differently, bringing the newly shared repertoire and acquired expertise, enabling new positionalities within their primary organizations, mainly due to the permeability of their roles supported by their boundary spanning.

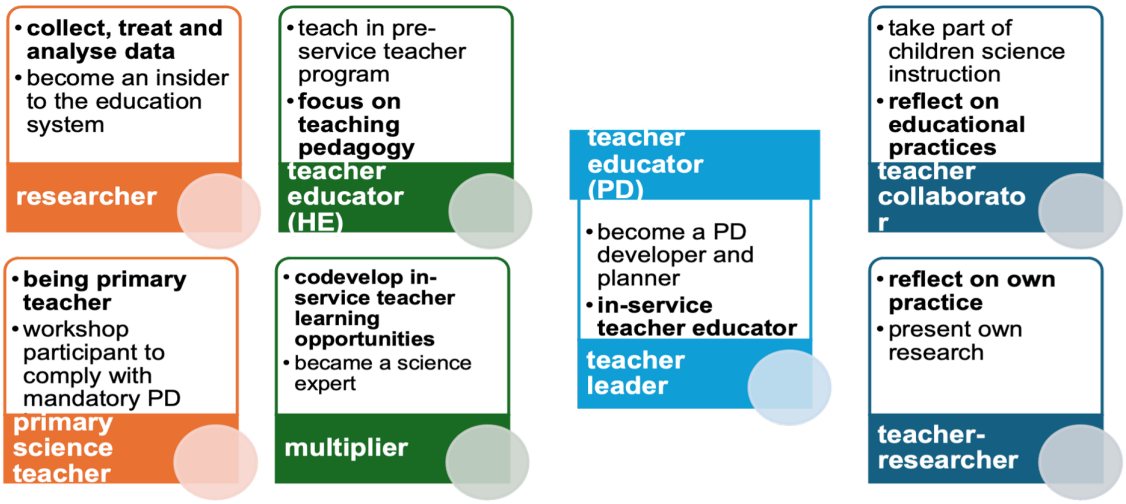
3.2. Distributed leadership and community of practice

The team members develop our relationship in the third space based on trust and care (Barbu et al., in review), establishing our work norms and collaborative structures, and binding as a social entity in itself. Furthermore, as the dedicated working hours are explicitly directed to the professional learning teaching process, the fact that all members are willing to meet every week for the development and reflective processes is additional evidence of our *Mutual Engagement*. By coming together to co-develop and co-teach, collaborate, and reflect, we are engaging in actions that are negotiated and become the reason we are bound, turning our endeavour into a *Joint Enterprise*. Finally, a *Shared Repertoire* emerges from the practice done together (offering professional development for others). All of these are the fundamental features of a community of practice (Wenger, 1998/2005).

Within the understanding that our partnership is a community of practice, the work done inside this partnership is guided by what Woods et al. (2004) determine as the three distinctive elements of distributed leadership: as the outcomes of the activities done in the community is more than just adding the resources and assets from the team – *Emergent Property*; as boundaries are fluctuant (including the leadership role), enabling all team members to take leadership or contribute to it – *Openness of Boundaries*; and, ultimately, as leadership shifts hands taking into consideration the skills needed to one particular initiative and the culture of trust in each other – *Leadership According to Expertise*.

The boundaries between the work of the researchers and the teachers (Penuel et al., 2015) within our partnership are spanned and crossed as we exit our role silos and meet to work together as in-service teacher educators (Figure 31).

Figure 31 – Boundary spanning of researcher and teacher



Source: adapted from Trigo et al. (in press).

Hamza et al. (2018, p. 170) argue that the partnership they investigated "suggests one way of reducing the gap between educational research and teaching through the emergence of practices where the roles of teachers and researchers become blurred". This study presents a partnership where our boundaries are permeable and we (teachers and researchers) evolve into each other's silos, and making sense of the roles of research and practice in the educational scenario

4. Methodological approach: methods, participants and datasets

This contribution is grounded on qualitative research approaches to inquiry (Creswell and Poth, 2018), in which critical ethnographic methods (Carspecken, 1996) were used for building a case study of a school-university partnership in Luxembourg. Data used here come from different sources and will be presented next, with a description of the participants.

4.1. Participants

Within the partnership, the researchers are Maiza Trigo, Christina Siry, Kerstin te Heesen and Ragnhild Barbu, and the teachers are Ed, Olga and Uriel. The workshop participants, who represent cases from interviews, are Quin and Sheldon. Aside from the researchers, all other participants portrayed here were pseudonymized.

4.2. Datasets

This research strives to explore the work of the team and look into this collaborative structure, and investigate emergent social phenomena by using the approach of analytic induction (Flick, 2018a). Aligned with the opening of the notion of triangulation (Flick, 2018b), data is addressed across a range of sources and methodologies by applying the notion of bricolage (Kincheloe, 2001; Kincheloe and Berry, 2004; Steinberg and Kincheloe, 2011). As different methodologies can each

reveal different features for analyses, bricolage allows for zooming in to the relational ways in which the partnership evolves at different grain sizes. The excerpts of data highlighted in this paper are presented as vignettes that draw on transcripts and narrative elaboration, and the data resources come from different sources of the partnership's activities and initiatives (Table 24).

Table 24 – Description of data foci, sources, and codes

Data focus description	Data sources		Data codes
Languages used by the team (after team meetings)	Field notes	researcher-teacher exchange	Nov21NLK Dec21DMM
Participants' profiles and reflections on science teaching (during/after co-teaching the workshop *Science and Language*)	Field notes	workshop co-teaching	Oct22W1-1 Dec22Wdf20 Feb23W2-1 Mar23W2-2 Apr23W3-1 Jun23W3-2
Discussions on the concept of "what is science?"	Field notes	team meeting	Jul22Sci
Researcher (1) and teacher (2) agreeing on the use of German	Video transcript	workshop planning	VT20220426
Researcher (1) and teacher (2) discussing about the need to use science as a universal language and include different forms of documentation	Video transcript	workshop planning	VT20220426
Individual reflection of team's achievement during 2022-2023	Video transcript	team reflection	VT20230712
Perceptions about the teacher profile, the separation of subjects and the lack of emphasis on science teaching in Luxembourg schools	Interviews		Case Sdc Case Qsn
	Video transcript	workshop planning	VT20220823
Observation of Uriel's posture during the interviews	Observation notes	interview Case Sdc	Oct23Sdc
Use of different languages in the workshop	Memos from videorecording	team meeting	20220125TMm
Reflection on personal language situation and the complexity of language use in Luxembourg schools	Memos from videorecording	team meeting	20220315TMm
Team discussion about the concepts of *interdisciplinarity* and *inquiry-based science*.	Memos from videorecording	team meeting	20220125TMm 20220322TMm 20220426TMm
Discussions on the concept of "what is science?"	Memos from videorecording	team meeting	20220315TMm

Note: description from datasets.

The team meets on a weekly basis and reflects on its work annually, and all meetings are video recorded. The team is multicultural, and all members are plurilingual, and as such, our exchanges

move across several languages, with our meetings typically beginning in English, and then participants using the languages they feel most comfortable in, often leading to extensive translanguaging in our exchanges. Aligned with our commitment to bricolage, diverse data resources were analysed with differing methodological approaches. Videos excerpts on the discussion about the development of the workshop *Science and Language* from team meetings (using the principle of zooming in – Roth, 2005) were treated through memoing (Saldaña, 2016) and from team reflection and workshop planning were coded through content analysis (Bardin, 1977/1979). Field and observation notes were treated using open coding (Glaser, 1978; Strauss and Corbin, 1990). Interviews were coded through content analysis and microanalysis (Green, Camilli and Elmore, 2006; Lejeune, 2019) was applied to focus on linking data about the concerns that emerged as themes across data sources. Data also have revealed how the features of the umbrella partnership unpack on its microlevel, through the work of a team and the collaboration between a teacher and a researcher to co-develop, co-teach and co-research an in-service teacher workshop.

5. The existing conditions of our partnership to sustain itself and enable responsiveness: findings

Ethics approval for the first author's doctoral research project, SuperSci, was received during the second semester of the school year 2021-2022, after which point our team began the co-development process for a new workshop focused on Science and Language, and this process is central to our analysis, as the vignettes that follow build from episodes where the workshop development recurred as a topic during our weekly team meetings throughout one semester. The co-development process brought to light challenges and opportunities related to the topic of language as relevant for the primary science teaching context. A thematic clustering done from data analytical memoing of team meeting video recordings through different stages of the co-development process (which is unpacked in later sections) revealed recurring themes, and we present two of these that were central concerns: *the use of languages* and *the teacher profile.*

5.1. Views on the role of language for science and the place for interdisciplinarity: a pedagogical uncertainty?

A concern that recurs in co-planning conversations relates to the question of what language to use for the workshop, which was consistently about the dichotomy between using English (our main working language) and the official language of instruction for primary science (German). This is shown, for example, by Maiza's expression of apprehension of not being able to speak German (even though she could support in French, which is another language used in primary level): "*One thing is that we, this might be the first one that we could offer in English, and have the option to*

have support in German and, of course, Luxembourgish for the detached [teacher] (...). I could offer French also" (20220125TMm). This could lead to a bigger workload for the teacher and might raise challenges for reaching primary science teachers when offering professional learning opportunities in a language other than the language(s) of instruction, as also recorded in Maiza's journal, through reflective notes after each exchange with the teachers, "*English won't work for Luxembourug teachers*" (Nov21NLK). At a later point, during a planning meeting, it was agreed that between Maiza, Ed and Uriel that "We will do that [workshop] in German. Remember that we [team members during team meetings] talked about the [issue of] language of instruction [not being used in the workshop]" (VT20220426).

This concern about the use of different languages returned into the dialogue in two related ways as the conversation unfolded two months later, in March 2022: the outline of the complexity of the language situation from a researcher and the linguistic diversity awareness from a teacher during a workshop Chris outlines the complex language situation in primary school in Luxembourg as often being linear in teachers' practice: teachers use first Luxembourgish, then German, and French; adding that there is most likely the existence of at least one other language in many children's repertoires. When reflecting about the fact that more pre-service teachers have these three languages and often a fourth and even fifth language in their repertoires yet seem to push back the use of other languages than the ones of instruction. Chris echoes this complexity of how "o*ur kids here are positioned to use and learn languages is very different than what teachers might empathize with or know themselves*" (20220315TMm).

Becoming aware of the personal language situation represented a milestone for Olga, and she expresses a wow-moment, as she builds from Chris's comment, reflecting back on a presentation by a previous doctoral researcher about an activity she did with students about the languages they use daily (using an outline of a body to express the diverse language uses in their repertoires). For Olga, she hadn't "*realized before what the students are going through, before seeing that presentation [about activity of a language profile]. And I think most of the teachers doesn't realize because we had too much in our languages. We had to, we know how to express, not always in English, but most of the languages, we know how to express and if we start with the language, then we are in that language. But I don't think that that's the, um, that's the situation for our kids"* (20220315TMm). This need for linguistic awareness connects to the tensions and complexity of the language landscape. The fact that primary pupils have to deal with three languages in school and, in many cases, have at least one other language in their repertoires, made Olga reflect that this could be something that needs to be "discovered" by other teachers, then suggesting that the activity of doing a language profile in a teacher professional development

(TPD) workshop could bring awareness of the complexity of the personal language situation and openness to reflect on the use of languages by their pupils.

At a later point, during the co-development of the workshop description to be submitted to IFEN for accreditation and dissemination, Uriel adds to the discussion on language the need to use science as a universal language, to which Maiza emphasizes that a range of documentation approaches should be included as a key point to demonstrate forms of communication other than writing, saying "*we also were talking about ways of documenting so we want to show them that they have a lot of opportunities to document besides verbal documentation, right?*" (VT20220426). This was built from the first team discussion in which the dialogue between science and language was outlined through the use of different forms of documentation, as we reflectively considered how we can use science for language learning and language for science learning through acknowledging the need for interdisciplinarity. This is seen, for example, when Chris comments that "this idea of documenting and lots of different ways and documenting as being one way to link language and science" and added a recollection from a previous conversation with Maiza about "s*ort of perspective of thinking about (...) when it's truly interdisciplinary, we can't tell is the focus on the language? Or is the focus on the science?, but rather it's on both*" (20220125TMm).

During the co-development of the workshop *Science and Language*, the collaboration between teachers and researchers, grounded on the school-university partnership and the emergent third space, allows for openly raising and addressing concerns about the condition of the changing classrooms and national contexts, the growing linguistic complexities, and how we can work towards being responsive to these. The rapidly changing context sets up uncertainty for teachers, as the diversity of cultural backgrounds of their students shifts and complexifies with each new school year. Even though the uncertainty is directly linked to the teachers' daily work, the partnership sees the need to support primary teachers by offering professional development courses. This allows for responding to the uncertainties by supporting teachers during these rapidly changing contexts, by working towards inclusive practices that are responsive not only to the expected plurilingual pupils that are already in the system, but also welcoming the children that are victims of forced migration (e.g., war in Syria and, most recently, in Ukraine and Palestine).

5.2. New views on teacher role and views on the curriculum: a structure enduring challenge/contradiction or a scientific uncertainty?

Primary teachers in Luxembourg have less teaching hours contractually than the mandated hours of schooling for pupils, and this leads to a school classroom having at least two teachers: a *titulaire*, main teacher who usually chooses to focus on language teaching; and a *surnuméraire*, who ends up (not often by choice) teaching subjects not included in the national standardized exams, such

as science, arts and/or sports. These two types of teacher roles have different profiles and related tasks. The teacher profile emerged as a concern firstly during the workshop co-development process, and the notion of how separately these two types of teachers often work was reinforced during the workshop planning and disclosed during the workshop itself, when participating teachers acknowledge that "I teach science, but my students don't know enough [lang 1]" (Feb23W2-1; Mar23W2-2) or "I don't teach science, but I came with my colleague who teaches it" (Apr23W3-1, Jun23W3-2). Finally, this re-emerged during the interviews (cases Sdc and Qsn), when Sheldon recalled the process of development of the Plan d'Études 2011 for science teaching (*Éveil aux Sciences*) and revealed that "what happened [was that] the *titulaire* teachers gave the topic [of science] away and there came a *surnuméraire* who taught *Éveil aux Sciences*", serving as evidence of the gap between the subjects and confirming that "the feeling that science often doesn't really exist for teachers. It's like a stepchild. So often teachers don't want to give science [lessons]", as stated by Quin.

One particular participant, who recently graduated from the bachelor programme to become a primary teacher and was in his first year of teaching, expressed his concern about the teacher profile being linked to the choices of pedagogical approaches to teaching science. The participant talked about the push back he felt from teacher colleagues when he tried to use the inquiry-based approach to science teaching, while describing the "burning feeling" of not being able to overcome the gap between science and language when being new to the job (Oct22W1-1; Dec22Wdf20).

5.3. Supporting teacher reflection and preparedness to tackle uncertainty: what role for school-university partnership?

Through a co-generated reflection on the team's accomplishments for the school year 2022-2023, it was possible to revisit the notion of the partnership as a community of practice. When Uriel expresses himself about his experience within the team, he started highlighting that what he likes the most is that "we are such a diverse team with a common ideology and we have access [to each other]... because we are so different and we are complementary to each other, and we are accepting one another and we reach out" (VT20230712), shining a light on how we are engaged and bound to each other. The existing feeling of reliability, security and trust indicates that this third space relies on the relationship developed through the collaboration, serving as evidence for what is the meaning of the SciTeach Center for us, as a team.

Enabled by distributed leadership, negotiation is part of the collaboration, and team members negotiate leadership by expertise, as we become aware of how we impact each other's work. This consistent bouncing impact and boundary permeability of our work are crucial for becoming aware of where we meet outside our silos (outside the university and outside the school)

and how we are changed when we go back to them. Uriel outlines this open-minded setting and our boundary spanning process when he states that

> what was really for me very new and uncharted grounds was working with or having access to the work that is being done on the other level of research, which I have never had access to (...) because she [the researcher] was kind enough to involve me and to show me, to make me in a way aware (...) what simple stuff that we usually do as teachers, what kind of impact, how you can describe that, how you can implement it into research, I was not aware at all (...) I think, okay, the workshop is done... [and] she [was saying]: – No, no, you said that, and be aware you can... (...) And afterwards, she convinced me of it. And it's still very... not strange, but it's almost untouchable for me because that's not the way... I think those are not my reflexes, but now, through this approach of the Language and Science workshop, I also only scratched the surface of your work [research]. But I could have a glimpse of what is being done and what is... (...) And yeah, I'm glad not only to work with peers, teachers, but also to work with other ones [researchers]. (VT20230712)

With the start of the school year 2023-2024, Maiza (the doctoral researcher) started to collect the workshop participants' perceptions about the relevance of the dialogue between science and language for their practice. Uriel was involved in this data collection process, further supporting the spanning of his boundaries as a teacher. The first step was a negotiation on how the interviews were taking place and what the roles would be for Maiza (the researcher) and Uriel (the teacher) within the interviews. Whilst the interview was predominantly in English, there were expressions spoken in German and Luxembourgish, where the presence of Uriel nurtured the space for the reflection with the interviewees in their comfort language. Maiza observed that, when Uriel took part of this first interview, there was a key moment when he changed his posture from helping with the language to the role of an interviewer, spanning his boundary and embracing the "teacher-researcher" role. This posture shift (highlighted next below) was triggered by the interviewee's comment that "*Science education is not, has no priority in* Luxembourg *school and it has no priority in other schools in other countries*" (Case Sdc), as described in Maiza's field notes as: "*passive posture – interaction with the interviewee to help with the language understanding – relaxed sitting back posture and note taking – gesture of insight– sitting forward and note taking*" (Oct23Sdc).

Adding to the foundation of this successful collaboration between teacher and researcher is the existence of the sense of belonging, as Uriel, at the end of the school year 2022-2023, reflects "It feels like a big acceptance of yours that I have the right and the honour to work with such a team" (VT20230712). Ultimately, it is the combination of the partnership being a community of practice that allows distributed leadership, based on nurturing boundary spanning that leads to a contextually responsive approach, which both respond to shifting contextual needs and related emergent uncertainty.

The dialogic design-based structure across the partnership creates a place that enables us to come across differences and develop a shared understanding about points that emerge from our co-development process, as questions crystalize in dialogue that serve as tools for generating

shared understandings that are central to our collective work, such as "what is science?", "what do we mean when we say interdisciplinarity?", and "do we all mean the same when we talk about inquiry-based science?". This space enables critical discussions of grounding concepts behind our work, with the central piece for the partnership not being the content of the discussion as such, but rather the phenomena of having the space to discuss in an ongoing, spiralling process. The establishment of a shared repertoire (Wenger, 1998/2005) leads us towards spanning our boundaries as we unfold our own professional development from the process of co-developing and co-teaching professional development for others (Engeström, et al., 1995).

5.4. Expanding the evidence of a sustained partnership collaborative structure

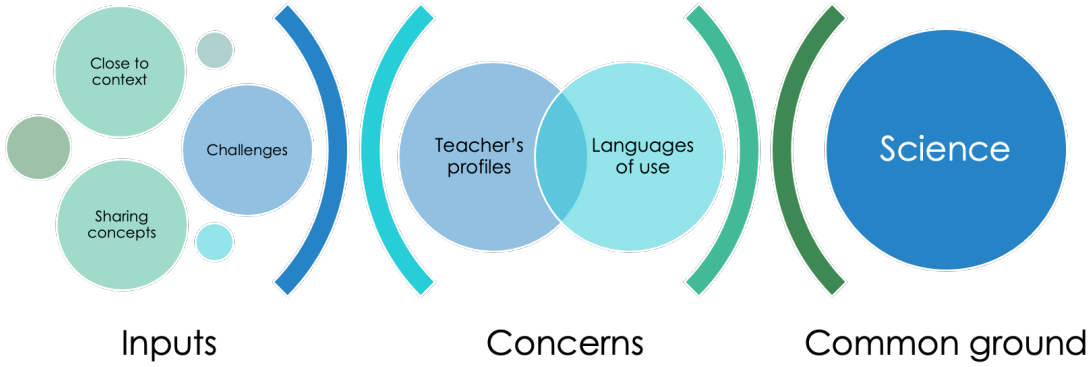
The structures of the partnership sustain beyond this microlevel study. While Maiza was working on treating the data from the workshop development (micro level), two other colleagues were also analysing data from the work done in different levels within the partnership.

On a macro level, where the SciTeach Center was hosting the funded project **Sci2School: Science Teaching to Support Children Learning Science**, Kerstin (the project coordinator) was preparing the project final report and put together reflection pieces and fields notes to reveal "What have we learned from establishing partnerships with school to provide professional development offerings?". Two main dimensions emerged from the data: i) the critical relation between teachers' Time-Engagement, which acknowledges the need to develop a relationship between the partners in order to build the sense of community; and ii) the responsiveness to the field, which reflected the need to be close to the field in order to respond to its needs, considering the benefits of developing resources together.

On a mezzo level, Ragnhild examined the work of the team across different initiatives, building a case study on collaboration in a time of crisis (responsiveness during COVID-19). Looking into team meeting recordings from early 2020 (Feb 4th – July 14th), she observed two main points: the team collaborative structure and how initiatives emerge in the work of The Center. By matching the national events (such as school closure and resume of whole class instruction) to the development of the Center's initiatives during this time, Ragnhild and Maiza started to discuss about their findings (mezzo and micro levels, respectively), and they layered the notion of being able to be responsive to the partnership being a community of practice in a manuscript (Barbu et al., in review).

And, going back to the micro level, looking at the development of a workshop to retrace a collaborative structure, while investigating "What themes emerge from our discussion while co-developing the workshop *Science and Language*?", Maiza was able to cluster three thematic dimensions: inputs, concerns and common ground (Figure 32).

Figure 32 – Thematic clustering of recurrent topics discussed during the workshop development



Note: from thematic analysis of analytical memos

The main goal to present here is not the content of each dimension, but point out that the topics, especially the concerns and the common ground as they were used in this manuscript, could only emerge in the team discussions based on the existing: **collaborative structure** (reflect-dialogue-act – from Wilmes, te Heesen et al., 2018); **access to each other** (through the notions of ethics of care and equity of voices, considering the distributed leadership framework from Woods et al., 2004); and **trust and commitment**. (from being a community of practice – aligned with Wenger, 1998/2005). Showcasing some aspects across the partnership levels that sustain the partnership work provides evidence about the partnership being a shared space, where people come across differences to work together upon a shared commitment and goal, being able to establish itself as a structure that can be contextually responsive due mainly to its closeness to the field.

6. Discussion

In reflecting on the guiding question for this manuscript, *What features sustain in a school-university partnership that allows it to address emergent uncertainties?*, several factors contribute to the successful collaboration between teachers and researchers, such as:

- negotiating a third space as a safe place to tackle concerns;
- sharing the process of co-developing and co-teaching to be contextually responsive;
- being open to different languages at the same time being aware of language complexity;
- having the sense of belonging within a community of practice;
- acknowledging the role of distributed leadership and boundary spanning as key features

These factors serve as a foundation for establishing the conditions for the partnership to sustain through collaboration, as we come together to support our efforts in the SciTeach Center to navigate emergent uncertainties such as those introduced in the above vignettes. The school-university partnership creates a space that goes far beyond the objectives of supporting teacher professional development for science teaching, as in the co-development process, there is a

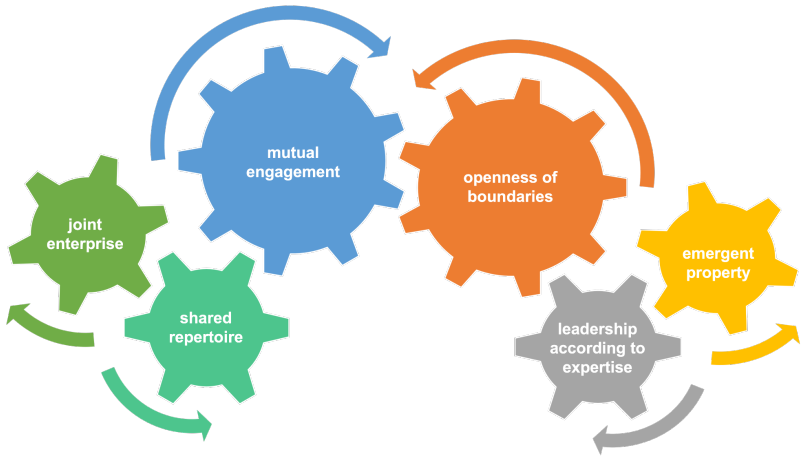
navigation of uncertainty that occurs in working towards shared goals. In this dialogic, iterative, and recursive process that emerges the space to highlight contextual complexities – in the case presented herein, as related to teacher profile and language use, for example – and thereby a reflexive opportunity to respond to shifting contextual complexities.

6.1. Entangling the community of practice and its distributed leadership within a third space

The partnership is a third space (both physical as well as relational) that enables its team members to come together as a community of practice and manage its initiatives to respond to uncertainties through distributed leadership. This first claim establishes that navigating uncertainties is linked to the condition of the partnership that exists within a negotiated third space**,** which is where distributed leadership happens, as we each come together as a community of practice to span our boundaries, enabling responsiveness as we take action to respond to uncertainties.

It is in our partnership that we acknowledge that the frameworks of communities of practice and distributed leadership function as the foundation wheel to our work (Figure 33). The togetherness mediated within the community of practice framework (including mutual engagement, joint enterprise, and shared repertoire) triggers and is triggered by the organizational dynamic aspects outlined within the distributed leadership framework (including openness of boundaries, emergent properties, and leadership according to expertise).

Figure 33 – Frameworks of community of practice and distributed leadership put together



Note: adapted from Wenger (1998/2005) and Woods *et al.* (2004).

This approach to our partnership values adaptability, flexibility and collaboration in order to address contextual uncertainties. We have to be open to engage in interaction in shared spaces, where initiatives can be discussed, tasks can be distributed, and professional learning takes place through exchange and negotiation. The sense of belonging is a contributing factor to successful collaboration. When team members feel accepted, valued, and honoured to work together, they are more likely to actively participate and contribute to the collaboration (Manz et al., 2022). This sense of belonging fosters trust, reliability, and security, creating a supportive and collaborative

environment for teachers and researchers to work together effectively (Cochran-Smith and Lytle, 1993).

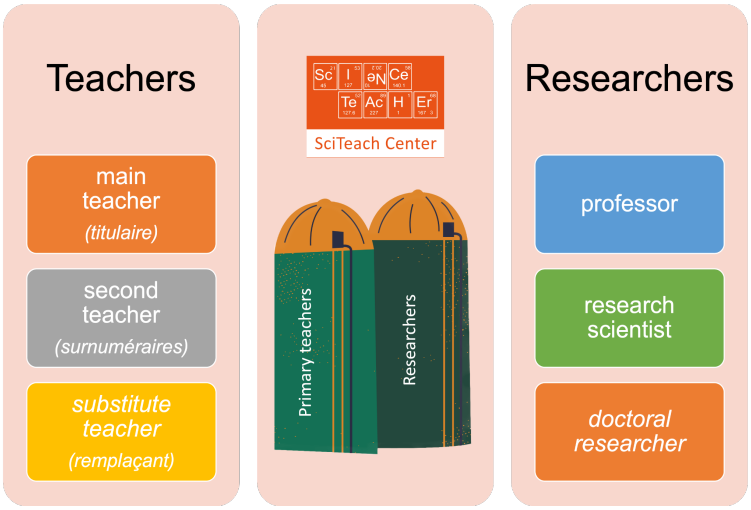
When we come together as individuals and engage in an initiative, we establish what actions to take, and we know we could not have reached the same result if we had done that in isolated work. Therefore, besides the collectiveness addressed by these frameworks, we also recognise that we change as individuals. We change ourselves especially by working together and spanning and crossing our roles' boundaries, and this interaction leads to our own learning (e.g., Engeström et al., 1995; Akkerman and Bakker, 2011).

6.2. Disentangling boundary spanning from collaboration and shared responsibility within a third space

The partnership is a space of collaboration and shared responsibility that allows its team members to span and cross their boundaries, enabling their own professional learning, which can be reflected on the response to uncertainty. This second claim establishes that boundary spanning through collaboration supports responsiveness to uncertainty and that uncertainty can foster productive collaboration, as for example revealed in a case study by Capobianco (2011), who highlights the role of collaboration and reflection between a teacher and researcher in an action research project.

Our research has shown how boundary spanning reflects directly on the collaborative work done by individuals and how individuals influence and are influenced by the permeability of their boundaries (Figure 34; see also Trigo et al., 2024), as people's changed perspectives and ideas shape what we do as a Center – allowing for responding to shifting contexts and related uncertainties. This work illustrates how collaborative approaches to teacher education provide a space to uncover, understand, and work with uncertainty in ways that work towards a contextually responsive teacher education praxis.

Figure 34 – Partnership participants, their silos and the third space for boundary spanning



Source: adapted from Trigo et al. (2024).

The importance given to boundary spanning in the collaboration between teachers and researchers involves reaching beyond one's own professional silos and engaging with different levels of research and practice. By spanning boundaries, teachers and researchers can gain new insights, share expertise, and develop a shared repertoire of knowledge and practices (Figures 31, 33 and 34). This boundary-spanning process can lead to transformative learning and the development of innovative approaches to teaching and research, capable of responding to contextual challenges and uncertainties. Herein, we have examined how a dialogic and collaborative structure to teacher education creates a space working with uncertainty as well as uncovering enduring structural considerations that emerge as contradictions – including the role of languages and the role of the teaching personnel.

6.3. Weaving the partnership factors to show longitudinal sustainability to navigate uncertainty and contextual responsiveness

The partnership has a longitudinal nature that allows for design-based processes over time, which lead to deep and refined understandings of the context and how to respond to and work within complex uncertainties. This third claim addresses the SciTeach Center as an ongoing partnership (over eight years to this point and continuing) that has been enabling a longitudinal design process, and, as we navigate uncertainty and create contextually responsive structures, we work towards finding ways to respond to and work with the uncertainties as tools for learning and reflection.

This contextually responsive approach allows for responding to changing classrooms and national context, as the partnership is a safe and trusting space that allows for raising and addressing concerns. This analysis has highlighted that the spaces to reveal the uncertainties create a space to come together in collaboration and work together to adapt our professional development offerings as well as our teacher educators towards a goal of being contextually responsive – both in terms of the science education practices that we are working to support as well as in regards the ways in which languages are navigated in our collective practice as a teacher education team. In uncovering and reflecting on these challenges together, a contradiction emerged (which is finding opportunities to productively navigate these uncertainties) and is challenged by the structural issues that become uncovered in dialogue around the two intertwined foci. Uncertainty highlights the tentative nature of knowing, learning and teaching, and creating spaces for dialogue around uncertainty allows for cogenerating new ways forward in our teacher education praxis

The confrontation between the use of languages in schools and the openness to different languages have shown that uncertainty of classroom settings can be addressed through awareness of language complexity. There is a need to recognize the complexity of language situations in schools, where primary pupils in Luxembourg have to deal with three languages in school (Luxembourgish, German, and French), often with language repertoires that extend beyond those

This awareness can help teachers and researchers understand the challenges faced by students and reflect on their own language practices. It can also lead to the development of strategies and approaches that support language learning and different uses in the classroom.

Adding to the systemic challenge of the use of languages, the teacher profile emerges as a structural challenge. The concern around this challenge cannot be solved within the partnership, but it is being addressed through different initiatives, such as the *Science and Language* workshop. As primary classrooms often have two teachers, the team recognizes that this leads to the separation between subjects and the lack of emphasis on science instruction. By discussing and addressing these concerns, the collaboration aims to bridge the gap between subjects and support teachers in teaching science with and without verbal documentation, while providing resources to put science and language instructions into dialogue.

7. Coming together across differences to navigate uncertainty: final remarks

In conclusion, the exploration of the school-university partnership as a third space created and negotiated (Bhabha, 2004; Gutiérrez et al., 1999) demonstrates the power of coming together across differences to navigate uncertainty in the field of education. Uncertainty highlights the tentative nature of knowing, learning and teaching, and creating spaces for dialogue around uncertainty allows for cogenerating new ways forward in our teacher education praxis. Finding opportunities to productively navigate these uncertainties is challenged by the structural issues that become uncovered in dialogue around the two intertwined foci. The partnership creates a safe and trusting place for teachers and researchers to collaborate, share expertise, and develop a shared repertoire of knowledge and practices in a third space. The success of the partnership lies in its ability to establish itself as a ***community of practice***, fostering a ***sense of belonging*** and ***trust*** among its team members, creating an environment where collaboration and shared responsibility and commitment can thrive. And, through the frameworks of ***boundary spanning*** and ***distributed leadership*** being layered together, the partnership enables a ***third space***, surrounded by an ***ethic of care***, where people openly discuss the contextual challenges and change perspectives and ideas that shape what we do as a Center, allowing us to respond to shifting contexts and related uncertainties in Luxembourg.

The space negotiated by the school and the university parties is renegotiated in order to establish the common grounds for the work of the partnership, considering that the members come *together* across differences (age, nationality, home language, spoken languages, educational tracks and professional paths). Trigo et al. (2024) outline that “this diversity in terms of spoken languages, cultures, and nationalities amongst the team also matches well the diversity of the country itself”. These differences are considered as assets to the collaborative work because, even

though some of these differences could lead to confrontation, the relational part of the partnership is based on the concept of the team being a community of practice, which implies the concept of togetherness.

A cross-level analysis has shown how the features of the partnership sustain, and a longitudinal reflection has examined the sustainability of the collaborative structure and its ability to adapt to changing contexts over time (Wilmes, te Heesen et al., 2018; Trigo et al., 2024; Barbu et al., in review). A theme that repeatedly is visible relates to the use of languages in our practice, bringing us to new understandings about our practice as well as about children's and workshop participants' experiences. The profile of the classroom teacher(s) in Luxembourg can enable a dialogue between science and language, or not. This is not consistent in our context, but raising the awareness of the language complexity, using the language profile for example, can shine a light on possibilities for language and science integration, addressing the uncertainty of the rapidly changing context: children's highly diverse language profiles.

This collaborative approach to teacher-researcher cooperation and continuous teacher education has implications for the research field by highlighting the importance of creating spaces for dialogue and collaboration to address changing contexts and following uncertainties by promoting innovative practices. By embracing uncertainty and working together to address its challenges, the partnership is able to navigate complex contexts and develop responsive initiatives. The partnership's focus on contextually responsive approaches allows for the development of innovative teaching and research practices that can adapt to changing contexts and support not only primary science teacher professional development but also our own.

Future research could further explore the impact of the partnership on teacher professional development and student learning outcomes. Additionally, research could investigate the role of boundary spanning and distributed leadership in other school-university partnerships and explore how these factors contribute to successful collaboration and responsiveness to uncertainty. By further understanding the conditions that make partnerships successful, researchers can continue to support teacher education practices.

Chapter VI –
Learning within the school-university partnership

This chapter explores the concept of organizational learning within the SciTeach Center (the school-university partnership). As different levels of learning were identified, the manuscript is composed of the discussions on what the individuals (the teacher and the researcher involved) have learned, what was learned from the project SuperSci and the workshop *Science and Language* (through the team discussions) and, finally, what the partnership has learned from its initiatives (by looking into the events that provoked change). This manuscript is co-authored by Maiza Trigo, Christina Siry, Sara Wilmes, and Kerstin te Heesen, and it is in the process of submission.

... what was really for me very new and uncharted grounds was working with, or having access to the work that is being done on the other level of research, which I have never had access to ...

[A direct quotation from team reflection]

Organizational learning as emergent from collaboration: a case study from a professional development module within a school-university partnership

This manuscript presents cases of organizational learning from a school-university/research-practice partnership that supports the teaching and learning of science in Luxembourg's primary schools. This partnership emerges from the work of a multiprofessional team currently consisting of eight researchers and ten teachers who collaborate to co-develop and co-teach professional development (PD) workshops for other teachers. This study highlighted herein draws from sociocultural theoretical frameworks and ethnographically grounded methods to examine both organizational and professional learning as emergent from the Center team's collaboration. Analysis is presented of three levels of organizational learning (individual, project, and partnership), through the narrative unfolding of central events related to the development of in-service teacher education. Specifically, the analysis explores the teacher-researcher collaboration to highlight aspects of the collaborative work related to the development of a PD offering focusing on Science and Language, which aims to address the national multilingual learning context. By retracing events within the organization, changes in the partnership's way of working are marked as organizational learning events, and implications are drawn for positioning partnerships as affordances for learning across different organizational levels.

Keywords
collaborative structure
organizational learning
school-university partnership
case study

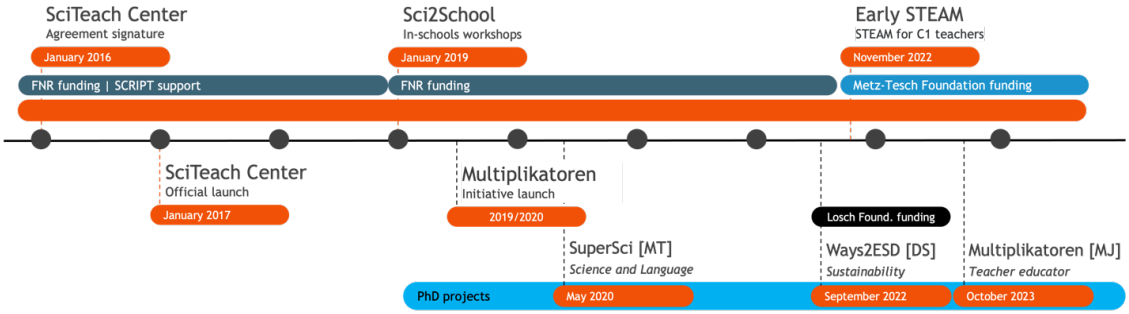
1. Context outline

1.1. The Center structure and resources

In 2016, the Center was created as a resource center for both pre-service and in-service teachers with the aim to support science education in primary schools in Luxembourg. To form this structure, a cooperation agreement was signed between the University of Luxembourg, the National Research Fund (FNR – *Fonds National de la Recherche*), the Ministry of Education (MENJE – *Ministère de l'Education nationale, de l'Enfance et de la Jeunesse*) and the Ministry of Research and Higher Education (MESR – *Ministère de l'Enseignement supérieur et de la Recherche*). The Center is dedicated to supporting the teaching and learning in Luxembourg's primary schools by offering a range of professional learning opportunities for teachers and making science teaching materials available for loan.

After the pilot phase (2016–2018), the Center became a host for a growing set of diverse projects and initiatives (Figure 35), such as ***Sci2School***, which focused on working with partner schools. Currently, the Center hosts three PhD projects: the ***SuperSci*** project explored herein, supporting teachers in dialoguing Science and Language; ***Ways2ESD*** to support teachers for Education for Sustainable Development; and ***Multiplikatoren*** accompanying teachers in becoming teacher educators.

Figure 35 – The Center history timeline



In addition to making teaching materials available for loan and hosting projects and initiatives, throughout the years, the Center also created open access pedagogical resources to support science education. Important to note is that all projects and initiatives from the Center are grounded in teacher professional development (PD) workshop and related coaching support, in order to support primary teachers to implementing science education topics in their classrooms. Teachers must comply with 48 professional development hours for every 3-year period (Luxembourg, 2017), and all PD offerings provided by the Center are accredited by the Ministry of Education. The Center provides these accredited teacher education courses mainly at its atelier on the university campus. These workshops are also carried out in different locations across the country depending on the topics and convenience, and school-based PD offerings are also delivered upon schools' requests.

Besides being a project based at the university to provide resources for primary teachers, the Center is an organization in itself that profits from being a physical space where university researchers and primary teachers come together in dialogue to co-develop primary science professional learning opportunities in ways that are responsive to the needs and challenges of teachers and students.

The Center's human capital consists of eight researchers and ten collaborating teachers, who can be positioned as the operating core of an educational organization[20] (Baker, 2011), supported by two administrative and technical staff members. The collaborating primary teachers are supported by the ministry to work together with the researchers, in that the teachers are freed from their teaching one day each week to collaborate as teacher educators on the Center's team. The collaborative work done between the teachers and researchers each week

[20] It's important to acknowledge that different team members from the SciTeach Center can be positioned also between the Strategic Apex and the Middle Line structures of the organization (Mintzberg, 1983) as they hold different roles and are able to encounter the individuals from other organization to negotiate the Center's human resources.

comprises co-developing, co-planning, and co-teaching PD offerings together, in addition to creating new pedagogical initiatives and participating in the dissemination of the team's work.

The Center team is diverse in professionalization, and each team member brings something complementary to the team's work (SciTeach Center, n.d.). These differences productively come together in dialogue and evolve because of the shared aim to support the Luxembourg competency-based elementary science education (MENFP, 2011), guided by an inquiry-based, practice-oriented teaching approach to science education (e.g., the 5E approach by Bybee, 2014).

1.2. Luxembourg language landscape and primary school system

Luxembourg is a small country in Europe with a highly diverse population, as almost 50% of the resident population are foreigners (Statec, n.d.). Luxembourgish, French and German are the three administrative languages used in the country daily, and they play different roles in different social settings (Reisdoerfer, 2009) and are also used in schools as the three main languages of instruction. The country's diversity is grounded on its long history of migration (Trausch, 2007) and the co-existence of several ethnolinguistic communities (Gómez Fernández, 2015; Gómez Fernández & Quintus, 2020), which leads to several languages being commonly spoken in homes aside from the country's three languages, including, for example, Portuguese, English, Italian (Fehlen et al., 2023).

When it comes to the pre-primary and primary school system (*école fondamentale*; fundamental school), Luxembourgish, German, and French are introduced in different stages within the public system. Primary school is divided into 2-year "cycles", beginning with cycle 1 (ages 4-6) (a preschool year, *précoce*, is optional for children aged 3), as they are before the stage of knowing how to read and write (there are several structures that enable the children to be exposed to French instead, such as pre-school [crèche] – MENJE, n.d.). However, when children enter Cycle 2 of primary education at the age of six (ISCED 1), they begin alphabetization in German[21], and French is introduced for oral communication in the second year of Cycle 2 and in written form from Cycle 3. As such, Luxembourgish is the first language used at school, German becomes the school's main language of instruction as of literacy age, and French is added as the third school language, leading to the majority of lessons being dedicated to language instruction (MENFP, 2011). Beginning in Cycle 2, students learn

[21] Since the school year 2022-2023, French is also being used as language for literacy as a pilot program (Luxembourg, règlement 2022).

subjects other than languages in German (e.g., science), highlighting the relevance of language diversity aspects for both students and teachers.

The multilingual learning contexts in Luxembourg do not reflect inclusion yet, as national reports have shown that not speaking the languages of instruction at home and having a migration background can pose challenges to schooling (LUCET & SCRIPT, 2016, 2019, 2022). Hu et al. (2015) have expressed concern about the need for cooperation between the different phases in school to develop the curriculum under plurilingualism, while Weth (2015) has raised the point that secondary school orientation is related to the students' language background (see also Trigo, 2023). Loureiro et al. (2019) have asked " Do students' language backgrounds explain achievement differences in the Luxembourgish education system?" in their article and came to the conclusion that their "empirical findings suggest that the students' language background does not play a crucial role in their success within the multilingual and highly stratified education system in Luxembourg, but rather that social origin (class) and immigrant origin do" (p. 23).

The Center and its team have been developing different initiatives to support science teaching and learning in this multilingual context and, using video analysis, Wilmes, Siry et al. (2018) have researched non-verbal communication during science investigations, outlining how an open-ended approach to science education enables the space for plurilingual children to develop their competences in science and language.

*1.3. The workshop **Science and Language***

The workshop *Science and Language* was co-developed by the SciTeach Center team to respond to the question how science and language could be put into dialogue in primary schools, with the focus of discussing with primary teachers about: language awareness, inquiry-based science education and interdisciplinarity. The co-development process, including planning meetings, happened during the first half of 2023. Even though the discussion focus of the team meetings changed from interdisciplinarity to the relationship between science and language, the inquiry-based approach was the theme that grounded the work done by the team. Questions raised during the meetings involved how to deal with multiculturalism and multilingualism, the relationship between the center and school, and how to best approach a dialogue between language and science, considering the teachers' context in Luxembourg.

The workshop itself was built upon the structure used in other initiatives of the Center, based on icebreakers, hands-on activities, theory, and discussion. For this PD course, the

icebreaker activity "Linguistic profile"[22], was used to trigger the discussion about the existing language diversity in Luxembourg with the goal of bringing awareness to the uses of different languages in school. The main hands-on activity was the construction of a car to later conduct investigations (e.g., on distance, speed), but the construction process included steps of designing and planning, whereas participants had to use the language of instruction to communicate.

The theoretical parts included discussions about the use of the inquiry-based approach in the classroom (e.g., Bybee, 2014), linked to the open-ended hands-on activity of building the car and designing investigations with it, and how interdisciplinary activities can be planned and conducted. These discussions with the participants brought to light different aspects of implementing the dialogue between science and language, such as the structural challenge of teachers' positions and related professional profiles, and the constraints of implementing open-ended and interdisciplinary approaches, which will be explored in the sections that follow.

2. Conceptual lenses

This manuscript unfolds organizational learning within the school-university partnership by exploring how the team co-develops and co-delivers professional learning opportunities to other teachers and also by looking into the team dynamics, through a process that seeks to reflect and highlight systemic barriers (especially those within the socio-cultural context) and uncertainties, thereby reflexively unfolding ways to address them (e.g., Allen, & Penuel, 2015; Barbu et al., in review; Trigo & Siry, in review).

2.1. Learning within an organization

Learning is a concept that can be defined through different lenses from different fields. In this research, learning is understood as practice-based, considering it as "legitimate peripheral participation" (Lave & Wenger, 1990). From the educational research field, Reischl (2017) draws upon contributions in a book section by presenting elements of practices within partnerships that "create opportunities for participants to co-construct new knowledge about teaching and learning" (p. 109). And, from the management field, Miller (1996) offers "a preliminary typology of organizational learning", presenting a taxonomy of the various ways that organizations can learn and adapt, listing six modes of learning based on the literature.

[22] This activity consisted of the workshop participants drawing a chosen outline (e.g., person, tree, etc.) and explicitly naming the languages to which they are exposed.

In the field of science education, professional learning overlaps organizational learning as of the use of sensemaking, "Facilitated sensemaking as a model for professional learning might also help us to better understand organizational learning as more and varied organizational actors share science education reform efforts across a school or district" (Allen & Heredia, 2021, p. 161). Brown and Duguid (1991) explored the intersection between organizational learning and communities of practice, suggesting that learning occurs through practice ("learning-in-working"). Therefore, in the context of a school-university partnership, collaborations between teachers and researchers "hold promise as contexts where people who approach the work of educating from different angles can come together to build new knowledge" (Reischl, 2017, p. 112). And so, from this promise, the study will explore the ways in which the Center as an organization has learned through the evolving school-university partnership structures.

2.2. The school-university partnership

The Center is characterized here as a school-university partnership (Clark, 1991), as well as a research-practice partnership (Coburn et al., 2013). This partnership has a unique organizational structure in that it brings together stakeholders from both school and university settings, establishing a foundation based on the dialogue between research and practice, with the motto "Research grounded in teaching. Teaching grounded in research". And considering Mintzberg's (1983) point that the operating core is the component of an organization that is responsible for carrying out its activities in order to deliver outputs, this specific partnership brings together the operating core of *both* schools (the teachers) and universities (the researchers) (see Baker, 2011), making possible the use of the terms "school-university" as well as "research-practice" for describing the partnership.

As the Center is a physical structure, which is under constant negotiation[23], it is a space where individuals meet to collaborate outside their own original settings (primary school and university), establishing the grounds to acknowledge the Center as a school-university/research-practice partnership (Kang & González-Howard, 2022; Penuel, et al., 2015; Guerrero & Reiss, 2020). It is in many ways a space that is nestled in-between organizations, and this partnership constitutes itself as a physically decolonized and negotiated third space (Bhabha, 2004; Gutiérrez et al., 1999; Gutiérrez, 2008), where individuals span and

[23] Besides the cooperation agreement yearly signed between the university and the ministry (IFEN), negotiation is also done amongst university's internal structures (faculty and bachelor program), especially linked to budget for materials.

cross their boundaries (Akkerman & Bakker, 2011; Kislov et al., 2017; Klein 2021) towards working together. A previous work has examined the profiles of the teachers and researchers as boundary spanners within the partnership and revealed the ways in which teachers and researchers meet by spanning their boundaries together in the role of teacher educators, facilitated by the partnership built upon/as a third space (Trigo et al., 2024).

Being a school-university partnership, the Center is able to be responsive to the field as its work emerges from the dialogue between the theory (researchers) and praxis (teachers). This responsiveness aspect is key to understanding how learning happens within the organization – transforming both the organization and its human capital. This dialogue and its outcomes emerge as team members work as a community of practice (Wenger, 1998/2005) and manage and are managed under the elements of distributed leadership (Woods et al., 2004).

2.3. Teacher-researcher collaborative structure

Collaboration and collaborative structures have been researched in different fields. Within Education and focusing on teacher-researcher collaboration, Herrenkohl et al. (2010) explored their own work to look at how they worked together to improve teaching and learning, how they related to each other in the work, and how they organized their time and resources to be able to do the work. This research brings a perspective to collaboration as leading to change as their "collaborative work suggests that to fully embrace a human science approach to education, we must engage processes of personal and institutional transformation" (p. 207), allowing them "to bring research and practice into regular dialogue and for each of us to be teacher and researcher" (p. 218). Manz et al. (2022) have recently published their work on this type of collaboration, also within the scope of science education. They explored how researcher-teacher collaboration "can be organized to support individual and collective learning" and "must recognize the strengths and agency of all participants" (n.p.).

The foundation of the work in the Center is based on collaboration between teachers and researchers, and we utilize cogenerative and dialogic approaches to our collaboration (e.g., Tobin, 2006). In prior work, we have explored the dynamics of our collaborative process, finding evidence of a structure that has emerged over time based on the process of ***reflect-dialogue-act*** (Wilmes, te Heesen et al., 2018). In revisiting this structure, relying on the power of reflection (Schön, 1987), and zooming in (Roth, 2005) on the processes of co-developing the *Science and Language* workshop within the partnership, and co-teaching the workshop

under teacher-researcher collaboration frame, patterns emerge on the team's dynamics, that unfolds different perspectives from the different members of the partnership[24].

As the team members come as individuals with multi-perspectives (different sociocultural backgrounds – age, language, nationality, training paths – diverse majors and degrees, professional experiences – education level) to work together advocating for the teaching approach of inquiry-based primary science education (e.g., Bybee, 2014) on the basis of the use of co- structures for its workshops (co-development, co-planning, co-teaching), this partnership setting enables the team's own professional learning through interaction and collaboration (Engeström et al., 1995) within an organizational setting for professional development of other teachers.

Team members are able to step outside their working silos (school and university) in this third space (e.g., Gutiérrez et al., 1999), acting as boundary spanners (e.g., Akkerman & Bakker, 2011), in order to benefit from the permeability of the silo-spaces. Researchers enter the primary science teaching field being part of the transformative professional development offerings and the teachers come from the field and return to research by participating in it by co-researching and co-writing with researchers (see also the work of Cowie et al., 2010). This team dynamic is grounded in cogenerative dialogues inspired by Tobin (2006; also, by Tobin & Roth, 2005), and the ways the voices are heard (Tobin, 2007).

3. Methods

This study is grounded in sociocultural perspectives and uses qualitative research approaches to inquiry (Creswell & Poth, 2018; mainly case study – Stake, 1995). In this work, participants of the research include both researchers and collaborating teachers, and approaches from participatory research (Bang & Vossoughi, 2016) and critical ethnography (Carspecken, 1996) guide the data analysis. The datasets have been collected at different points in time during the development of the *Science and Language* PD, and participants include the four authors of this manuscript as well as other colleagues in the Center Team.

Data sources include: one teacher's and one researcher's (Maiza) coding of a poster collaboratively generated by the Center team to respond to the question "What is science?",

[24] Other researchers have explored similar teacher-researcher collaboration structures, such as Kang and González-Howard (2022), who used the narrative of two teachers explore to beginning of two school-university partnerships "for transformative social change in science education", and Guerrero and Reiss (2020), who investigated the work of in-service teachers and researchers in co-designing outdoor science activities within three research-practice partnerships.

video recordings from Center team meetings while brainstorming challenges and opportunities of the workshop *Science and Language*, and senior researchers' (Chris, Sara and Kerstin) lived experiences in events/episodes within the partnership recorded in interviews.

Adriansen (2012) presents "the use of timeline interviews for life history research" (p. 41). This tool was used to retrace the history of each senior researcher within the partnership, with the goal of looking across their lived experiences and identifying events of organizational learning. As each researcher presented their own story to retrace the history of the partnership, three recurrent events were chosen through data immersion (using strategies from micro-analysis – Lejeune, 2019), and these events are treated as episodes.

The primary data collection tool was video recording through WebEx, a tool for web/video conferencing by Cisco Systems, and the Conceptboard app was used as a tool for timeline production. These data sources layer together to present views on the different levels of learning that emerge from ongoing co-development processes (see Table 25).

Table 25 – Description of data usage, sources and codes

Level	Focus description	Data sources	Data codes
Individual	Teacher-researcher collaboration/exchange	"What is Science?" poster	RcMTqca TcTFintlab
Project	Teachers' profile in classroom	Team meeting video recordings	20220315TMm 20220517TMm
Partnership	Events' description and reflection from senior team members	Timeline interviews	KtHti240424 CSti240425 SWti240426

Note: description from datasets.

Analysis considered the individual, project and partnership levels to shed light on organizational learning, taking views on/through multiple forms of data that provide insight into the partnership to address the overarching research question *How does organizational learning occur within the school-university partnership?*. As learning becomes evident in different levels, different research sub-questions emerge: *How do the researcher and the teacher code (cluster patterns) from the discussion about "What is Science?"?* (Level Individual); *What theme emerged from the team discussion during the development of the workshop Science and Language that led to learning within the organization?* (Level Project); and *What have we learned as an organization from past events?* (Level Partnership).

Through analytic induction (Flick, 2018a), coding occurred through memoing (Saldaña, 2016), content analysis (Bardin, 1977/1979) and labeling (Rapley, 2016), and analysis was

constructed on microanalysis procedures (Lejeune, 2019), comprised with the phenomenological approach (Smith et al., 2009). Data sources are presented in the form of narrative vignettes to present key events drawn from analysis to provide views on the different levels of interactions that support organizational learning within the Center. Data analysis components have been layered together using bricolage (e.g., Kincheloe, 2001; Steinberg and Kincheloe, 2011) to retrace the collaborative structure and resulting organizational learning phenomena that become visible at different organizational levels through interpretive analysis. In considering the levels as presented in Table 25, there are three data sources that are drawn upon, each of which are elaborated in the section that follows.

4. Levels of organizational learning

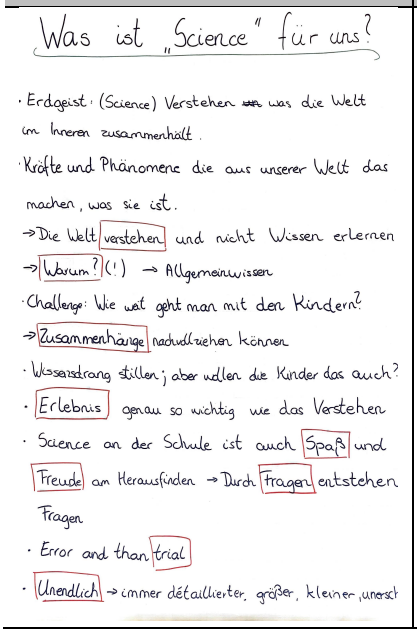
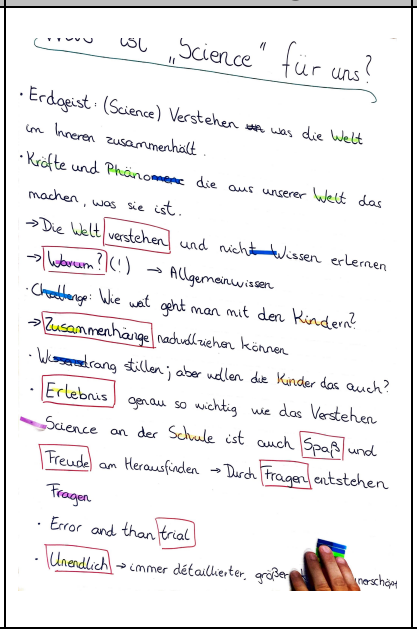
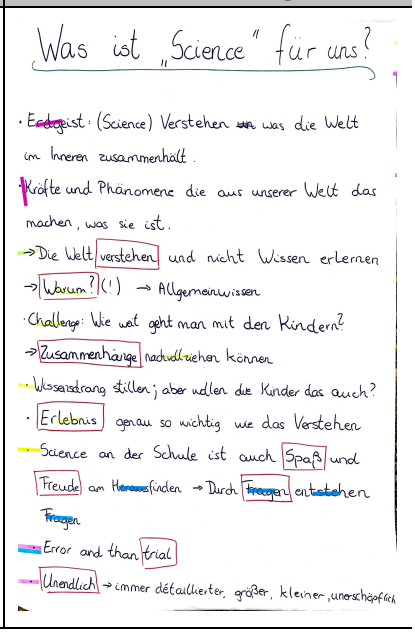
Organizational learning emerges in different collaboration settings within the school-university partnership, and in this section, we explore the ways in which organizational learning can be traced through three sets of data sources. Through the first author's PhD research about supporting primary teachers through science education for multilingual contexts, the organization has learned about itself as a partnership operating as a community of practice in a third space, where team members span their boundaries in order to enable change of habitus (see McPherson, 2023); implying that habitus is produced from "structures constitutive of a particular type of environment" (Bourdieu, 1977, p. 72), change can be retraced through offering professional learning opportunities for other teachers centered on inquiry-based approach to science education. This organizational learning takes place on different levels, which are intertwined and continually in interaction with each other. In the sections that follow, we present vignettes drawn from data sources to represent examples of the ways in which organizational learning emerged and unfolded.

4.1. Individual level

Organizational learning emerges at the individual level and can be traced, for example, during the process of co-developing the workshop *Science and Language*, where the brainstorming led to several questionings, including whether we meant the same when we said "science". The existing trust amongst the team members (as boundary spanners; Williams, 2002) enables the space for such questions to emerge as open dialogue endures, and it is a common team practice to engage in individual as well as collective reflection and dialogue around such questions, as a way to work towards shared understandings.

Having the Center collective reflection about "What is science?" on paper enables each person from the team to look at the document and reflectively consider what themes emerge. The researcher Maiza (Author 1) and the teacher Uriel, who have been collaborating closely, each coded the poster "What is science for us?" separately (first Maiza, then Uriel). To trigger Uriel's coding process, Maiza talked about how themes can be clustered by looking into patterns and divergences. After coding, Uriel took the time to walk Maiza through his reasoning, and they debriefed their coding systems. These coding systems are compared here as both participants were engaging in the process of learning how to co-research together. The visual comparison enables the extraction of indicators and themes, even though the highlights appear in different formats (Table 26) – Maiza used the different colors to identify text units to be used in the analysis, and Uriel used the colors by theme (later, Table 27 shows the treated data).

Table 26 – Coding sequences by the researcher and the teacher

Raw data	Maiza's coding	Uriel's coding
		

When the codes are looked at side-by-side (Table 26), it is clear that the basis for coding is different. As a trained researcher, Maiza grounds her coding on qualitative content analysis by using the identification of indicators (Amado, 2014) that later are clustered into themes. Uriel uses his reasoning and meaning-making around the concept of science in an intuitive labelling process by clustering themes that emerge for him (coding by labelling – see Rapley, 2016).

Even though codes and labels were different in how they were marked down (using text highlighting stickers), the reasoning of the themes led to the same interpretations, as together in dialogue, they came to the shared interpretations based on shared epistemic orientations (i.e.,

as proponents of inquiry-based learning and interdisciplinarity). The organizational learning here is the individual learning within the organization, as the teacher-researcher collaboration is a constant structure within the partnership, the endeavor of engaging in co-researching processes connects the individual learning level to the organizational one. As Table 26 offered a visual comparison, the next one (Table 27) shows examples of the codes from the researcher and the teacher beside each other.

Table 27 – Examples of codes and labels used on "What is science for us?"

			Maiza (the researcher)		Uriel (the teacher)
#	**Original**	**Translation**	**Text unit 1**	**Indicator 1**	**Label**
1	Erdgeist: (Science) Verstehen was die Welt im Inneren zusammenhält	Earth Spirit: (Science) Understanding what holds the world together inside	...**Understanding** what…	process (learning)	subject – more empirical
2	Kräfte und Phänomene, die aus unserer Welt das machen, was sie ist	Forces and phenomena that make our world what it is	Forces and phenomena…	content	subject – more empirical
3	Die Welt verstehen und nicht Wissen erlernen	Understanding the world and not learning knowledge	**Understanding** the world…	process (learning)	transmission ≠ understanding
4	Warum?! Allgemeinwissen	Why?! General knowledge	Why?!...	process (learning)	positionality – kids (+)
5	Challenge: Wie weit geht man mit der Kindern?	Challenge: How far do you go with the children?	...**with the children**?	positioning children	positionality – kids (+)
6	Zusammenhänge nachvollziehen können	Being able to understand connections	…**understand** connections	process (learning)	transmission ≠ understanding
7	Wissensdrang stillen; aber wollen die Kinder das auch?	Satisfy the thirst for knowledge; but do the children want that too?	...do the **children** want that too?....	positioning children	attitude – kids (+) moving into (-)
8	Erlebnis genau so wichtig wie das Verstehen	Experience is just as important as understanding	Experience … **understanding**	process (learning)	transmission ≠ understanding
9	Science an der Schule ist auch Spaß und Freude am Herausfinden -> Durch Fragen entstehen Fragen	Science at school is also fun and the joy of finding out -> Questions create questions	**Questions** create questions	process (teaching) discovery	positionality – kids (+) cycle of discovering
10	Error and than trial	Error and than trial	Error and than trial	process (learning)	common sense concept
11	Unendlich -> immer détaillierter, größer, kleiner, unerschöpflich	Infinite -> always more detailed, bigger, smaller, inexhaustible	Infinite…	process (reflection)	infinite cycle of discovering

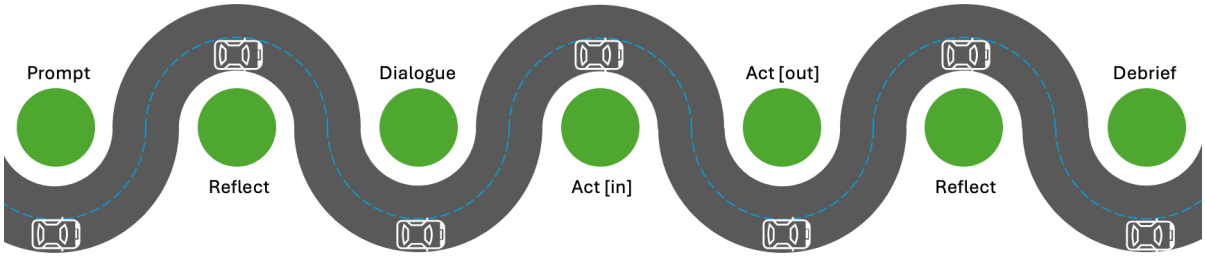
Note: extracted from dataset "What is science for us ".

The process of coding "What is science for us?" from the researcher and the teacher can be observed from finding intersections in the reasoning of the two individuals (Table 27), such as for ***children*** and ***questions***. When looking at the occurrences of the word ***understanding*** on the poster, the researcher links it to the ***process of learning*** science, and the teacher links it to the differentiation ***transmission ≠ understanding***. As an organization where teachers and researchers come together to collaborate on co-developing and co-teaching PD courses, having the space to co-develop research enables learning through boundary spanning. Coding of the text from the poster "What is science for us?" has enabled the process of learning of the teacher to be a researcher, and the researcher to learn how to co-research from and with the teacher's perspective.

4.2. Project level

The collaborative structure of teacher and researcher working together in a project is consistent in different projects and is at the heart of this school-university partnership. Using as a starting point the previous structure identified within the partnership, based on **reflect-dialogue-act** (Wilmes, te Heesen et al., 2018) introduced earlier, the project on Science and Language was able to reflect on how that the structure sustained through changes, including changes in members of the team; even after team members were not all the same. Through analyzing the emergent co-development process for this specific workshop, the collaborative structure of **reflect-dialogue-act** was unfolded to elaborate further steps of the process that emerged, being **prompt – reflect – dialogue – act(in) – act(out) – reflect – debrief** (Figure 36).

Figure 36 – Unfolding of the collaborative structure



The unfolding of the collaborative structure emerges as a scaffolding of the original structure. The original ***Reflect*** unfolds into *Prompt* and *Reflect*, as the dialogue is prompted and developed throughout the discussion. The original ***Dialogue*** unfolds into the *Dialogue* before the action happens and the *Reflect* (also grounded on the original ***Reflect***) and *Debrief* moments after the action, as all team members share the next steps (for example, before the workshop) and returns to the team to share how the workshop happened (after a reflection is done between

the co-teachers and a debriefing is shared with the team). Lastly, the original ***Act*** is unfolded into *Act-in*, as the first action registered is the co-planning process, and *Act-out*, referring to the co-teaching process itself.

Zooming in (Roth, 2005), with the purpose of presenting one analytical axis (Lejeune, 2019), two meetings are presented next, both including the initiation of a discussion about how to frame the concept of interdisciplinarity. This conversation served a trigger for revealing and outlining the existence of a systemic, structural challenge related to particular teacher roles and professional profiles.

The first excerpts (20220315TMm) come from a meeting when Maiza presented the first ideas to co-develop the workshop *Science and Language*, and a visiting scholar shared her experience implementing the CLIL approach (Content and Language Integrated Learning) in secondary school in another country. The team discussion emerged around the topic of interdisciplinarity as Chris triggered the dialogue, and Uriel picked up with the point of view from the field:

> [what] would then get them to that point of where they need to be investigating something and thinking about, then on the meta level, how is that interdisciplinary in practice? (...) [what] sort of a framework we can give to teachers to be like: – here, think about a lesson you've done, and try and adapt it in this way to make it more interdisciplinary(...) (Chris)

> if we say teachers...I might say [there are] two main groups of teachers (...) those who teach science and those who don't teach science (...) the first problematics will, which will come up is, [imitating potential replies from participants] but I only teach science... but I have no access to those German, French, mathematics lessons, and vice-versa too. (Uriel)

The discussion about how to give tangible examples of implementation for interdisciplinarity goes from the positive tone of brainstorming to the negative surprise of the emergent "problematic", when acknowledging the gap between the teachers who teach science and who teach languages: "but I only teach science". A second event takes place two months later, during a Center team meeting (20220517TMm), the challenge of how to work towards interdisciplinarity, given the structural constraints that divide teachers *who teaches science from those that don't* re-emerges as a concern to overcome the separation not only between the topics (science and language), but the school internal organization: with one teacher being the science teacher, another one teaching German language instruction. In discussing how to move forward with a focus guided by interdisciplinarity, Uriel reflectively mentions that overcoming this division is bounded in the structural division that positions one teacher as the German teacher, while typically a different teacher is the science teacher, as he emphasizes that "Then it's going to be even more difficult to overcome that" (Uriel).

The project of putting science and language into dialogue has a structure that is consistent with the approaches to co-development and co-teaching adopted in other Center projects, from co-development to co-teaching the PD offer itself to brainstorming, debriefing, and reflecting on issues around it. The learning process emerged here through the discussion about dialoguing science and language as the group reflexively considered how to present "interdisciplinarity" in concrete ways for teachers while revealing how the school system presents challenges to its implementation.

These challenges are concerns more present to the field, inflicting barriers to the work of putting science and language into dialogue, as each classroom will have, at least, two teachers: the main teacher (*titulaire*), who is the immediate person responsible for the classroom; and the second teacher (*surnuméraire*), who is usually the one teaching science but not languages. This structural challenge emerged from the dialogue in the team, and the teachers were able to unpack certain aspects that weren't visible to the researchers.

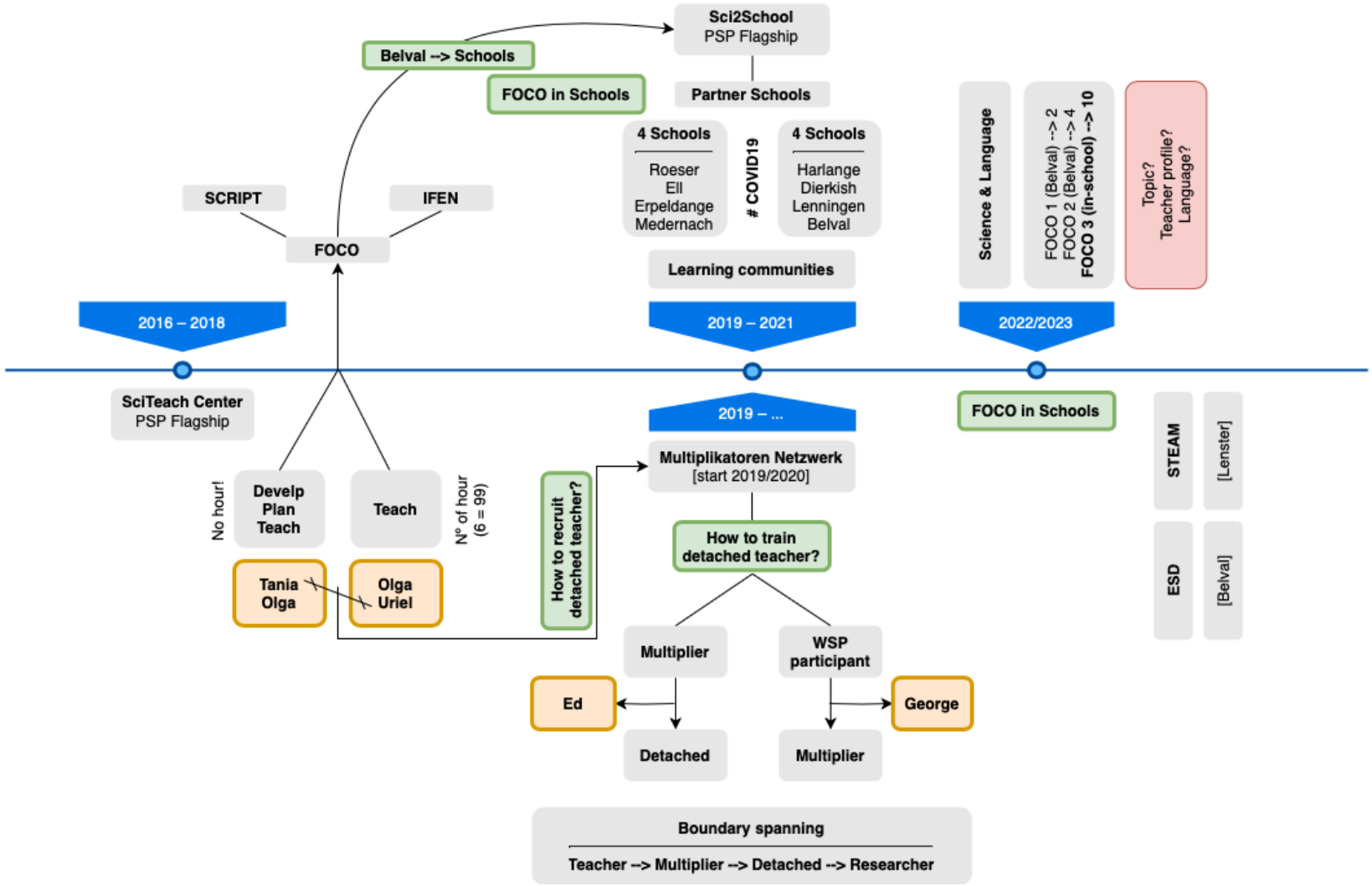
It is the team dynamics grounded on the collaboration structure that keeps facilitating open dialogue, which made it possible for the organization to learn from the praxis (or, at least, made it visible to the research field) about the teacher profile being a challenge. Through the co-developing process of the workshop *Science and Language*, several concerns emerged, and this led to learning within the organization, thereby shaping initiatives (how to incorporate different concepts in the PD course, such as interdisciplinarity and forms of documentation) and influencing decision-making (how to offer and deliver the workshop).

4.3. Partnership level

Assuming the school-university partnership as an independent educational organization (considering the perspective of Baker, 2011), it is important to reconstruct the history of the organization not only from documents but also from narratives of those involved within. In order to do that, this level of organizational learning is presented here based on the overlap of events from timeline interviews conducted with three senior researchers, who are co-authors of this paper. Timeline interviews (Adriansen, 2012) allow for looking back in time with a focus on key events, thereby enabling reflexively considering the ways in which particular events prompted a response from the organization as such. A microanalysis procedure (Lejeune, 2019) was utilized, whereby data immersion was followed by zooming in on three events that emerge across the interviews as central for considering how the organization has learned from them.

Dewey (1939) presents context as background (both spatial and temporal), elaborating that time and space are central to the need to look into context. These narratives provide evidence of the aspects of *space* and *time* as critical background context from events that have provided opportunities for the organization to learn from external factors, thus shaping initiatives to respond to the context. The context is a point of interest as it plays a key role in explaining the connections between the events that will be narrated next, and which are presented in Figure 37 below. The comprehensive timeline, built from the convergence of the events from the three timelines of the senior researchers, presents three learning events (green labels): the shift on how teachers were detached to work with researchers (event 1); the launch of a project to provide school-based PD (event 2); and the shaping of the initiative to provide learning opportunities for teacher educators (event 3). Shifts in human capital (yellow labels) triggered event 1, which leads to event 3. Possible barriers (red label) are reflected upon, as projects turn to providing PD offerings in school (learning event 2).

Figure 37 – Events from which the organization has learned



Note: blue for time pin, green for learning events, yellow for human capital, red for possible barrier / FOCO stands for *formation continue*, meaning PD offering

The pilot phase of the Center was marked by material and human resources being put together to develop a space where teachers could come to borrow materials and get inspired (by attending PD offerings). During the period of the start-up funding (as a Flagship[25] project), the innovation division of the Ministry of Education provided the Center with detached hours for two teachers to work with the researcher from the university. The team met to co-develop, co-plan, and co-teach workshops, outlining the foundations of the work to be done by the Center, such as the implementation of the inquiry-based approach to science education, without the concern about how these hours were distributed into tasks. As the Ministry support was intended as start-up resources for the duration of the initial funding, the division ended the support of detached hours when the pilot funding concluded, and a new agreement needed to be established with a different division of the ministry (event 1), which changed in how detached hours were provided as well as how they were being counted (one detached hour turns into 16,5 hours of teaching PD courses).

This shift in how teachers were detached to work with researchers is the first event narrated by the three researchers as a milestone, where the organization had to ***regroup resources*** and establish new partnerships. While the pilot phase was running, workshop participants shared that coming to Belval was not convenient for teachers from the center-north, and, more importantly, they very often mentioned that they would appreciate having this kind of workshop with their direct colleagues in their school, in order to work collaboratively towards shared goals for their respective schools. This served as one of several triggers for the submission of a new project, which later launched a second grant from the national research agency to establish a partnership program with schools to provide school-based professional learning opportunities (event 2).

School-based partnerships are supportive of transformative changes, and the Sci2School project allowed for building structures that could respond to teachers' expressed needs for school-based PD. With the successful funding request for the project, the Center launched a call to establish partnerships with schools for providing school-based PD accordingly to each school's needs. The mobility of the offerings has shown the organization that *in loco* presence enables ***in-depth relationship building***, raising awareness that partnerships can be built outside the third space of the organization itself (the Center), while still being a part of the organization. When the project started to kick off its in-school meetings and workshops in 2020, the COVID-19 pandemic happened, and that created a lot of constraints for working inside schools. The umbrella partnership (the Center) was able to take some of the planning further as the shift to online settings became more familiar to the stakeholders. As the project was able to get a time extension at the end, the

[25] PSP stands for Promoting Science to the Public, a FNR funding initiative. The PSP Flagship consists of a 3-year project, which "aims to set up long-term science outreach activities with a sustainable and lasting impact on the promotion of science to the public in Luxembourg".

relationships were measured by the number of initiatives undertaken, and the schools that were open to remote initiatives (mainly online meetings) and kept close contact with the project team were the ones with which the project achieved the most significant impact.

Event 1, how teachers were detached to work at the center, was central in all three timeline interviews, referring to when one detached teacher had decided to leave the team to pursue a change in career and become a special needs teacher, and this led the organization to establish the parameters for how to train detached teachers (event 3). Relatedly, and in response to event 3, the Multiplikatoren Netzwerk was created, shaping the initiative to prepare teacher educators into a two-step process. At the first moment, to become a detached teacher, one has to go through becoming a Multiplier, which consists of attending monthly meetings to co-develop their own PD workshop. This experience supports the teachers to become familiar with the teaching approach (inquiry-based science education) and professional learning aspects (planning, assembling materials, organizing presentation) to provide the teacher educator with the necessary tools to give one's workshop aligned with the pedagogical approaches and underlying philosophies of the Center. When one teacher applied to become a Multiplier, but it was the first time in contact with the SciTeach Center, the organization learned about the importance of adding a step before the application; one had to attend a workshop previously, leading to the process of ***workshop participant*** to ***multiplier*** to ***detached***.

4.4. Findings

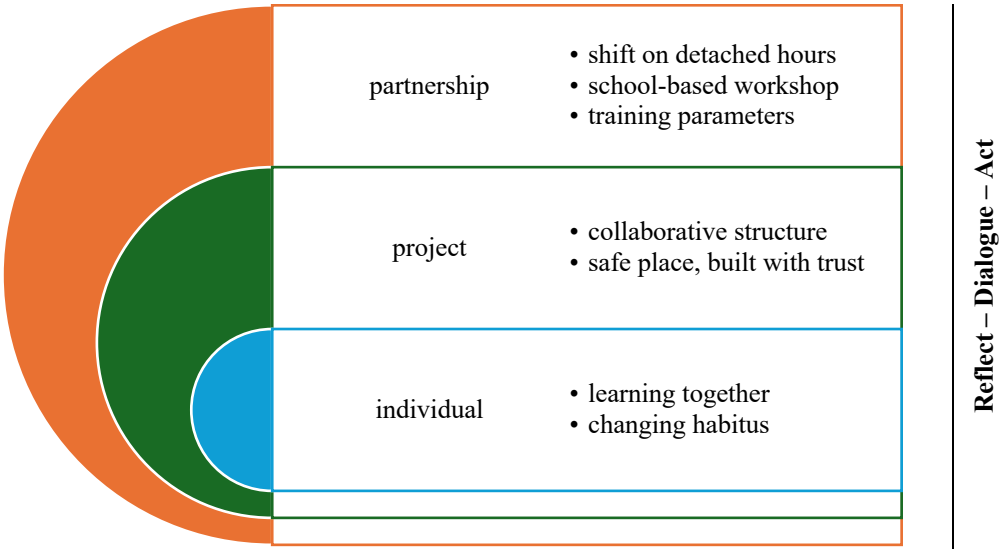
The consistency of the collaborative structure layered ***with the open-ended and dialogic nature of the collaboration allows for organizational learning to unfold*** - recursively and iteratively. As the Center enables team members' own professional learning through developing professional learning opportunities for others, it also learns as an organization and adapts to be responsive to the context. The collaboration based on trust and dialogue is consistent throughout the different projects (e.g., *Sci2School*, *Science and Language*, *Multiplikatoren*), which explains the sustainability of the school-university umbrella partnership based on the collaborative structure ***reflect-dialogue-act*** (Wilmes, te Heesen et al., 2018).

The shifting from the collaboration with SCRIPT to partnering with IFEN is an event that reflected into two others (Figure 37): *the Multiplikatoren teacher network*, which emerges from the idea of having collaborating teachers without the need to negotiate a detachment, but would be linked to this long-term professional learning opportunity[26], and a special step for those who would then become detached teachers; and *the Sci2School project*, which was developed from the

[26] This opportunity has been providing the space to have particular structures to understand the process of teaching PD courses with the focus on inquiry-based science education to other teachers.

workshop participants' feedback, addressing the possibility of building learning communities within the schools. As other projects are hosted in the Center, the aspect of delivering PD courses in school was instituted and the organization has learned, again, that the possibility of moving the PD to the partner school is key for sustaining partnerships. This also reflects on the project level, when the workshop *Science and Language* was held in a school and had the highest number of participants attending it (Figure 38).

Figure 38 – Levels of organizational learning



In the one-to-one learning level, Maiza learns about the process of co-researching as she discovers that the coding systems are divergent. The patterns emerged from different coding systems, but their common orientation led to a common understanding and interpretation of the data (see also the work of Park Rogers et al., 2010[27]). However, the analysis leads to the same major findings, and both participants have learned through the process of coding, looking into intersections and reflecting on orphan thoughts. The collaboration between teacher and researcher is impacted by the relationship and trust that is developed through the collaboration (Engeström et al., 1995) on the project level. This exchange of skills is grounded in a created organizational learning setting, the Center, where teachers and researchers come together and engage in co-developing and co-teaching and take a further step of co-researching one dataset from the co-development process ("What is science for us?").

The partnership has revealed in time, looking at these three events in particular, that the consistent collaborative structure (reflect-dialogue-act) has enabled new initiatives to be drawn and unfolded. In this space of ongoing cogenerative dialogue, the organizational settings evolve, enabling the development of one's own professional learning, in a spiraling process, going from

[27] Park Rogers et al. (2010) examined how orientations to science teaching and learning is directly linked to practice, showing it in the process of delivering professional development.

the organizational to the person, and then returning to the organization as the person contributes to it. It is the collaborative structure of ***reflect-dialogue-act*** that enables the partnership to evolve and sustain, and the organizational learning to occur, linked to the context. Therefore, organizational learning settings as third spaces enable professional development through the exchange of skills.

5. Final remarks

This manuscript highlights the ways in which organizational learning occurred in a school-university partnership across multiple levels, as participants work together in collaboration towards a sustainable and transformative space for teacher education. The partnership creates an organizational learning setting that is based on a third space, where teachers and researchers exit their siloing spaces and negotiate their positionings within this third space (Bhabha, 2004), with its own interactional culture (Gutierrez et al., 1999). Elements negotiated include the use of languages (including tacit agreements), the establishment of shared concepts, the acknowledgment of each other's expertise, and a shared commitment to open-ended science teaching.

As the partnership provides the space for teachers and researchers to come together, becoming mutually engaged in co-developing and co-teaching PD offerings, towards a joint enterprise to support primary science education, and considering a shared repertoire on inquiry-based science education (all elements of communities of practice – Wenger, 1998/2005). Still, in the context of Luxembourg, this partnership is enabled by the existing distributed leadership (Woods et al., 2004), as it is open to spanning/crossing boundaries, where leadership emerges from each one's expertise, yet the result is a collective one.

The team's professional learning through the development of professional learning for others is grounded on a collaborative structure, in which team members engage in "co-" processes, that enable and are enabled by their boundary spanning (Akkerman & Bakker, 2011; Klein, 2021) as they shift roles within this negotiated third space, a school-university partnership (Kang & González-Howard, 2022; Penuel, et al., 2015). Through the process of thinking about and co-designing professional development opportunities for other teachers, these boundary spanners are engaging in their own professional learning, in a process that emerges through interaction (Engeström et al., 1995).

Every level indicates that organizational learning occurred due to the open structure of the partnership, based on open dialogue and trusting relationships. Findings reveal the team's work dynamics to support inquiry-based science education is grounded on the structure of collaboration reflect-dialogue-act (Wilmes, te Heesen et al., 2018), in which the process of active learning for both researchers and teachers involved in this partnership can provide recommendations to support

sustainable school-university/research practice partnerships based on ongoing open dialogue and trusting relationships. Episodes presented demonstrated the ways in which participants work together across different positionalities and professionalizations, and how this results in an analysis that showed how the interactional structure unfolds and what it has accomplished in the interaction.

The analysis also demonstrated how each of these components created an opening for coming together across different perspectives to create something new (like the *Science and Language* workshop). By reflecting on one's own and each other's practices, researchers and teachers within the umbrella partnership revealed the alternating roles and thereby developing different layers of expertise in a supported process, contributing to this work in solidarity with teachers (Roth, 2007) in ways that honor the contextualized needs of teachers and students in the places in which all of us learn. The implications from this work highlight the value of long-term partnerships and collaborations across different positionalities, while underscoring the complexities and possibilities of organizational learning as mediated by such partnerships. Of particular relevance for others working within partnerships is ways in which organizational learning reveal itself at different levels and emerges in a recursive and iterative process between the consistency of the partnership and the openness of the team's cogenerative process.

Further, this manuscript presented a contribution on the use of a methodological approach for working between teachers and researchers, which can support a transformative research practice nested in the voice of teachers and teacher leaders, and those who work with teachers (at universities, within partnerships) towards supporting diverse student learners. Different data sources were layered together in a bricolage (e.g., Kincheloe, 2001) to tell how the concept of teacher-researcher collaboration can unfold across different levels of learning within an educational organization.

Chapter VII –
Views from the field

This chapter aims to explore the framework of the Sociodynamic Perspective from a theoretical and methodological point of view. Considering that research should pay close attention to the context, this framework was chosen to explore the testimonies of the participants of the workshop *Science and Language*. As this framework was developed within the field of History of Education and this manuscript offers its application in the field of Teacher Education, the text is co-authored by Rooney Pinto (History of Education) and Maiza Trigo (Teacher Education).

Written documents are fixed;
they exist whether we are aware of them or not.
Oral testimony is only a potential resource
until the researcher calls it into existence.

[Portelli, 1981, p. 103]

The sociodynamic perspective for studies in education: a multidimensional approach to oral testimonies[28]

From a multidimensional analytical framework, this contribution aims to demonstrate the application of the sociodynamic perspective to explore how time, space, conditions and their effects shape the oral testimonies about experiences in the school microcosms. Adopting a qualitative methodology the oral testimony, two studies are presented: one from Portugal, where interviews gathered former teachers school memories during the Estado Novo regime; and from Luxembourg, where interviews captured teachers' perceptions about the education system after attending a workshop on science and language. Content analysis, microanalysis and thematic analysis were employed to code and interpret the data grounded on the sociodynamic perspective. The analysis of the Portuguese testimonies showcases how the socio-political backdrops and disciplinary practices manifest the dynamics of time, space, conditions and effects in the narratives. The Luxembourgish testimonies highlighted how the teacher profile and the place of science were shaped by such contextual dimensions. Applying the sociodynamic perspective to these two distinct cases demonstrates its comprehensive framework for studying oral testimonies in education across diverse contexts. By considering the multidimensionality of context and the interdisciplinarity approach, the sociodynamic perspective enables deeper insights into how educational memories and narratives are socially constructed within specific milieus.

Keywords
school
teachers
oral testimonies
sociodynamic perspective

This chapter presents an interdisciplinary approach to a more comprehensive analysis of the sociodynamic perspective, with a particular focus on its potential applications in diverse educational research contexts. The sociodynamic perspective offers a comprehensive framework for understanding the intricate dynamics and social structures that shape our educational systems. It offers valuable insights into the analysis of oral testimonies, illuminating the complex interplay between school culture, socio-political influences, and individual experiences.

By examining these narratives through a sociodynamic lens, researchers can uncover deeper layers of meaning, exploring the contextual factors that shape educational practices and the social dynamics that underpin them. This multifaceted approach integrates theories from diverse fields, acknowledging the variables of time, space, conditions, and their effects. The sociodynamic perspective enables researchers to examine the relationship between memory and social imaginaries and representations within the school environment.

[28] This manuscript has been adapted for publication in the book *Re-Membering Education: Temporally Inflected Approaches to Edges of Inquiry* (from the book series Transdisciplinary Perspectives in Educational Research, Springer), for the section Theories/Epistemologies, co-edited by Lajos Somogyvári (University of Pannonia, Hungary) and Tamar Groves (Extremadura University, Spain).

1. Grounding concepts

The challenges imposed on education in contemporary society have not necessarily emerged recently nor will end at this time. Education, as an activity developed in the microcosms of human groups, is subject to their social morphologies in the broadest sense (Halbwachs, 1970, 1972). At the same time, it is also a reflection of the way in which those involved experience these realities and interact with these contexts, constituting ordered realities (Berger & Luckmann, 1966/1991) in their frameworks of social experience (Goffmann, 1974/1986). In this way, the social, economic and political contexts combine and interact directly with the individual contexts of all of those who inhabit the microcosms of education.

> In a given proposition, either the temporal or the spatial aspect may be uppermost. But every narration has a background which, if it were made explicit instead of being taken for granted, would be described; correspondingly, what is described exists within some temporal process to which "narration" applies (Dewey, 1939, p. 220).

Research in educational settings is not oblivious to the existence of external factors to the education system and school and schooling but should also recognize that the context is necessary to understand that its presence gives connections (Dewey, 1985/2008) to what is experienced and narrated by those involved and it should be situated within the time of the events (social phenomena) and considered within the time in which it is narrated (combining the concepts of episodic, semantic and biographical memory; accordingly to Baddeley et al., 2009/2020).

1.1. The relevance of context

> *We are not explicitly aware of the role of context just because our every utterance is so saturated with it that it forms the significance of what we say and hear* (Dewey, 1985/2008, p. 4)

The context can be referred to as part of the conceptual construct assuming relevance in analysing the phenomenon studied, or as it is more commonly referred to, as part of the setting in which the phenomena under study are situated. This second option reduces the relevance of context to a mere overview of events, without involving it in the analysis of phenomena or comprehension of the realities represented.

According to Kovala (2014, p.168) "the definition of context developed in this brand of radical contextualism clearly comes close to – and has indeed drawn on – Gilles Deleuze and Félix Guattari's conception of rhizome." This statement is based on the principle that the branches of the context provide dichotomies, multiple levels, and types of approaches (Deleuze & Guattari, 1976). In accordance with the principles of rhizomatic logic, phenomena are shaped by a complex network of interrelated events (contexts) that operate at various levels, without necessarily

adhering to a linear structure. In this regard, contexts serve as both the indicator and the object of an event that has been recorded in the memory of social actors.

The epistemology related to theories of context is largely associated with the philosophical presuppositions of pragmatism as a theoretical current, particularly with regard to aspects related to representations of reality (James, 1907/1975), especially when the research uses oral testimonies as a primary source for the study. From an epistemological point of view the contextual element is relevant in order to grasp the nature of the phenomenon, while cognitive action allows us to understand the object under study. This premise follows the same line as the epistemological phenomenon in communication, namely through the capacity for understanding, which leads to knowledge related to the subject under discussion by the interlocutors.

1.2. The role of time

> *Intelligent understanding of past history is to some extent a lever for moving the present into a certain kind of future.* (Dewey, 1939, p. 239)

The variable of "time" plays a significant role in the study of contexts in oral testimonies (Hamilton & Shopes, 2008). This is due to several factors that influence the accuracy, interpretation, and significance of the recollections shared. The temporal distance between the event or experience and the time of the testimony can influence the recollection of details and may result in potential inaccuracies. This is due to the fact that memories can fade or change over time (Schacter et al., 2011).

From a philosophical standpoint, Augustine (2009) postulated that time is not an objective entity but rather a subjective experience dependent on individual perception. This perspective emphasises the malleable and personal nature of time, which may shape the way individuals recount their experiences in oral testimonies. In addition, sociologists have examined the social construction of time, demonstrating its impact on human behaviour and interactions (Bergmann, 1992). Berger and Luckmann (1966/1991) referred that the social reality, including time, is constructed, maintained, and subsequently shapes individuals and their experiences. Consequently, the social understanding of time may influence the content and structure of oral testimonies, as individuals' recollections are situated within their unique socio-temporal contexts.

Furthermore, sociologists have also examined the concept of "social time" (Sorokin & Merton, 1937), which emphasises the interplay between social structures and temporal dimensions. This perspective emphasises the importance of understanding the temporal context in which oral testimonies are situated, as societal changes and events may significantly shape individuals' narratives and recollections (Giddens, 1984).

In addition to the temporal dimension, the socio-cultural context in which the testimony was given can influence how individuals interpret (giving it meaning) and report their experiences. This is because their perspectives may evolve due to changes in societal norms, personal growth, or exposure to new information (Josselson & Lieblich, 2015). The variable of time also allows researchers to analyse the impact of historical events and social changes on the narratives shared in oral testimonies, thereby providing valuable insights into the dynamics of personal and collective memory (Misztal, 2003).

1.3. The place of oral testimonies

In the field of education, oral testimonies have served a dual role in the understanding of phenomena and the contexts in which they are embedded. Firstly, they have illuminated the past through memoir narratives, which are predominantly analysed with a social-historical focus. Secondly, they represent lived experiences that are remembered and narrated from a social-mnemonic perspective. According to León (2016) the narrative memory is a facet of episodic memory and procedural-semantic memory, which together enable the reconstruction of past experiences. It is therefore evident that the episodes recorded in memory are not consistently reflected in the testimonies that constitute narratives.

In this sense, oral testimonies occupy a central position in the corpus of research focused on understanding social phenomena linked to the microcosm of the school. In this sense, oral testimonies encapsulate a past that moves between the time of the events and the time of the narrative, thereby revealing the social dynamics that affect the social actors and the events they experience (Pinto, 2022). In this vein of inquiry, the interaction between the subject and the environment and their social morphology (Halbwachs, 1970, 1972) point out aspects that are close to the assumptions of symbolic interactionism.

From the perspective of Symbolic Interactionism presented by Herbert Blumer (1969) and drawing on Georg Simmel's sociological view of everyday social reality (Simmel, 1950/2006), oral testimonies through memory narratives mirror the social dynamics and their contents concerning the social structures in which they are embedded. These social dynamics of memory enable distinct insights into the ways social groups directly impact memories, and, by extension, the resulting oral testimonies.

It's also important to highlight that the oral testimonies are a form of historical record that can be traced back to the etymological root of the word "history" in different cultures. In the Indo-European matrix, the term *weid* translates as "to see", while in Sanskrit, *vettas* means "witness", denoting someone who remembers the past because they were present and knowledgeable about

it (Le Goff, 1988). It is important to note that this history itself constitutes a form of testimony, reflecting the social dynamics associated with it and the temporalities of the events and narratives.

2. Social dynamics, sociodynamics and sociodynamic perspective

The field of social dynamics is concerned with the processes and changes that occur within societies over time. It encompasses various elements that shape social life, including culture, institutions, and interpersonal relationships. It seeks to understand the underlying mechanisms and factors that lead to the transformation, adaptation and stability of society and helps to explain how individuals, groups and communities interact, adapt, and contribute to the overall social fabric (Moscovici, 1988/2005).

As an interdisciplinary branch of praxeology, the sociodynamics combines sociology and social psychology, amongst other fields, exploring the dynamic relationships between individuals, groups, and their social environments (Fauvet, 2004). Sharing similarities with social dynamics, the sociodynamics places greater emphasis on the psychological aspects of human behaviour in social contexts. Examining group dynamics and the forces that shape social behaviour, it aims to understand the interaction between individual experiences and social influences, including the processes of cooperation, conflict, and social change (Fauvet & Fourtou, 1996).

The term “sociodynamics” has become more widely used since the second half of the 20th century, following the publication of sociometric studies by Moreno (1934, 1941). It was subsequently explored in the field of communication as *Sociodynamique de la Culture* by Moles (1967, 1971), with a focus on socio-cultural aspects of communication and technologies in the mass communication. In the field of social economy, Weidlich (2003, 2006) presents his sociodynamic concept, which employs mathematical models for probabilistic analysis of individual and group mobilisations in urban areas, changes in social microcosms and economic impacts.

In the field of education, Pineau (2007, 2014) employs a sociodynamic vision to address issues of dialogue between content from disparate domains within the training process and also highlights aspects pertaining to the evolution of the appropriation processes of knowledge. Ferreira (2008) explores a sociodynamic approach, considering the time, space, conditions and effects as elements that should be taken into account in comparative education studies. In the field of language teaching, Cognigni and Vecchi (2018) employ sociodynamics to contextualise their analysis of gender stereotypes in Italian language teaching materials. In a similar vein, Junior et al. (2016) employs a sociological approach, as proposed by Norbert Elias (2000), to examine the sociodynamics associated with the inclusion of deaf students in Brazilian higher education.

The sociodynamic perspective, which employs interdisciplinary qualitative approaches, builds upon Dewey approach to context (1939) and the theoretical-methodological assumptions established by some of the cited authors to elucidate the ways in which the dynamics of the context can influence social phenomena. This framework was constructed considering that time, space, conditions, and their effects shines a light on social phenomena not only as background, but as variables of analysis.

From this perspective, the temporality of events and the temporality of testimonies are considered in the light of the contexts associated with them. This allows the significance of the events narrated to be understood as part of a mnemonic-social construct. In this way, the memories and narratives are embedded in an understanding of social representation as a sociodynamic concept that moves between individual and collective perceptions, which manifests themselves in social interactions and reflect time, space, conditions, and their effects.

The epistemological presupposition on which the sociodynamic perspective is founded upon constructionist relativism and based on interpretivism, as stated in the ontological positioning of this research (Amado, 2014; Cohen et al., 2018; Crotty, 1998). Given that the subjectivities of the oral testimonies were observed through a mixed ethnographic approach (academic and ethical), the subjectivist epistemological position was adopted with variations. The interpretive framework employed is informed by theoretical tenets derived from the disciplines of symbolic interactionism and phenomenology (Blumer, 1969; Simmel, 1950/2006).

3. Applying the Sociodynamic Perspective

This section aims to showcase how *time*, *space*, *conditions* and their *effects* are especially relevant to research in Education, by presenting the application of the sociodynamic perspective in two studies that are temporal- and spatially distinct. One study is within the field of History of Education in Portugal and the other one of Teacher Education in Luxembourg. While the first study investigates school memories of former teachers from the Estado Novo period in Portugal, the second study explores how a school-university partnership impacts teacher continuous professional development in Luxembourg. Both studies use qualitative approaches to research, whereas oral testimonies were employed as primary data sources, utilising comparable coding and analysis procedures, each of which were adapted in accordance with their specific objectives.

> The experience of the sociohistorical world cannot be raised to a science by the inductive procedure of the natural sciences. Whatever "science" may mean here, and even if all historical knowledge includes the application of experiential universals to the particular object of investigation, historical research does not endeavor to grasp the concrete phenomenon as an instance of a universal rule. The individual case does not serve only to confirm a law from which practical predictions can be

> made. Its ideal is rather to understand the phenomenon itself in its unique and historical concreteness (Gadamer, 1989, p. 4).

3.1. School memories from the time of dictatorship in Portugal

3.1.1. Research context

The analysis from two subcategories from the doctoral thesis "Memory and Education: Narratives of memories from school time during Estado Novo in Portugal[29]" (Pinto, 2023) are presented here to illustrate the Sociodynamic Perspective in the research context of memory studies: *Memories from home* (Category: Family; Dimension: Socioeconomic characterization); and *Punishing students* (Category: What emerges from the school memory; Dimension: Memories from being a teacher).

3.1.2. Methodology

Data was collected through semi-structured interviews conducted between 2017 and 2019 in the northern region of Portugal, respecting the ethical and legal procedures applicable to the study and the recommendations of the Oral History Association, which were audio-recorded, transcribed, and anonymized accordingly. Data was treated and analysed using MAXQDA Analytics Pro 2022 software. The research was guided by the following questions: 1. What aspects of social experiences are retained in collective memory, and what processes or factors influence the way they are remembered?; 2. How does the temporal context of remembering interact with the temporal aspects of narrating in shaping social memory?; 3. How do the spatial dimensions of memory storage, the conditions surrounding them, and their effects become evident in narratives of social memory?

Using a qualitative approach to content analysis data coding, a mixed procedure (inductive and deductive) was carried out to categorise the data, combining previously defined categories with those arising from axial codes (Amado, 2014; Cohen et al., 2018). Interpretive line-by-line microanalysis procedures were applied (Lejeune, 2019), comprised with the phenomenological analysis (Smith et al., 2009), and the analytical framework (indicators/recording units, themes/meaning units and context units) was organised to facilitate a deeper understanding of the phenomenon of school memory through the coded extracts. The context units encompass relevant interview segments, adopting both relevance and contingency criteria to define their scope within the analysis corpus (Bardin, 1977/2013).

3.1.3. Data and analysis

The Case-E5 and Cases E6, E9 and E18 are presented here as examples respectively to the subcategories *Memories from home* and *Punishing students*. When asked about *What to you*

[29] Research conducted within the PhD programme in Contemporary Studies at the University of Coimbra.

remember about your family during Estado Novo?, Case-E5 talks about the family situation and how the restructuring of the family denounces the financial constraints that would have motivated the father's economic emigration to France:

> My father emigrated because I went to study (...) Ah, but I didn't tell you that my mother was arrested because my father went to France. Someone accused him, she was imprisoned by PIDE in a house on the edge of where the town hall is, she and an uncle of hers were imprisoned there. (...) I was studying, was imprisoned there by PIDE for a whole day to tell them where my father was. "I don't know anything about him, he doesn't send me any money, he doesn't care about his children, I don't know anything about him". And she stayed there all day and didn't say anything about him being gone, she pretended she didn't know, and her uncle did the same thing. In the evening, she had her children alone at home, she didn't say anything, they let her go, but she was locked up in the PIDE for a day. (Case-E5)

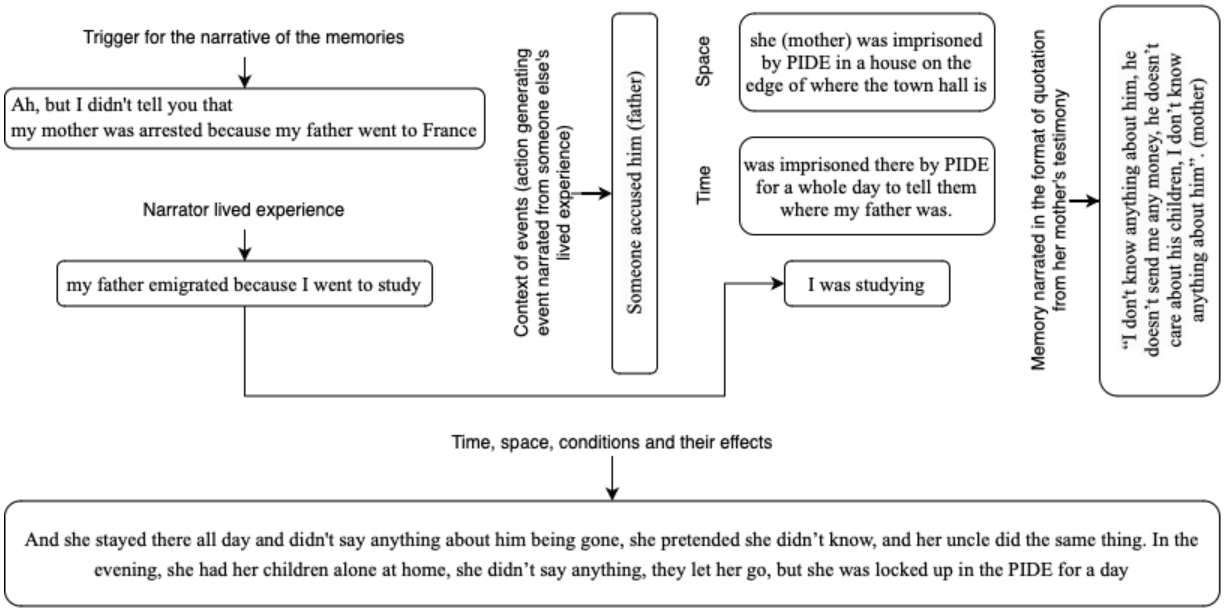
Case-E5's narrative presents at least two central aspects that can be considered as indicative of the family's socio-economic context (unit of record) in the national socio-political context (unit of meaning), the first of which is the statement that the father had emigrated because she went to school (Table 28).

Table 28 – Narrative segmentation Case-E5 - Memories from school time

Testimony structure	Line	Narrative segment
Introduction	L1	Ah, but I didn't tell you that
Indicator	L2	my mother was arrested because my father went to France.
Signification	L3	My father emigrated because I went to study (...)
Context	L4	Someone accused him, she was imprisoned by PIDE in a house on the edge of where the town hall is, she and an uncle of hers were imprisoned there. (...) I was studying, was imprisoned there by PIDE for a whole day to tell them where my father was. "I don't know anything about him, he doesn't send me any money, he doesn't care about his children, I don't know anything about him". And she stayed there all day and didn't say anything about him being gone, she pretended she didn't know, and her uncle did the same thing. In the evening, she had her children alone at home, she didn't say anything, they let her go, but she was locked up in the PIDE for a day. (Case-E5).

In a proposal for analysis from a sociodynamic perspective, it is necessary to situate the elements of the narrative in their contextual structures so that they can be understood according to the domains and engrams activated at that point in the interview (Figure 39). Case-E5 recalls events that happened in the family (Table 28), while at the same time revealing specific aspects off the impact of the socio-political context.

Figure 39 – Domains and engrams activated in the narrative of Case-E5



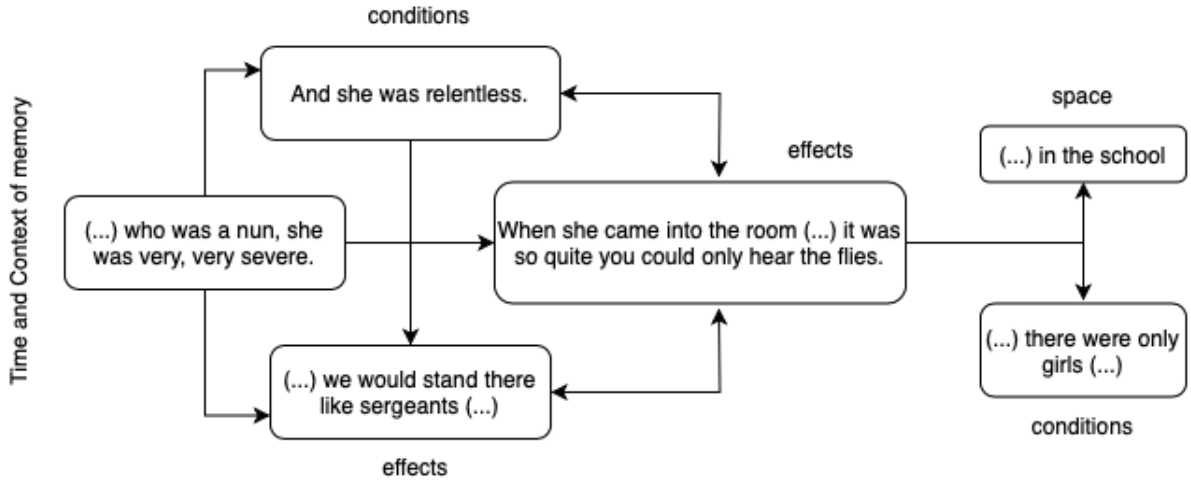
Introducing a forgotten element in the testimony, as the trigger of the biographical event in which her mother was arrested by the International and National Defense Police (PIDE) because the father had emigrated[30], the Case-E5 reveals the social dynamic between the past of the events and the present of the narrative (Figure 39). The testimony recounts an experience that the mother and uncle had when Case-E5 was at school. In the form of quotations, also adds to the narrative what the mother told the PIDE interrogators. Although Case-E5 was not physically present at the location where the event occurred, in the temporality of the context incorporates the experience into the biographical memory. This is reinforced in the final section of the narrative, where revisits the entire event, punctuating the time, space, conditions and effects linked with the biographical events.

When asked about the topic of punishment at school, the testimonies of the Cases E6, E9 and E18 were associated (as justification) with issues such as respect, discipline and learning. This aspect can be observed both in the memories as pupils and in the memories as teachers.

> They would hit the pupil on the head. The cane was used to point, it was the pointer, but it was also used to hit the pupil on the head from time to time. I remember vividly in the first year, which is now the fifth, the French teacher, who was a nun, was very, very severe. When she came into the room, there were only girls in the school, and it was so quiet you could only hear the flies. We would stand there like sergeants, as they say. And she was relentless. Any little thing you didn't know, she'd slap you with her hand. There was a lot of severity there. (Case-E6)

[30] It's important to notice that was necessary to obtain government permission to leave the country during the Estado Novo.

Figure 40 – A sociodynamic perspective on selected segments of the Case-E6's narrative



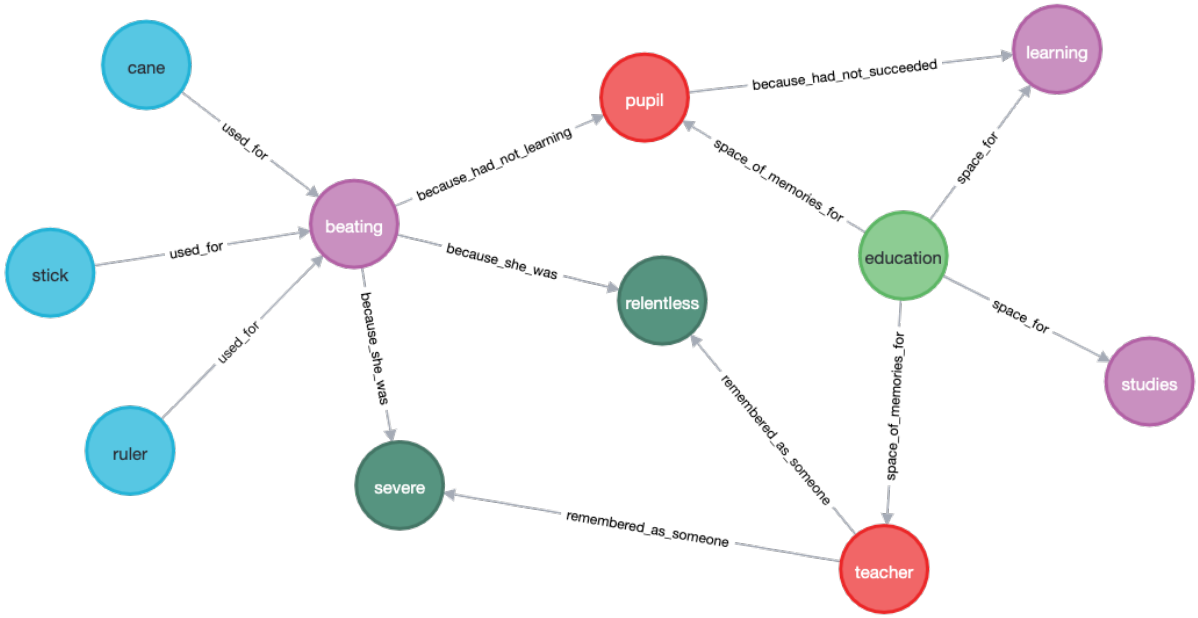
The narrative segments of Case E6 reveal the recollection of a particular lesson as a context where the conditions are punctuated by the teacher's severe attitude, resulting in tension on the part of the students (Figure 40). If they made mistakes in this lesson, the pupils could be punished with the cane, something also mentioned by the Cases E18 and E9. However, both testimonies reflect memories as a teacher.

> Ah, yes... A beating because they hadn't learnt the multiplication table and didn't know the multiplication table, so they were beaten with a stick for doing the math's wrong on the board. (Case-E18)

> Indeed, I did use the ruler, and I am not going to deny that fact. (...) The ruler has been a tool in education since I began my studies, and it may have been in use prior to that. It continued to be used in my time. The frequency with which I employed it is open to question. Now that it had become a tool (Case-E9).

In both testimonies, the discourse is structured around a mnesic engram that highlights words such as cane, rod, ruler, education, teacher, student, beating, severe, among others (Figure 41). In their testimonies, the objects cane, stick and ruler are directly associated with the teacher's severe attitude. This memory of school (space) reflects contexts as students or teachers (temporality), in which punishments were applied as penalties for not achieving the expected results in learning (conditions and their effects).

Figure 41 – Mnesic engram of the narratives of Cases 6, 9 and 18.



The sociodynamic perspective is employed to demonstrate how social dynamics and the relationship between time, space, conditions and their effects are manifested in oral testimonies, which constitute a narrative of the experiences lived by the narrator or absorbed by him as part of his biographical memory.

In the cases examined, while oral testimonies are regarded as a primary source, the sociodynamic perspective examines the potential reflections on themes that emerge through discourse. This allows us to gain insight into the phenomenon of the school's social memory through the lens of its social actors (teachers and students).

3.2. Exploring changes in a school-university partnership in Luxembourg

3.2.1. Research context

The analysis from two emergent themes from interviews conducted to workshop participants are presented here to illustrate the Sociodynamic Perspective in the research context of teacher education studies: *Structural challenge* (Category: Teacher profile; Dimension: Concern); and *Place of science* (Category: Science; Dimension: Grounds). This analysis is from the open-interviews dataset and is part of the work from the doctoral thesis "Supporting primary education through science teaching for multilingual learning contexts[31]" (Trigo, in review).

3.2.2. Methodology

Data was collected through open interviews (semi-structured guidelines) conducted between 2023 and 2024 in Luxembourg, respecting GDPR and ethical procedures applicable to the study under the guidelines of the University of Luxembourg, which were audio-recorded, transcribed, and

[31] Research conducted within the PhD programme in Educational Sciences at the University of Luxembourg.

pseudonymized accordingly. Data presented here was treated and analysed using Obsidian Version 1.5.11. This dataset analysis was guided by the question on *what themes emerge from workshop participants' perceptions about the dialogue between science and language*.

Using qualitative research approaches to inquiry (Merriam & Tisdell, 2016; Creswell & Poth, 2018), analytical memoing was used for data treatment (Saldaña, 2016) and, supported by the axial code approach to identify data themes (Cohen et al., 2018), indicators emerged from the inductive procedure to categorise the data. Thematic analysis procedures were applied (Guest et al., 2012), in order to expedite the understanding of the phenomenon of primary science teacher continuous education and its implications in schooling. The indicators emerged from the participants voices, which led to relevant reflections within interview segments.

3.2.3. Data and analysis

Quinn and Sheldon are the two participants presented here to explore the case of a continuous professional development opportunity, the workshop *Science and Language*, which led to a discussion about the Teacher profile (*Structural challenge*) and Science as topic (*Place of science*).

In the Luxembourgish primary school system, as the standard student timetable has more school hours (contact hours) than the number of teaching hours allocated on the teachers' standard task[32], each grade classroom has one main teacher (called *titulaire*[33]) and a second teacher (called *surnuméraire*[34]). Also, students are exposed to three languages (Luxembourgish, German and French) throughout the primary years and German is both the language of literacy and instruction for science starting at age six (from ages three to six, Luxembourgish is used as language of instruction to the project-based approach to the competence-based curriculum).

When asked about Quinn's perceptions about *the (possible) dialogue between science and language in primary years in Luxembourg*, attention is drawn to two aspects on her narrative: one presented that she is a "second teacher" (her position); and the other that she sees that the two subjects are given different attention (her positionings).

> So, in my special case, as I'm *surnuméraire*, so it's mostly the dialogue between the teacher [*titulaire*] and me to implement something that is not only for two hours, but something that will be done about maybe one, two or three weeks, or maybe longer (...) So, if I had my own class, it

[32] For example, a Cycle 2 teacher has 23 lessons of direct teaching whilst a Cycle 2 student schedule comprises 28 lessons (Luxembourg, 2009a; MENFP, 2011; Trigo, 2023).

[33] The titulaire is the "main teacher" who, most of the time, will be teaching the main subjects (languages and math, as these subjects are subjected to national examination). In general terms, this teacher is responsible for the classroom, especially about the student promotion, as of being the reference person for all stakeholders about the students' educational path/track.

[34] The *surnuméraire* is the "second teacher" who, most of the time, will be teaching in more than one classroom and will take the subjects not selected by the "main teacher" (most of the time, the subjects are science, art, music, sports. The "second teacher" will take the exceeding hours from the "main teacher".

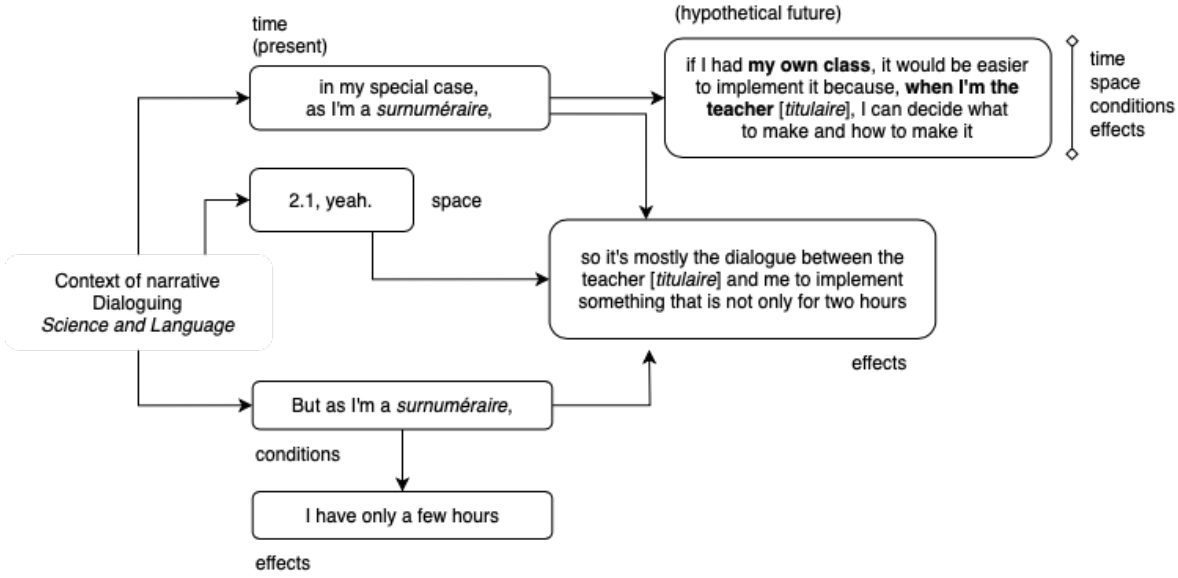
would be easier to implement it because, when I'm the teacher [*titulaire*], I can decide what to make and how to make it. But as I'm a *surnuméraire*, I have only a few hours...

(...)

[When asked about to what class she was giving science...]
2.1, yeah [first year of Cycle 2[35], equivalent of 1st grade]

There is the need to segment the elements of the narrative into the analytical structures from the sociodynamic perspective, in order to understand Quinn's position as a "second teacher" and how she positions herself in her school context (Figure 42). By establishing her position as *I'm surnuméraire* in a first-grade class (Cycle 2.1) (*space*), Quinn not only limits her position to the current situation (*time*), but also reveals how her science teaching takes place (*conditions*). Being a *surnuméraire* have direct implication on her work (*effects*) as of the time she spends in the classroom teaching science and her relationship with her classroom colleague (the main teacher).

Figure 42 – A sociodynamic perspective on Quinn's positionality



The transit between *time*, *space*, *conditions* and their *effects* from her current situation to a hypothetical one reveals how the sociodynamic perspective enables the analysis of one's testimony grounded on the context, both as research background and key-interest. As she reports that in order *to implement something that is not only for two hours, but something that will be done about maybe one, two or three weeks, or maybe longer* there has to be the willingness of both classroom teachers, it becomes clear that the dialogue between subjects that are not considered core is bounded by the main teacher's choices, and, consequently, revealing that the dialogue/cooperation between the classroom teachers might stand as a *structural challenge* of the teacher profile.

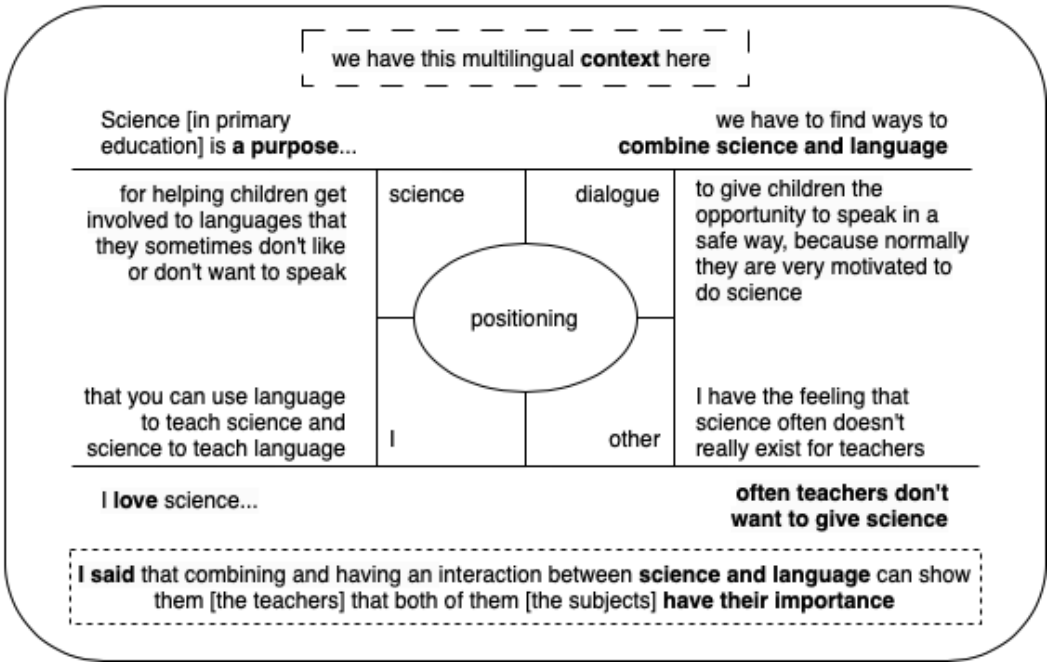
[35] Primary education in Luxembourg comprises four cycles, and each cycle consists of two mandatory years: Cycle 1 (ages 4-6); Cycle 2 (ages 6-8); Cycle 3 (ages 8-10); Cycle 4 (ages 10-12).

Trying to connect the open question to the context of Quinn attending the workshop *Science and Language*, she immediately links the possibility of the dialogue to the country's school language context as she informs

> On the one hand, I love science (...) on the other hand, we have this multilingual context here in [Luxembourg]. For me, science is a purpose ... for helping children get involved to language that they sometimes don't like or don't want to speak. So, I think that, in our multilingual context here, we have to find ways to combine Science and Language, to give children the opportunity to speak in a safe way, because normally they are very motivated to do science (...). That's one thing and the other thing is I have the feeling that science often doesn't really exist for teachers (...). So, often teachers don't want to give science, and I said that combining and having an interaction between Science and Language can show them, that both of them, have their importance and that you can use language to teach science and science to teach language.

As Quinn continues her testimony about the dialogue between science and language, she draws the attention to the different positionings of Science (*Figure 43*), in relation: to herself (*I*), as she informs her feelings towards Science and the possibilities of teaching science in dialogue with language(s); to the other teachers (*others*), who are portraited as distant to the subject; to the subject itself (*science*) as means for learning; to the connection between Science and Language (*dialogue*), outlining the space for the students to enhance their language skills as supported by the motivation for doing science.

Figure 43 – Quinn's positionings about the dialogue between Science and Language



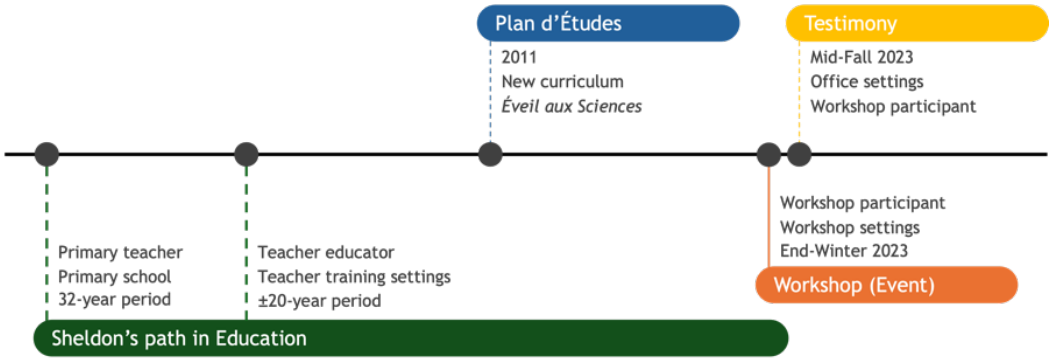
Besides Quinn's motivation towards teaching science, it is the multilingual context that leads her to emphasise that Science and Language have both their importance and that this should be shown to the teachers (Figure 43). At the same time that Quinn's provides positive highlights for the *place of science* in schooling (learning), she exposes the *place of science* in the classroom/school system as distant from the core subjects (system).

Sheldon's narrative illuminates the analysis from the dichotomous position of the (dis)connection between Science and Language.

> Science and language are often split so that they obviously are not related together. But, in my view of the teaching reality and how it is done, how we can do it in teaching, I use it as an interdisciplinary area or transdisciplinary area so that the language is used to get developed and the content is about science topics. So, this is a possibility to merge and in one activity you have two topics: language and science at the same time. And when children collaborate in doing science with real materials, I have observed over the last 32 years where I am a teacher in school, that children are very engaged in communicating and speaking together in a larger way than if they do it only when they do exercises. (...) These are always topics that belong to science education and also the use of the language they get, the children forget that they are doing language education.

His testimony bounces in time (*Figure 44*), from his reflection based on his participation on the workshop and his memories from the different pasts when he recollects reasonings about science in the Luxembourgish system.

Figure 44 – Sheldon's timeline of narrated events



Sheldon starts underlining the gap between science and language, but he shifts his discourse into the positive aspect of dialoguing the subjects by emphasising his views about how teaching should take place, grounded on his views about the curriculum (MENFP, 2011) and his experience as a schoolteacher for a long period of time (Figure 44). The jump between what is his approach and the others' approach to interdisciplinary in teaching matches Quinn's positionings about the dialogue between science and language. And, exploring the *place of science* in the school system, he adds that

> If you are doing mathematics or language education, children and parents are happier than if you are wasting time with science, it's not a topic in orientating children to the second-degree [secondary] school. I was working with an *inspecteur d'École* [school inspector] who was looking in a lot of schools (...) he realized that when the teacher did no science, nobody blamed them, and they are doing instead of language or mathematics and topics who are more important than science. So, science is not good, situated part.

As Science and Language were being narrated as separated subjects and knowing that Sheldon was in a unique position of also being a teacher educator, he was triggered about his perceptions on the *teacher profile* in the school system. His narrative moves attention to the time of the development and launch of the new curriculum event (Figure 44) as a milestone to the attempt of

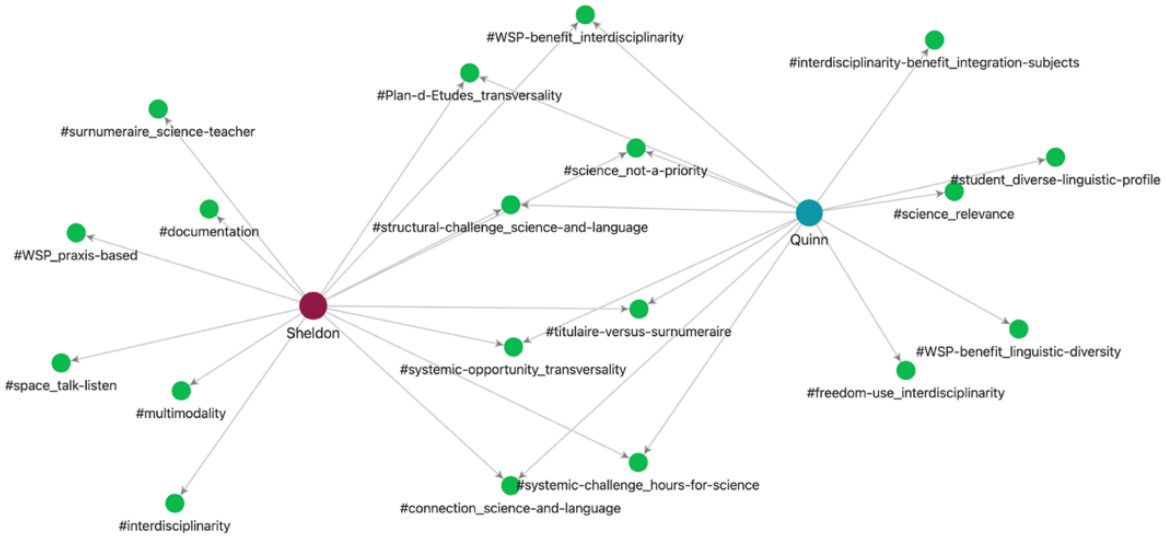
bringing science together with other subjects due to the curriculum being competence-based and addressing transversality, as well as, to the gap building by the system enabling the presence of two teachers.

> Yes, this I had in my head when I was speaking now five minutes ago when the topic *Éveil aux Sciences* [discovery of sciences] came to school before it was *sachunterricht* [lessons per subject] and then science and language was more related together, it was not separated and the topic from *Éveil aux Sciences* they have developed, it was a *équipe* [team] of [Professor Z] and they wrote a curriculum for the primary school (...) when [Professor Z] was working out the curriculum for *Éveil aux Sciences*, elaborated very good curriculum and what happened the teachers gave the topic away and there came a *surnuméraire* who taught *Éveil aux Sciences* and often these were teachers who had no teaching degree and they came as *surnuméraire* (...) [who] became specialists in science education, so this is a good part of it, but it was also a negative evolution in separating language and science topics.

Sheldon's testimony brings to light how *time*, *space*, *conditions* and *effects* are key elements to his narrative. His condition of being both a schoolteacher and a teacher educator for a long period of time, enable him to see the system from inside-out. His convictions about interdisciplinarity remains as time passes and as his spatial settings change. Sheldon's reflections about the dialogue between science and language also addresses the effects of the situation, both on the schooling and the teacher.

The sociodynamic perspective was applied here in testimonies aiming not directly a stretched historical recollection, but based on the workshop participants' perception about how Science and Language could be connected in the school system as they attended a workshop about this topic (Figure 45). Demonstrating how the relationship between time, space, conditions and their effects are manifested in these oral testimonies, which consist of narratives of their lived experiences, their positionalities reveal how *personal values, views, and location in time and space influence how one understands the world* (Warf, 2010, p. 2258).

Figure 45 – Connecting narratives' themes from Quinn's and Sheldon's testimonies



4. Conclusion

This chapter presented the sociodynamic perspective as a multidimensional approach for analysing oral testimonies in educational research. The sociodynamic perspective considers time, space, conditions, and their effects as key variables that shape social experiences and how they are remembered and narrated.

The authors illustrate the application of this perspective through two studies. The first one, "School memories from the time of dictatorship in Portugal", examines school memories of former teachers during the Estado Novo regime. This study employed a sociodynamic perspective to examine how teachers' memories of the school context were shaped by the interplay between past experiences and the narrative on the present. This approach also highlighted the significance of contextual factors, such as the physical environment and the circumstances (time and conditions) under which events occurred, in the formation of a social memory of the school.

The second study, "Exploring changes in a school-university partnership in Luxembourg", presents an analysis of two themes from interviews with workshop participants, focusing on the Sociodynamic Perspective in teacher education studies within multilingual learning contexts. They demonstrate how aspects like family language contexts, school discipline practices, teachers' positionalities, and the place of science in the curriculum can be analysed through the lens of time, space, conditions and effects manifested in the oral testimonies.

For the study on school memories during the Estado Novo regime in Portugal, the authors analyse excerpts from the interviews coded under the subcategories "Memories from home" and "Punishing students".

Looking to the grounding concepts, in the Portuguese teacher testimonies, the memories of family socioeconomic conditions (Case-E5) and school disciplinary practices (Cases E6, E9, E18) are grounded in the broader socio-political context of the Estado Novo dictatorship and its impact on the "microcosms of education".

The narratives demonstrate how the "temporal context of remembering" (current time) interacts with the "temporal aspects of narrating" (time of the event narrated), shaping how experiences are recollected, as highlighted in the grounding concepts section (Goffman, 1976; León, 2016). In this sense, the role of "space" emerges clearly, with the school serving as the spatial context within which the narrated events and experiences take place (Deleuze & Guattari, 1976; Dewey, 1939).

The memories of the Portuguese study enable the recollections of the experiences of the social microcosm of the school to be placed in dialogue with the social macrocosm of Portugal in the temporality of the events recorded in the memory (dictatorship period). In this context, the testimonies can be seen as an exercise in mental time-travelling (Suddendorf & Corballis, 1997),

whereby the narrator revisits and reconstructs the past recorded in their memory when recalling it. This can be represented through mnesic engrams, which enabled the network of relationships between the elements that made up the narratives to be verified (Baddelley et al., 2009/2020). Consequently, when the narrator recalls disciplinary measures at school, one also recalls a severe teacher, the instruments used for punishment (cane, stick) and how these elements are associated with the justification that discipline led to learning and indiscipline to punishment.

In the study on teacher professional development in Luxembourg, the authors analyse testimonies from workshop participants Quinn and Sheldon regarding the potential dialogue between science and language in primary education.

The testimonies from Quinn and Sheldon in the Luxembourg study are firmly grounded in the specific socio-spatial and temporal contexts of the primary education system there. Quinn's narrative stems from her positionality as a "second teacher" (*surnuméraire*) in the school context, which shapes the conditions under which she teaches science and the effects this has on implementing interdisciplinary science-language activities over extended periods (Blumer, 1969; Dewey, 1939; León, 2016). Her testimony reflects how the "social morphology" (Halbwachs, 1970) of having two teachers per class interacts with the individual perceptions of the contexts. Quinn's aspirations to integrate science and language are impacted by the structural realities (Berger & Luckmann, 1966/1991; James, 1907/1975) of sharing classroom time with the main teacher (*titulaire*).

Sheldon' recollections further exemplify how memories are situated "within the time of the events" and "the time in which it is narrated". His long experience allows him to trace the evolution of science education in Luxembourg schools across recent curricular reforms – from planning of the *Éveil aux Sciences* approach within the current competency-based model to the reality implemented, separating science from language instruction. His narrative deftly moves across this temporal plane (Suddendorf & Corballis, 1997), reflecting on how pedagogical approaches to relating science and language have shifted over time based on "the conditions surrounding them" (teacher profile) and analysing "their effects" (unintended consequences like separating the subjects).

In the Luxembourgish study, the themes around teacher positionality, structural challenges, and perspectives on science education are grounded within the specific contexts of that school system, the specific multilingual environment, and the curricular changes over time – aligning with the emphasis on context in the grounding concepts (Bergmann, 1992; Cognigni & Vecchi, 2018). Moreover, both testimonies are grounded in the distinct spatial context of Luxembourg's multilingual education system (Kovala, 2014). In this sense, Quinn advocates for using science to create "safe" spaces for developing all three languages and Sheldon's view that an interdisciplinary

approach increases student engagement resonates with the realities of teaching science through German from first grade onwards (Berger & Luckmann, 1991; Fauvet, 2004; Luxembourg, 2009a).

In both studies, the sociodynamic perspective enabled the authors to elucidate the intricate interrelationship between individual experiences, social contexts, and the temporal and spatial dimensions that shape how these experiences are remembered and narrated (Josselson & Lieblich, 2015; Pinto, 2023). The application of interpretive line-by-line microanalysis procedures (Lejeune, 2019), in conjunction with phenomenological analysis and an analytical framework, facilitated a more profound comprehension of the oral testimonies, as evidenced by the coded extracts.

In all the cases examined in both presented studies, oral testimonies were the primary source of data, both using interviews for data collection and thematic analysis to look into education systems with different lenses: History of Education and Teacher Education. Therefore, the uses of the sociodynamic perspective in research in education, one relying on memory studies (with historical distancing) and the other relying on reflection about changes within an educational organisation (which still exists and keeps changing to respond to context) present the direct link between the research participants' self-perception (identity), their transit between time and space, and how context takes part in the puzzle (Bayeck, 2022).

In summary, this chapter introduced the sociodynamic perspective as a useful theoretical and methodological approach for qualitative research in education, highlighting its potential to unpack the complexities underlying oral testimonies through a multidimensional analysis of narrative contexts.

Chapter VIII –
Concluding Remarks and Discussion

This chapter aims to present concluding remarks of the chapters of this dissertation and how these different chapters dialogue with each other to bring to light the story of how a teacher-researcher collaboration structure in science education can support primary teachers in multilingual learning contexts.

A summary about the Luxembourgish context

Luxembourg has a long history of migration fluxes and is a country where the population diversity reflects directly the student diversity (see MENJE/SCRIPT, 2021). Almost half of the resident population consists of foreigners (Statec, 2021), and two-thirds of children in primary education speak a language at home other than Luxembourgish (SCRIPT, 2022). The country counts with three administrative languages (Luxembourgish, German and French – Luxembourg, 1984) and the co-existence of several ethnolinguistic communities can pose challenges to learning in a multilingual country (Gómez Fernández & Quintus, 2020).

According to the Luxembourgish curriculum (MENPF, 2011), all three administrative languages are used throughout the primary schooling years; yet, German is mainly used as the language of instruction for the other subjects, such as Mathematics, Science, etc. This scenario exposes issues of equity, access, and language, as a high percentage of students do not speak the languages of instruction at home. Hence, the school system has put in place the School Integration and Welcoming Service (MENJE, n.d. a; n.d. b), which provides a two-year support to incoming children who need to learn the languages of instruction.

Current research has highlighted the importance of recognizing that science learning in multilingual education contexts should not focus solely on learning vocabulary (Siry, 2017), but should also consider alternative forms of expression beyond written formats (Doris, 1991; Gallas, 1995; Kirch & Siry, 2012; Monteira et al., 2024). In Luxembourg, this is particularly crucial for supporting student understanding and promoting science and scientific literacy (e.g., Siry & Gorges, 2019; Wilmes & Siry, 2020).

Therefore, the complex social and educational settings in Luxembourg need to be under constant reflection, especially when researching the school system (Chapter I). By revealing the importance of the historical and cultural contexts of the country, researchers can navigate the school system and understand how changes in policies have impacted the field. For primary science education in Luxembourg in particular, there is the need to understand how (and put in place actions) to support teachers in providing opportunities for students to explore, engage in inquiry, and express their understanding through multiple modes of communication, not bounded by but in integration with language learning.

The need for exploratory mappings and systematic reviews

The state-of-the-art (Chapter III) presented exploratory mappings conducted to examine research gaps in primary science education in multilingual contexts, including one on primary science teacher education and a mapping on the tendency for 'language' and 'inquiry' in key journals[36] in science education.

The main exploratory mapping consists of one where data is related to the occurrences of the terms "inquiry" and "language" in various science education journals. The analysis of scientific literature on primary science education shows a significant focus on "inquiry" and "language", with the former primarily linked to various conceptions of scientific inquiry and the latter related to English learners, minority languages, and language policies in education. A connection between "inquiry" and "language" emerges in 2013, possibly linked to the publication of the NGSS and discussions about language diversity in education. There is an upward trend of "language" in 2016 onward possibly reflecting ongoing developments in language policies and practices in Europe.

The dialogue between "inquiry" and "language" is an emerging trend in primary science education research and practice, given the increasing mobility and migration worldwide and the importance of fostering language skills in science education. The mapping of the literature has contributed to a better understanding of the issues related to primary science education in multilingual contexts, but it had limitations including the lack of using thesaurus strings and the limited use of the Boolean system.

The exploratory mapping about "inquiry" and "language" revealed the need to conduct a systematic review (Chapter IV) that would consider a broader data source. Therefore, a systematic scoping review was conducted in order to provide valuable insights into the current state of research on primary science education within multilingual learning contexts. By analyzing studies published between 2008 and 2023, the review has identified key themes and trends that highlight the complexities and challenges of teaching science in linguistically diverse learning landscape. The review also revealed a growing focus on the integration of science education with language learning, but the main focus is for English Learners (ELs), so not necesseraly in multilingual contexts.

One of the primary findings of this review is the predominance of studies that address the development of instructional materials aimed at supporting ELs in acquiring both academic content and language skills. This reflects the increasing recognition of the need to adapt

[36] Journals comprise: Cultural Studies of Science Education (CSSE); International Journal of Science Education (IJSE); Journal of Research in Science Teaching (JRST); Journal of Science Teacher Education (JSTE); Research in Science Education (RISE); Science Education (SE); and Studies in Science Education (SSE).

educational practices to the realities of multilingual classrooms. However, the review also revealed that the application of inquiry-based learning in these contexts is still limited and often not explicitly integrated with language learning strategies. This suggests a need for more research that explores how inquiry-based approaches can be effectively employed in multilingual settings to enhance both science understanding and language proficiency.

The review process also highlighted methodological challenges, particularly in terms of how multilingual contexts are defined in the results. The varying definitions and understandings of what constitutes a multilingual learning environment led to difficulties in filtering and analyzing relevant studies. This underscores the importance of developing more precise criteria and frameworks for future research in this area, ensuring that studies can be more accurately compared and synthesized. Yet, divergent information from database were discovered during the analysis, which also posed a risk to conducting the scoping review.

Moreover, the review has shown that, while there is a substantial body of work on bilingual education and language learning, research specifically focused on multilingual contexts is still underdeveloped (where students may speak multiple languages at home and at school). This gap presents an opportunity for future research to explore more deeply the intersections of language, culture, and science education in these complex learning environments. Also, this emerges as an opportunity to support teachers in addressing linguistic and cultural diversity in their classroom, and to develop teaching strategies that enable inclusive, inquiry-based learning experiences for all students.

Using the sociodynamic perspective

The sociodynamic perspective was explored as a multidimensional approach for analyzing oral testimonies in educational research. This perspective considers time, space, conditions, and their effects as key variables shaping social experiences and memories. In this dissertation, the use of the sociodynamic perspective was presented through case studies from Portugal and Luxembourg, highlighting the importance of context in shaping educational narratives. Context, encompassing socio-political, historical, and cultural elements, influences how events are perceived and narrated within educational settings.

As a joint manuscript, ***The sociodynamic perspective for studies in education: a multidimensional approach to oral testimonies*** (Chapter VII), both researchers used microanalysis procedures and phenomenological analysis to delve into oral testimonies, employing an analytical framework to facilitate a deeper understanding of the complexities

underlying narratives. The narratives shared by individuals within educational environments provide insights into the diverse influences and dynamics present within education systems.

The Portuguese research case shows (using embedding memories within broader social, institutional, and environmental contexts) how context shapes identities, roles, and perspectives within education systems. This case examines how memories of past events are influenced by present narratives and contextual factors, highlighting the significance of temporal and spatial dimensions in shaping recollections. The Luxembourgish case study provides insights about the current system, revealing participants' concerns when reflecting about the possible dialogue between science and language.

By analyzing the narratives through the lens of the sociodynamic perspective, researchers were able to provide examples on how to use the perspective to uncover deeper layers of meaning, exploring the contextual factors that shape educational practices and the social dynamics that underpin them, taking into consideration the interconnectedness between personal experiences, social structures, and institutional practices within educational narratives, showcasing the rich tapestry of experiences that reflect the complexities of education systems.

The story of a school-university partnership in Luxembourg

Luxembourg is a multilingual country with a complex stratified school system. While the country's population is almost an equal balance between foreign and native residents, the school system shows a highly diverse student population. Schooling is mandatory between the ages of four and 16 and it operates in a multilingual context, with Luxembourgish, German, and French being the languages used across instruction. Primary education in Luxembourg is comprised in four cycles, each one consisting of two years, and German is the main language of instruction (Cycles 2 to 4).

Primary teachers are allocated direct teaching hours in a lower number than the student's schooling hours, leading to a classroom to have at least two teachers. The main teacher (*titulaires*) keeps the responsibility of the classroom and, usually, focus the teaching on language and mathematics. A second teacher (*surnuméraires*) comes in to teach other subjects, such as science, arts and sports. Thus, the profile of the teachers in Luxembourg emerges as a critical structural challenge, leading to issues where science instruction is not consistently integrated with language instruction, posing challenges for teachers and students in this multilingual context. The system faces challenges related to language instruction, teacher roles, and integrating innovative pedagogical approaches.

To support primary science education in transformative ways, the SciTeach Center was established in 2016 at the University of Luxembourg as a resource center dedicated to support the

teaching and learning of science education by providing teaching materials for loan and professional development offerings. It operates as a physical space where teachers and researchers come together to co-develop innovative professional learning opportunities, focusing on inquiry-based teaching practices. As a collaborative educational organization, the center emerges as a partnership between the school and the university settings, research and practice.

The story of this school-university partnership in Luxembourg is explored through the collaboration of one teacher and one researcher that co-developed and co-taught the workshop *Science and Language*. This one-to-one story is narrated in the three core chapters of this dissertation and recapitulated next.

The manuscript ***Exploring boundary-spanning in teacher education: supporting elementary science education through a school-university partnership*** (Chapter V) explored the SciTeach Center as a school-university partnership in Luxembourg that fosters a space for teachers and researchers to work together, develop new teaching methods. By presenting the collaboration between researchers and teachers to co-develop and co-teach the PD offer *Science and Language* (that aimed to integrate inquiry-based science education with language learning), the study highlighted the importance of having a space that enables boundary-spanning, where individuals from different sectors collaborate across traditional roles to innovate educational practices. The collaborative structure of the SciTeach Center, which involves teachers and researchers working as equals and based on the process of *Reflect-Dialogue-Act*, has enabled sustainable professional learning opportunities to be developed and delivered.

The concept of boundary-spanning is explored through the collaborative efforts of myself, a doctoral researcher, and Thierry, a teacher. Our work at the SciTeach Center was enabled by the existing school-university partnership as a third space, where we exited our silos. Our work at the SciTeach Center exemplifies how individuals from different educational backgrounds can come together to create professional development initiatives for primary science education.

I'm originally trained as a secondary school language teacher and had to bridge the gap between my previous teaching experience and my current role in researching primary teacher science education. I collaborated with Thierry, who transitioned from being a primary school science teacher to a teacher educator at the SciTeach Center. Through co-developing and co-teaching the workshop *Science and Language*, we both extended our expertise across different educational levels and contexts. We both illustrate the dynamic nature of boundary-spanning, as we navigated roles that shifted from traditional classroom teaching to collaborating in being teacher educators (and, later on, co-researchers).

The manuscript ***Examining a school-university partnership in Luxembourg: supporting elementary science education in times of uncertainty*** (also Chapter V) brings to light how a

school-university partnership in Luxembourg can be responsive to uncertainties. This manuscript examines how this partnership functions as a third space, enabling collaboration and boundary spanning between teachers and researchers. The chapter explores how this partnership fosters a responsive and collaborative environment that adapts to contextual uncertainties such as the rapidly changing multicultural student demographics and ongoing curricular reforms in Luxembourg. The partnership is sustained through distributed leadership and a strong sense of community, allowing team members to co-develop and co-teach workshops that integrate science education with the complexities of language learning in multilingual classrooms.

A significant aspect of the partnership is its ability to address uncertainties in the educational environment by providing professional development opportunities that respond to teachers' immediate needs. The chapter highlights how boundary-spanning activities – where teachers and researchers cross their traditional roles – enable deeper collaboration and innovative approaches to teaching. The collaborative structure supports ongoing professional learning and reflection, fostering an environment of trust and shared responsibility.

Despite challenges, including the complexity of integrating language and science instruction, the SciTeach Center demonstrates how a school-university partnership can create a sustainable framework for educational innovation. By continuously negotiating their roles and developing contextually responsive strategies, the partnership supports teachers in navigating uncertainties and promotes a culture of shared learning and adaptability. This partnership serves as a model for how educational institutions can collaborate effectively to enhance teacher professional development and improve educational outcomes in diverse, multilingual contexts.

Finally, the manuscript ***Organizational learning as emergent from collaboration: a case study from a professional development module within a school-university partnership*** (Chapter VI) highlighted the concept of organizational learning within a school-university partnership. This chapter examines the collaboration between researchers and teachers that contribute to the Center's evolution as an organization. The analysis identified three levels of organizational learning – individual, project, and partnership – emerging from this partnership. It retraces key events in the development of the PD workshops, particularly one focused on integrating science and language.

The study highlighted how the collaboration fosters professional and organizational learning through shared dialogue and reflection, grounded in the *Reflect-Dialogue-Act* framework. Individual learning is exemplified through a teacher-researcher collaboration, where co-researching took place, and the individuals learned how to research individually and together, and the organization learned that epistemic orientation is key to look into the intersection of co-researching. At the project level, the collaborative structure evolves, revealing systemic challenges related to teacher roles, from which the organization has become aware particularly about this

challenge around implementing interdisciplinary approaches. The partnership's ability to adapt and respond to change in the organization shows how learning happens on the partnership level, all towards the goal of sustaining the organization's mission.

Finally, the manuscript emphasizes that the consistent collaborative structure, underpinned by open dialogue and trust, is key to the organization's success. The SciTeach Center learns from its ongoing projects and adapts to external factors, such as changes in teaching roles or funding structures. Conclusion highlights that this recursive process of learning across different organizational levels supports the Center's sustainability and its capacity to foster transformative professional development in primary science education.

In conclusion, with these three core manuscripts, we can answer the research question, ***How can we support primary education through science teaching for multilingual contexts?***, by reflecting on the collaborative structure between the fields of school and university in Luxembourg. Overall, the school-university partnership presents conditions for the successful development of teacher-researcher collaborations, namely: it consists of a third space, where collaboration is based on dialogue and trust, and team members are acknowledged by expertise. The teacher-researcher collaboration enables permeability on boundary spanning, which leads to continuous learning from exchange.

The why science education matters

Science education matters for several key reasons, especially in fostering critical thinking, interdisciplinary learning, and inclusion in diverse educational contexts.

Fostering inquiry-based learning and critical thinking. Science education encourages students to engage actively in learning by asking questions, exploring phenomena, and developing critical thinking skills, particularly when using inquiry-based approaches for teaching and learning. Chapters throughout this dissertation highlight how science education is not just about the acquisition of knowledge but about understanding processes and fostering curiosity, from the perspective of providing professional learning opportunities. This scientific inquiry approach also helps students build a mindset that embraces problem-solving and creativity, which are considered 21st century essential skills.

Supporting multilingual and interdisciplinary learning. In multilingual contexts such as in Luxembourg, science education can also play a vital role in bridging language barriers and promoting interdisciplinary learning. Throughout different chapters, the dialogue between science and language is emphasized, as science education offers opportunities to integrate language learning, supporting students in developing their linguistic competencies while engaging in

scientific inquiry. This integration not only helps with language acquisition but also fosters a holistic understanding for teachers of how different subjects intersect.

Addressing diversity and promoting inclusion. Science education, particularly in multicultural and multilingual settings, can become a powerful tool for inclusion and integration. Through professional development and collaborative structures (the SciTeach Center), teachers and researchers have worked to foster science learning of diverse student populations. By using science education as an inclusive learning environment, students can see themselves engaging with science (and teachers see them as capable of engaging with science), even in the existence of barriers within the language of instruction.

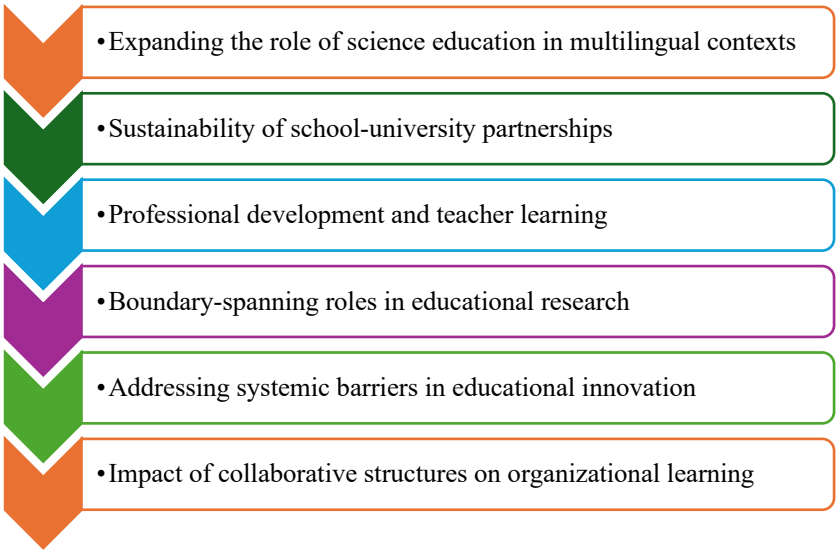
Overall, science education matters because it empowers students to think critically, and teachers can use interdisciplinary approaches to integrate science and language in multilingual learning. Even though there are structural and systemic challenges, there is a need to support primary teachers to engage with science across other disciplines, serving as a position towards implementing the new curriculum (see *Project Plan d'Études 2025*).

Implications

The research presented offers a rich set of implications for further studies. By focusing on the intersections of science education, multilingualism, professional development, and collaborative partnerships, future research can expand on the insights gained here to foster more inclusive, innovative, and effective educational practices with the use of science. There is a need for more research in exploring how education systems can adapt to diverse needs and how collaborations between teachers, researchers, and institutions can be optimized for greater impact.

We understand that certain elements can be expanded, such as focusing on: exploring the use of *science education to promote language learning*; looking into *partnerships' features that sustain in collaborative structures*; recording how *professional development offerings impact and change* the education system; observing *long-term changes in the work of researchers and teachers* who collaborate and span their boundaries; planning *joint effort to implement interdisciplinarity and inquiry-based learning* with the support of administrative structures; and, looking *how collaboration impacts organizations and how learning happens within* (Figure 46).

Figure 46 – Elements to be expanded through research



We unfold these implications with possible examples of actions to be taken in future research designs. Please bear in mind that these are elements from this PhD research that can be expanded. Comparative studies are also welcome as they enable to create frameworks that can serve as example for planning the implementation in other contexts.

Expanding the role of science education in multilingual contexts

The research shows that science education can serve as a bridge for language learning in multilingual environments like Luxembourg. This highlights the need for more research that explores how science education can support language acquisition. Future research could also focus on how specific instructional strategies in science can facilitate language development and how these strategies can be adapted for various linguistic backgrounds.

Sustainability of school-university partnerships

The research emphasizes the importance of sustained collaborative partnerships between schools and universities. Research should continue to explore the long-term impacts of these partnerships, particularly regarding how they evolve over time and how they can be scaled or adapted to other contexts. Further studies could also investigate what structures are most effective for sustaining collaboration and how partnerships can continue to foster intra- and interprofessional learning.

Professional development and teacher learning

The research underscores the importance of ongoing professional development (PD) for teachers, especially in inquiry-based science education and interdisciplinary approaches. One implication for research is the need to investigate the long-term effects of PD on teachers' practices, student outcomes, and school cultures (e.g., considering the transfer of skills framework). Also, future

studies could explore how different models of PD (such as those used by the SciTeach Center team, co-developing and co-teaching, coaching, etc.) impact teacher learning.

Boundary-spanning roles in educational research

Boundary-spanning is a key concept that emerges from the collaboration between teachers and researchers. These collaborative roles challenge traditional divides between practice and research, and future studies should further examine how boundary-spanning impacts the roles and identities of both teacher and researcher (using the permeability concept). Research could also explore how these collaborations reshape the work of teachers and researchers alike, focusing on new hybrid roles and responsibilities in the field of education.

Addressing systemic barriers in educational innovation

The research reveals structural and systemic barriers, such as teacher profiles (main teacher and second teacher) and the compartmentalization of subjects, that inhibit the implementation of interdisciplinary approaches. Future research could focus on identifying and addressing these systemic barriers at different levels of the education system, maybe through an action-research in collaboration with curriculum working groups. Studies might additionally investigate how organizational structures, policies, and leadership strategies can be reimagined to support interdisciplinary and inquiry-based learning more effectively.

Impact of collaborative structures on organizational learning

The findings highlight the significance of collaborative structures, such as the *Reflect-Dialogue-Act* framework. Future research could furthermore explore how these types of frameworks can be applied in other educational contexts, examining their effects on both professional development and organizational change. Additionally, studies could focus on how different types of organizations, beyond school-university partnerships, can adopt and benefit from similar collaborative frameworks.

Chapter IX –
Research Reflections

This chapter presents a reflection on the PhD research conducted over four years and six months at the University of Luxembourg, which explored the intersection of primary science education and teacher professional development in multilingual learning contexts. The reflection consists of the study's direction shifts due to the COVID-19 pandemic and the low participation on the workshop to, finally, being able to the story about a teacher-researcher collaboration within a school-university partnership.

PhD path: challenges, overcomes and opportunities

Four year and six months, this is the period in which I have carried out my PhD in Educational Sciences at the University of Luxembourg. Under the supervision of Prof. Dr. Christina Siry (Chris), I was able to immerse myself in the world of primary science education and, because of my background with international curriculum, I immediately related to the inquiry-based approach to primary science education.

Starting during the COVID-19 crisis had major implications to my research. Our original plan was to work with Lusophone children while doing science investigation in their classrooms, under the proposed project "Examining Lusophone student interactions while engaging in science investigations in primary school". After realizing that external visits were going to be restricted in schools due to the pandemic, we decided to change to research focus to the teachers of Lusophone students, aiming to bring together both Portuguese primary teachers acting in Luxembourg and the students' Luxembourgish primary teachers into a joint endeavor in science education ("Supporting primary education through science within the Portuguese-speaking community in Luxembourg"). As possible partners in this second initiative attempt were having to deal with uncertainties in their own projects given the pandemic, the focus of this research needed to shift once more to the current PhD study presented in this dissertation: ***Supporting primary education through science teaching for multilingual contexts***.

This study focuses on Early Childhood and Primary Science Education, with a related focus on Multilingual Learning Contexts and Primary Teacher Continuous Professional Development, the central research participants are primary teachers in Luxembourg, and the overall goal of the project is to support these teachers for multilingual learning contexts through science education support. One PD workshop was co-developed with the focus on "interdisciplinarity" to be offered through the SciTeach Center, drawing on competency- and inquiry-based approaches to science education.

The workshop *Science and Language* was delivered three times during the course of this study, having a low number of enrolment and attendance for the first two times. For the third offering, we shifted the place of deliverance to a school, which enabled a bigger participation. As primary teachers who were teaching science or not attended the workshop, we were able to hear their perspectives of the use of science to integrate language learning. The teaching approach of inquiry-based was also new to some of the participants. On the overall, there is a tension for putting science and language in dialogue and the use of open-ended teaching strategies.

Five participants agreed to be interviewed after the PD workshop, and shared their thoughts on how we can support them in the future (such as having coaching hours allocated to support them during their direct teaching) and provided key insights about the school system.

The research highlighted the potential of sustainable school-university partnerships and teacher-researcher collaborations through deep understandings of the collaboration and the context within; though it acknowledges limitations such as a narrow focus on one partnership and the pandemic's impact on external collaborations. Despite these challenges, the findings contribute valuable knowledge to the field of primary science education and open paths for future research on long-term collaboration effects and broader applications in educational contexts.

Limitations

The limitations of a study are always linked from what point of view someone looks at any research that is done. For this research, a limitation could be the focus on a specific school-university partnership in Luxembourg, which one may say it limits the generalizability of findings to other contexts. However, through the process of looking into one case (Yes, one is enough!), this research was able to present the conditions that enables the school-university partnership to be sustainable and transformative. Yet, the study's emphasis on primary science education may overlook insights from other educational levels or subject areas.

This research relies on qualitative research approaches and, for instance, a quantitative study, through a questionnaire, could bring another perspective on how to support primary teachers through science education from a possible larger set of data. However, it is not guaranteed a broader participation and nor the drawing of an accurate understanding of the system, especially if open questions are not included in the questionnaire.

The composition of participant groups mainly consisting of researchers and teachers may introduce bias and overlook perspectives from other stakeholders. However, this research presented an in-depth understanding of one teacher-researcher collaboration, which could be compared to other case studies and draw sets of intrinsic and extrinsic factors to inform organizations on how to create possible structures/spaces to host and nurture collaborative structures.

Lastly, the study was impacted by the COVID-19 pandemic in ways that the research focus changed as external partnerships were not fulfilled nor in-school investigations (with children) took place. As the research kicked-off, time constraints set the possibility to research long-term effects of the teacher-researcher collaboration. However, this research can be replicated with other team members as participants and the research field would benefit from knowing the factors that sustain between the different collaboration between the different stakeholders.

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Softwares, Apps and Digital tools

Audio transcriptions using MacWhisper (https://goodsnooze.gumroad.com/l/macwhisper) and Adobe Premiere Pro CC (https://www.adobe.com/lu_en/)

Content analysis with coding and data analysis using MaxQDA (https://www.maxqda.com)

Data mining and graph generated using Orange Data Mining (https://orangedatamining.com)

Diagrams and fluxograms build on using Draw io (https://www.drawio.com)

Grammar checking using Grammarly (https://www.grammarly.com) and DeepL (https://www.deepl.com/pt-PT/translator)

Graphs and charts generated using Python 3.12.5 [libraries: matplotlib, networkx]

Graphs and identify thematic clusters generated using Infranodus (https://infranodus.com)

Network graphs and clusters generated using Neo4J (https://neo4j.com)

Planning and conducting the literature review in Parsifal (https://parsif.al)

Text edition, data organisation, and connections between contents using Obsidian Markdown (https://obsidian.md)

Timeline generation using Conceptboad (https://conceptboard.com)

Research/Academic activities (2020–2024)

This section presents all activities carried out during the PhD period, including presentations, publications, award, collaborations, teaching courses, academic and editorial tasks.

Grant and Award

Research grant	**EScEPT – Empowering Science Education in Primary Teaching** Institute for Teaching and Learning [project cancelled due to COVID-19] Pilot project to compile all resources used at the SciTeach Center and develop new pedagogical sets to be used by in the professional development offerings in Luxembourg.
Award	**ESERA Travel Award 2022 [report]** Travel Award granted to partially fund a research visit in Brazil.
Research grant (proposal submitted for funding request)	**SKILLS – Science Knowledge Integrated with Language Learning in Schools** Partner-school: North of Luxembourg (under negotiation) Dates: November 1st 20024 until April 30th 2025 Pilot project to facilitate language acquisition and science literacy simultaneously among migrant children (in *accueil*) through an integrated curriculum approach.

Outreach

Summer School	**ESERA Summer School 2021 [online]** Adam Mickiewicz University, Poland Dates: July 5th – 9th, 2021
Research visit	**Research visit at the Federal University of Rio de Janeiro, Brazil** Institute Nutes of Education in Science and Health (NUTES) Host: Prof. Dr. Isabel Martins Dates: November 21st to December 2nd 2022
Research visit	**Research visit at the University of Coimbra, Portugal** Faculty of Psychology and Education Sciences (FPCE) Host: Prof. Dr. António Gomes Ferreira Dates: December 13th-16th 2023
Research group	**Centre for Interdisciplinary Studies (CEIS20)** **University of Coimbra, Portugal** GRUPOEDE (Grupo de Políticas e Organizações Educativas e Dinâmicas Educacionais) [Education Policies and Organisations and Educational Dynamics Research Group] Collaborative researcher since 2013

Research group	**Science Education Research Group [online]** Supported by the Institute for Teaching and Learning (DESW/FHSE) Participant since May 2020
Network	**Rede Internacional de Investigação em Educação [International Network for Research in Education]** Coordinator since 2021
Exchange group [Austauschgruppe]	**Teaching in Higher Education University of Luxembourg, Luxembourg** Supported by the Institute for Teaching and Learning (Department of Education and Social Work – DESW, Faculty of Humanities, Education and Social Sciences – FHSE) Academic year 2022-2023

Presentations

Oral presentation [Academic paper]	**Co-generating professional learning through teacher-researcher collaboration** Authors: Maiza Trigo and Thierry Frentz EAPRIL Conference 2024 – Hasselt, Belgium 25-29 November 2024
Roundtable	**School-University Partnerships for Responsive Primary Science Education** Authors: Maiza Trigo, Christina Siry, Sara Wilmes and Kerstin te Heesen EAPRIL Conference 2024 – Hasselt, Belgium 25-29 November 2024
Oral presentation [Academic paper]	**Unpacking the dynamics of a school-university partnership for transformative science education professional development in Luxembourg: a case study of teacher-researcher collaboration** Authors: Maiza Trigo, Christina Siry and Thierry Frentz ATEE 2024 Spring Conference – Bergamo, Italy 29 May - 1 June 2024
Oral presentation [Academic paper]	**Examining a Boundary-Spanning Case Study Within a School-University Partnership That Supports Science Teacher Professional Development** Authors: Maiza Trigo, Christina Siry and Thierry Frentz NARST Conference 2024 – Denver, USA 8 March 2024 [online]
Symposium [Academic paper]	**Examining a School-University Partnership to Support Elementary Science Education in Luxembourg** Authors: Maiza Trigo, Kerstin te Heesen, Sara Wilmes, Ragnhild Barbu and Christina Siry ESERA 2023 – Cappadocia, Turkey 28 August - 1 September 2023
Oral presentation [Academic paper]	**When Science Meets Language in Primary Education: Supporting Teachers for Linguistic Diversity** Authors: Maiza Trigo and Christina Siry ESERA 2023 – Cappadocia, Turkey 28 August - 1 September 2023
Oral presentation [Poster]	**Research Shifts, Developments and Outcomes Since the Participation on the ESERA Summer School 2021** Author: Maiza Trigo ESERA 2023 – Cappadocia, Turkey 28 August - 1 September 2023

Oral presentation [Academic paper]	**Outlining the History of Primary Science Education in Luxembourg: from Normative Education Acts to Stakeholders' Voices** Authors: Maiza Trigo, Christina Siry, Rooney Pinto and Kerstin te Heesen ISCHE 44 – Budapest, Hungary 18-21 July 2023
Oral presentation [Academic paper]	**School-University Partnerships in Support of Equitable Primary Science Education** Authors: Maiza Trigo, Ragnhild Barbu, Sara Wilmes, Kerstin te Heesen and Christina Siry NARST Conference 2023 – Chicago, USA 18-21 April, 2023
Oral presentation [Academic paper]	**Building School-University Partnerships to Support Primary Science Education in Luxembourg** Authors: Maiza Trigo, Ragnhild Barbu, Sara Wilmes, Kerstin te Heesen and Christina Siry LuxERA Conference 2022 – Luxembourg 09-10 November 2022
Oral presentation [Academic paper]	**The case of the Brazilian Journal of Comparative Education** Authors: Maiza Trigo, Evelise Antunes, Juliana Lima, Eliacir França and Luis Enrique Aguilar 4th WCCES 2021 18-20 November 2021 [online]
Oral presentation [Academic paper]	**What Tendency for "Inquiry" and "Language": Examining the Cultural Studies of Science Education Journal** Authors: Maiza Trigo and Christina Siry LuxERA Emerging Researchers' Conference 2021 – Luxembourg 10-11 November 2021 [online]
Oral presentation [Academic paper]	**Adapting to Covid19 in Luxembourg: Centering community, diversity and access in remote primary teacher education for science** Authors: Ragnhild Barbu, Maiza Trigo, Sara Wilmes and Kerstin te Heesen ESERA Conference 2021 – University of Minho, Portugal 30 August to 3 September 2021 [online]
Oral presentation [Academic paper]	**A educação da infância num contexto multilíngue de aprendizagem: o caso do Luxemburgo [Early childhood education in a multilingual learning context: the case of Luxembourg]** Author: Maiza Trigo 7º Congresso Internacional CESPE 2021 27 and 30-31 August 2021 [online]
Oral presentation and Poster	**Supporting primary education through science within the Portuguese-speaking community in Luxembourg** Author: Maiza Trigo ESERA Summer School – University of Adam Mickiewicz/Poland 5-9 July 2021 [online]
Oral presentation [Academic paper]	**Governação em Educação: um estudo comparativo dos casos de contratos em prol da autonomia escolar [Governance in Education: a comparative study of cases of contracts in favor of school autonomy]** Author: Maiza Trigo XIV CIHELA 2021 – University of Lisbon, Portugal 20-23 July 2021 [online]
Oral presentation [Academic paper]	**The case of *Casas da Criança* in the History of Education in Portugal** Authors: Rooney Pinto and Maiza Trigo ISCHE 42 – Örebro University 14-25 June 2021 [online]

Symposium [Academic paper]	**The COVID-19 in Portugal: new school year, similar responses, accountabilities and research** Author: Maiza Trigo From Disruption to Recovery during COVID-19 [Mid-term conference]– Seoul National University, South Korea 7 June 2021 [online]
Oral presentation [Academic paper]	**Working towards responsive science education pedagogies during a time of crisis: centering community, equity and access** Authors: Kerstin te Heesen, Christina Siry, Maiza Trigo and Sara Wilmes SEEDS January 2021 Conference 28 January to 1 February 2021 [online]
Symposium [Academic paper]	**Covid-19 in Portuguese educational scenario: actions, responses and reflections** Author: Maiza Trigo From Disruption to Recovery during COVID-19 – Seoul National University, South Korea 6 and 13 November 2020 [online]
Symposium [Academic paper]	**SciTeach Center responses to COVID-19 crisis: actions, partnerships and teaching/learning supports** Authors: Christina Siry, Sara Wilmes, Kerstin te Heesen and Maiza Trigo From Disruption to Recovery during COVID-19 – Seoul National University, South Korea 6 and 13 November 2020 [online]

Publications

Article [English]	**When contexts change: a case study on collaboration and re-imagined primary science education pedagogy in a time of crisis** Authors: Ragnhild Barbu, Maiza Trigo, et al. Cultural Studies of Science Education (in review)
Book chapter [English]	**The sociodynamic perspective for studies in education: a multidimensional approach to oral testimonies** Authors: Rooney Pinto and Maiza Trigo Re-Membering Education: Temporally Inflected Approaches to Edges of Inquiry – section edited by L. Somogyvári and T. Groves – Springer (in press)
Book chapter [English]	**Brazilian Society of Comparative Education: preliminary notes of a four-decade chronology in favor of education and comparative research** Authors: Luis Enrique Aguilar and Maiza Trigo WCCES Brill Book Series (in press)
Article [English]	**Scientific publications in Comparative Education: challenges, patterns, and the case of the Brazilian Journal of Comparative Education** Authors: Maiza Trigo, Luis E. Aguilar, Eliacir França, Juliana Lima and Evelise Antunes World Voices Nexus: The WCCES Chronicle (October 2024) https://www.worldcces.org/vol8-no3-oct2024
Article in media [German]	**Lët'z talk about Science: Was hat das mit Sprache zu tun?** Authors: Maiza Trigo and Kerstin te Heesen FNR – science.lu (2 December 2024) https://science.lu/de/naturwissenschaften-sprache/letz-talk-about-science-was-hat-das-mit-sprache-zu-tun

Book chapter [English]	**Exploring boundary spanning in teacher education: Supporting elementary science education through a school-university partnership** Authors: Maiza Trigo, Christina Siry and Thierry Frentz Boundary-Spanning in School-University Partnerships Edited by K. Zenkov, D. Polly and L. Rudder Emerald Publishing (2024)
Article [English]	**What tendency for "inquiry" and "language": examining key journals in science education** Author: Maiza Trigo Revista Brasileira de Educação Comparada (2024), v. 6, e024008
Editorial [English]	**40 years of the Brazilian Society of Comparative Education** Authors: Luis E. Aguilar, Maiza Trigo, Eliacir França, Juliana Lima and Evelise Antunes Revista Brasileira de Educação Comparada (2023), v. 5, e023016 https://doi.org/10.20396/rbec.v5i00.18763
Article [English]	**Researching primary science education in a country with cultural and linguistic diversity: the relevance of understanding historically the context of Luxembourg** Author: Maiza Trigo Revista Portuguesa de Pedagogia (2023), v. 57, e057011
Encyclopaedia entry [English]	**Curricula; International in Higher Education (Luxembourg)** Author: Maiza Trigo Bloomsbury Education and Childhood Studies (2022) https://doi.org/10.5040/9781350887176.024
Article [English]	**Multiculturalism as a topic of interest for Comparative Education in Wolfgang Mitter's publications** Authors: Maiza Trigo and Rooney Pinto Revista Brasileira de Educação Comparada (2022), v. 4, e022007 https://doi.org/10.20396/rbec.v4i00.16593
Article [Portuguese]	**Refletir sobre infância, educação e cultura a partir do livro "O mundo até ontem" [Reflecting on childhood, education, and culture from the book "The world until yesterday"]** Authors: Rooney Pinto and Maiza Trigo Educação, Ciência e Cultura (2021), v. 26(3), 1-16 http://dx.doi.org/10.18316/recc.v26i3.7569

Teaching

Bachelor in Educational Sciences	2020-2021	Naturwissenschaftliche Bildung im Elementar und Primarstufenbereich [BScE-561] Natur- und Gesellschaftswissenschaften im Unterricht [BScE-461]
	2021-2022	Naturwissenschaftliche Bildung im Elementar und Primarstufenbereich [BScE-561]
	2022-2023	Naturwissenschaftliche Bildung im Elementar und Primarstufenbereich [BScE-561]
Professional development offerings [Formation continue]	2020-2021	Forschendeckendes Lernen [Multiplikatoren]
	2021-2022	Bionik
	2022-2023	Science and Language [3x]
	2023-2024	Makerspace [Multiplikatoren]

Organization of/collaboration in events

Organizing Committee	**Brazilian Journal of Comparative Education – Webinar 2020 [RBEC Webinar2020]** [Pandemic and its impacts: voices of world comparatists] – June 25th, July 16th and 23rd, and August 5th, 2020 – Brazilian Society of Comparative Education, Campinas/Brazil
Session Chair	**Brazilian Journal of Comparative Education – Webinar 2020 [RBEC Webinar2020]** [Pandemic and its impacts: voices of world comparatists] – July 23rd, 2020 – Brazilian Society of Comparative Education, Campinas/Brazil

Collaboration

Researcher	**Science Education Research Group** – Prof. Dr. Christina Siry University of Luxembourg (Luxembourg) – Research team member **Innovation in Education** – Prof. Dr. António Gomes Ferreira University of Coimbra (Portugal) – Early Career Researcher [GRUPOEDE] **Publications in Comparative Education** – Prof. Dr. Luis Enrique Aguilar Brazilian Society of Comparative Education (Brazil) – Research team member
Coordinator	**Rede Internacional de Investigação em Educação** **[Research in Education International Network]**

Editorial tasks

Editorial board	**Revista Portuguesa de Pedagogia [Portuguese Journal of Pedagogy]** – Faculty of Psychology and Educational Sciences, University of Coimbra, Coimbra/Portugal **Assistant Editor** [Editor-Manager OJS] – since 2019 **Revista Brasileira de Educação Comparada [Brazilian Journal of Comparative Education]** – Brazilian Society of Comparative Education / Campinas University, Campinas/Brazil **Associate Editor** [Editor-Manager OJS] – since 2018
Reviewer	EERJ – Partnership– 2024 [article] CSSE – Science education – since 2020 [4 articles] AJE – School organization – [article] RBEC – Comparative Education – since 2020 [2 articles] Springer – Science education – 2021 [book] Bloomsbury – Educational leadership – 2020 [book chapter] – Comparative Education [book chapter] – History of Education [book chapter]

Appendices

With the goal of scientific transparency, we present the documents used in this research:

- Appendix A – Ethics approval
- Appendix B – Information sheet and Consent form
- Appendix C – Interview prompts
- Appendix D – Articles included in the systematic review

Appendix A – Ethics approval

Prof. Dr. Christina Siry
Université du Luxembourg
Maison des Sciences Humaines
11, Porte des Sciences
L-4366 Esch-sur-Alzette

Esch-sur-Alzette, 10 January 2022
ERP 21-050 SuperSci GZ/kk

UNIVERSITÉ DU LUXEMBOURG

Research project: Supporting primary education through science teaching for multilingual learning contexts (ERP 21-050 SuperSci)

Dear Prof. Dr. Siry,

The Ethics Review Panel of the University of Luxembourg received your request on 15 October 2021 and a revised version on 17 December 2021 concerning the approval of your project: **Supporting primary education through science teaching for multilingual learning contexts (ERP 21-050 SuperSci).**

Your request included:

- application form
- consent form
- information sheet
- appendix

After examining all the documents, the Ethics Review Panel has decided to **approve** the amended project description and the related documents, in the form provided to the Ethics Review Panel.

Please note that the ERP has to be informed of any changes to the study that affect the parts that were subject to ethics approval.

Yours sincerely,

Dr. Gerben ZAAGSMA
Chair of the Ethics Review Panel

Ethics Review Panel of the University of Luxembourg
Address for correspondence:
2, av. de l'Université
L-4365 Esch-Belval
erp-submissions@uni.lu
cc: Maiza de Albuquerque Trigo

Appendix B – Information sheet and Consent form

PhD RESEARCH IDENTIFICATION			
i. Project title:	Supporting primary education through science teaching for multilingual learning contexts (SuperSci)		
ii. Summary:	The central research participants are primary teachers in Luxembourg, and the overall goal of the project is to support [these] primary teachers for multilingual learning contexts through science education support.		
iii. Researcher:	Maiza Trigo (maiza.trigo@uni.lu)	**iv. Supervisor:**	Christina Siry (christina.siry @uni.lu)

INFORMATION SHEET ON THE RESEARCH PROJECT [INFORMATIONSBLATT ZUM FORSCHUNGSPROJEKT]	
Procedures:	During our research, you will be recorded (audio and/or video) while participating in meeting(s), workshops (*formation continue*), interview(s) and focus group(s). We wish to share selected anonymized excerpts from these data with other teachers or research colleagues to share what we have learned.
Risks:	There are no potentially harmful risks associated with participation in this research.
Benefits:	Participation may increase your awareness of the teaching-learning process, especially in science. The research will provide insight into different approaches and practices in science teaching and learning.
Withdrawal:	Participation in the research is voluntary. If you decide to participate, you may withdraw at any time without consequence. Should you decide not to participate, there will be no consequences for you.
Alternatives:	You may choose not to participate in this research. If you choose not to participate, you and all data related to you will not be considered research data. Video and audio recordings will be made, and you will not be included nor take part of the further data collection (interview and/or focus group).
Anonymity:	Data collection, storage, and publication will be handled in a manner that maintains the anonymity of all participants' identities. All recordings (audio and video), interviews, focus groups, and other productions in which you are involved will be anonymized. This means that all names and identifiers from written work and recordings will be deleted. Faces and all identifiable aspects of recordings will be blurred or disguised. Data in paper format will be scanned and digitized, as all data shall be kept on secured University of Luxembourg servers in digital formats. Data retention will comply with EU directives and Luxembourg laws but guaranteed for at least 10 years. Access to the data on the University server will be restricted to the researcher and her supervisor. Investigators from the SciTeach Center project will be granted access in order to include the SciTeach Project assessment and for data treatment towards future co-authored publications.
Confidentiality:	All information collected in this research will be treated confidentially and will not be shared with third parties. Identification by name will not be possible at any time. In individual cases, for publication and dissemination of the research, pseudonyms will be used and all factors that may be used to identify specific students' identities, teachers' identities, or schools will be removed.
Reserved Rights:	If you have questions about your rights as a participant in this participant in this research, you may contact the researchers listed above or to the University of Luxembourg Ethics Review Panel (erp-submissions@uni.lu) or the University of Luxembourg Ethics Advisory Committee (cce@uni.lu).
Final Remark:	If at any time you have questions or wish to withdraw your participation in this research, you may contact Maiza Trigo (maiza.trigo@uni.lu).

PhD RESEARCH SUMMARY

Research Project: Supporting primary education through science teaching for multilingual learning contexts (SuperSci)

Researcher: Maiza Trigo (maiza.trigo@uni.lu) **Supervisor:** Christina Siry (christina.siry @uni.lu)

INVITATION

Dear Primary teacher,

We would like to invite you to participate in this research that aims support you for multilingual learning contexts through science education. This research, which is being conducted within a PhD and with the support of the SciTeach Center team and researchers from the University of Luxembourg, is interested in how primary teachers teach science with multilingual students.

During our research, you will be recorded (audio and/or video) while participating in meeting(s), workshops (*formation continue*), interview(s) and focus group(s). We will select anonymized excerpts from the collected data and share with other teachers or research colleagues to show what we have learned. Yet, documentation of the individual phases is essential in order to trace changes as well as continuities in the development and implementation of teaching. So as to draw conclusions from this and to further develop the PhD project in a goal-oriented way, a detailed analysis by means of various data collection tools/instruments (video and audio recordings of interviews, focus groups, written surveys, etc.) is necessary.

All information collected in this research will be treated confidentially and will not be shared with third parties. Identification by name will not be possible at any time. In individual cases, for publication and dissemination of the research, pseudonyms will be assigned and all factors that may be used to identify specific students' identities, teachers' identities, or schools will be removed.

To conduct this data collection, we need your written consent, that can be granted by signing the enclosed consent form. Thank you for your interest and we hope you'll join as a participant.

Our best regards,

MSc. Maiza Trigo and Prof. Dr. Chrsitina Siry

FREQUENTLY ASKED QUESTIONS

What personal data will be collected and processed?

Data will include: a) First and last name; b) E-mail address; c) E-mail address of your school; d) Information about your professional background and current activities; and e) Recordings (audio/video) of meetings, workshops, interviews and focus groups.

On what legal basis is your personal data processed?

The processing of your personal data is based on your consent to Article 6.1 (a) of the GDPR. Results of the research will be used exclusively for scientific purposes, i.e. to directly improve workshops and resources, as well as for scientific articles and conferences.

What are my rights as a participant?

Under the GDPR, you have certain rights, including: the right to information, the right of access, the right to erasure ("right to be forgotten"), the right to restriction of processing, the right to data portability, the right to "delisting", the right to object, and the right to lodge a complaint with a supervisory authority. You may find further information on the following homepage from the University of Luxembourg: https://www.uni.lu/university/data_protection/your_rights. In practice, you can exercise this right by contacting our Data Protection Officer (DPO) by email (dpo@uni.lu) or by post: Université du Luxembourg | À l'attention de: DPO – Exercice des droits de la personne concernée | Maison du Savoir | 2, Avenue de l'Université| L-4365 Belval.

PhD RESEARCH IDENTIFICATION

Research Project:	Supporting primary education through science teaching for multilingual learning contexts (SuperSci)
Researcher:	Maiza Trigo (maiza.trigo@uni.lu)
Supervisor:	Christina Siry (christina.siry @uni.lu)

RESEARCH PARTICIPANT CONSENT FORM
[EINVERSTÄNDNISERKLÄRUNG DER FORSCHUNGSTEILNEHMER]

I, _____ [family name, first name], born on _____ [date of birth], have been informed by _____ orally and in writing on the nature as well as the potential consequences and risks of the study within the scope of the above-mentioned project, and I had sufficient opportunity to clarify any questions.

I have been informed that I am entitled to withdraw my consent at any time without giving reasons and without negative consequences to myself. Furthermore, I can object to a further processing of my data and samples, as well as request these to be deleted.

I agree that data concerning my person collected within the scope of the study are used for scientific purposes only and are treated as strictly confidential according to the regulations of the Data Protection Act.

Place and date: _____

_____

Signature of the Participant

RESEARCHER

I, _____, as _____ at the University of Luxembourg, have informed the above-mentioned participant orally and in writing on the nature as well as the potential consequences and risks of the study, and that I have given the participant the opportunity to ask any questions.

In addition, the participant received a copy of the information sheet(s) and of this consent form.

Place and date: _____

_____

Signature of the Researcher

Contact person for further questions

Name: Maiza de Albuquerque Trigo

Position: Doctoral Researcher

Tel: (+352) 46 66 44 9633 / (+352) 621 477734

Email: maiza.trigo@uni.lu

If you have a concern about any aspect of your participation, please raise this with the researcher, or with

Name: Dr. Christina Siry

Position: Professor

Tel: (+352) 46 66 44 9717

Email: christina.siry@uni.lu

Appendix C – Interview prompts

D	Goal	Prompt/Question

Teaching science	To try to frame teacher's perceptions about the language situation	• Language in the classroom
		  • What is the language profile of your students?
		  • What languages do your students speak?
		  • How do the different languages co-exist in your classroom?
		  • What are the possibilities?
		  • What are the challenges?

		• Language in the science classroom
		  • What guidelines do you follow to teach science?
		  • Language guidelines?
		  • How is Luxembourgish and German used in a science lesson?
		  • Is there space for other languages?

FoCo Science & Language	To understand the reasoning behind the choice and suggestion on moving forward	• FoCo Science & Language
		  • Why did you choose to attend the FoCo?
		  • What did you like the most about the FoCo?
		  • What did you not enjoy about the FoCo?
		  • What would you change about the FoCo?
		  • How useful was or can it be to your practice?

		• Interdisciplinarity
		  • How free do you feel to plan across subjects?
		  • Have you done activities/projects across subjects?
		  • What benefits do you see in using this approach?

Transfer of skills	To have the space to share practices	• Evidence
		  • Teaching materials?
		  • Students' artifacts?

	To establish a possible collaboration	• Begleitung
		  • What kind of support would you like to have from the SciTeach Center?
		  • Would you like us to come and support you somehow?

Appendix D – Articles included in the systematic review

Nº	Author(s)	Title	Year	Journal	Publisher	Author affiliation
1	Grapin, Scott E. and Haas, Alison and Llosa, Lorena and Lee, Okhee	Developing Instructional Materials for English Learners in the Content Areas: An Illustration of Traditional and Contemporary Materials in Science Education.	2023	TESOL	Willey	(1) University of Miami; (2), (3) and (4) New York University
2	Mercuri, Sandra and Ebe, Ann E.	Developing Academic Language and Content for Emergent Bilinguals through a Science Inquiry Unit.	2011	Journal of Multilingual Education Research	New York State Association for Bilingual Education	(1) The University of Texas at Brownsville; (2) Hunter College, City University of New York
3	Fine, C. G. McC. and Furtak, E. M.	A Framework for Science Classroom Assessment Task Design for Emergent Bilingual Learners.	2020	Science Education	Science Education - Wiley	(1) School of Education, University of Colorado Boulder, Boulder, Colorado: (2) School of Education, University of Colorado Boulder, Boulder, Colorado
4	Busse, Vera and Cenoz, Jasone and Dalmann, Nina and Rogge, Franziska	Addressing Linguistic Diversity in the Language Classroom in a Resource-Oriented Way: An Intervention Study with Primary School Children.	2020	Language Learning	Wiley	(1) University of Münster, Department of Educational Sciences; (2) University of the Basque Country, UPV-EHU; (3) University of Vechta; (4) University of Vechta
5	Lyon, Edward G. and Bunch, George C. and Shaw, Jerome M.	Navigating the Language Demands of an Inquiry-Based Science Performance Assessment: Classroom Challenges and Opportunities for English Learners.	2012	Science Education	Wiley	(1), (2) and (3) Education Department, University of California–Santa Cruz, Santa Cruz, CA 95064, USA
6	Martínez-Álvarez, Patricia	Multigenerational Learning for Expanding the Educational Involvement of Bilinguals Experiencing Academic Difficulties.	2017	Curriculum Inquiry	Taylor & Francis Online	Teachers College, Columbia University, New York, NY, USA
7	Esquinca, Alberto and Araujo, Blanca and de la Piedra, María Teresa	Meaning Making and Translanguaging in a Two-Way Dual-Language Program on the U.S.-Mexico Border.	2014	Bilingual Research Journal	Taylor & Francis Online	(1) and (3) University of Texas at El Paso; (2) New Mexico State University
8	Spycher, Pamela	Learning Academic Language through Science in Two Linguistically Diverse Kindergarten Classes.	2009	Elementary School Journal	The University of Chicago Press	University of California, Davis and WestEd
9	Ralston, Nicole and Shortino, Mary and Smith, Rebecca and Waggoner, Jacqueline	"We're Actually Teaching Science!": A Partnership Approach to Investigating a New Model for Embedding Language in Science.	2021	School-University Partnerships	?	(1), (2), (3) and (4) University of Portland
10	Fine, Caitlin G. McC.	Translanguaging Interpretive Power in Formative Assessment Co-Design: A Catalyst for Science Teacher Agentive Shifts.	2022	Journal of Language, Identity, and Education	Taylor & Francis Online	University of Colorado Boulder
11	Virdia, Simone	The (Heterogeneous) Effect of CLIL on Content-Subject and Cognitive Acquisition in Primary Education: Evidence from a Counterfactual Analysis in Italy.	2022	International Journal of Bilingual Education and Bilingualism	Taylor & Francis Online	Provincial Institute of Educational Research and Experimentation (IPRASE), Rovereto, Italy

12	Lee, Okhee and Grapin, Scott and Haas, Alison	Teacher Professional Development Programs Integrating Science and Language with Multilingual Learners: A Conceptual Framework.	2023	Science Education	Wiley	(1) Department of Teaching and Learning Steinhardt School of Culture, Education, and Human Development, New York University, New York, New York, USA; (2) Department of Teaching and Learning, School of Education and Human Development, University of Miami, Coral Gables, Florida, USA; (3) Department of Teaching and Learning Steinhardt School of Culture, Education, and Human Development, New York University, New York, New York, USA
13	Roper, Soleil and Carpenter, Daniel and Garza, Esther	Teacher Approaches to Writing in Science in Bilingual Elementary Classrooms.	2021	International Journal of Bilingual Education and Bilingualism	Taylor & Francis Online	(1) College of Education, Texas Tech University, Lubbock, TX, USA; (2) College of Education, University of Findlay, Findlay, OH, USA; (3) College of Education, Texas Wesleyan University, St. Forth, TX, USA;d College of Education, Texas A&M University – San Antonio, San Antonio, TX, USA
14	Pierson, Ashlyn E. and Clark, Douglas B. and Brady, Corey E.	Scientific Modeling and Translanguaging: A Multilingual and Multimodal Approach to Support Science Learning and Engagement.	2021	Science Education	Wiley	(1) Department of Teaching and Learning, The Ohio State University, Columbus, Ohio, USA; (2) Werklund School of Education, Learning Sciences, University of Calgary, Calgary, Alberta, Canada; (3) Department of Teaching and Learning, Vanderbilt University, Nashville, Tennessee, USA
15	Esquinca, Alberto and de la Piedra, María Teresa and Herrera-Rocha, Lidia	Hegemonic Language Practices in Engineering Design and Dual Language Education.	2018	Association of Mexican American Educators Journal	The University of Texas at San Antonio - College of Education and Human Development	(1), (2) and (3) University of Texas at El Paso
16	Lan, Shu-Wen and de Oliveira, Luciana C.	English language learners' participation in the discourse of a multilingual science classroom.	2019	International Journal of Science Education	Taylor & Francis Online	(1) Department of Modern Languages, National Pingtung University of Science and Technology, Pingtung, Taiwan; (2) Department of Teaching and Learning, University of Miami, Florida, USA
17	Valdés-Sánchez, Laura and Espinet, Mariona	Coteaching in a Science-CLIL Classroom: Changes in Discursive Interaction as Evidence of an English Teacher's Science-CLIL Professional Identity Development.	2020	International Journal of Science Education	Taylor & Francis Online	(1) Facultat de Ciències de d'Educació, Universitat Autonoma de Barcelona, Bellaterra, Spain; (2) Facultat de Ciències de d'Educació, Universitat Autonoma de Barcelona, Bellaterra, Spain

18	Gómez Ramos, José Luis and Palazón Fernández, José Luis and Lirio Castro, Juan and Gómez-Barreto, Isabel Mª	CLIL: Graphic Organisers and Concept Maps for Noun Identification within Bilingual Primary Education Natural Science Subject Textbooks.	2022	International Journal of Bilingual Education and Bilingualism	Taylor & Francis Online	(1) Department of Pedagogy, Universidad de Castilla-La Mancha, Albacete, Spain, (2) Salus Infirmorum, Universidad de Cádiz, Cadiz, Spain, (3) Department of Pedagogy, Universidad de Castilla-La Mancha, Albacete, Spain, (4) Department of Pedagogy, Universidad de Castilla-La Mancha, Albacete, Spain
19	Leal, Johanna P.	Assessment in CLIL: Test Development at Content and Language for Teaching Natural Science in English as a Foreign Language.	2016	Latin American Journal of Content and Language Integrated Learning	Universidad de la Sabana	Gimnasio Los Andes
20	Martinez-Alvarez, Patricia	What counts as science? Expansive learning actions for teaching and learning science with bilingual children	2019	Cultural Studies of Science Education	Springer	Bilingual/Bicultural Education, Teachers College, Columbia University, 525 West 120th Street (Box 122), Macy Suite 351, New York, NY, 10027, USA
21	Quintero, Josefina and Álvarez, Diana Yurany and Arcila, Andrea	Cross-disciplinary lessons in an elementary public institution; [Lecciones interdisciplinarias en una institución pública de básica primaria]	2021	Profile: Issues in Teachers' Professional Development	Universidad Nacional de Colombia	(1) and (2) Universidad de Caldas; (3) Centro Colombo Americano, Manizales
22	Navarro Martell, Melissa A.	"Ciencias bilingües": How Dual Language Teachers Cultivate Equity in Dual Language Classrooms.	2022	International Journal of Bilingual Education and Bilingualism	Taylor & Francis Online	Department of Dual Language and English Learner Education, College of Education, San Diego State University, San Diego, CA, USA
23	de Larios, Julio Roca and Coyle, Yvette and García, Vanessa	The Effects of Using Cognitive Discourse Functions to Instruct 4th-Year Children on Report Writing in a CLIL Science Class.	2022	Studies in Second Language Learning and Teaching	Department of English Studies, Faculty of Pedagogy and Fine Arts, Adam Mickiewicz University, Kalisz	(1), (2) and (3) University of Murcia, Spain Spain
24	Williams, Melanie and Tang, Kok-Sing	The Outcomes of Fifth-Grade Emergent Bi/Multilinguals' Introduction to a Visual Metalanguage When Constructing Scientific Explanations in Hong Kong.	2021	Asia-Pacific Science Education	Brill	(1) and (2) School of Education, Edith Cowan University Perth Australia
25	Kiramba, Lydiah Kananu and Harris, Violet J.	Navigating Authoritative Discourses in a Multilingual Classroom: Conversations with Policy and Practice.	2019	TESOL Quarterly: A Journal for Teachers of English to Speakers of Other Languages and of Standard English as a Second Dialect	Wiley	(1) University of Nebraska-Lincoln, Lincoln, Nebraska, United States; (2) University of Illinois at Urbana-Champaign, Urbana, Illinois, United States
26	Siry, Christina and Wilmes, Sara E. D.	Working toward Equitable Research Practices: The Value of Highlighting Complexity and Respecting Context.	2020	Cultural Studies of Science Education	Springer	(1) and (2) Institute for Teaching and Learning, The University of Luxembourg, Esch-sur-Alzette, Luxembourg

27	Poza, Luis E.	The Language of "Ciencia": Translanguaging and Learning in a Bilingual Science Classroom.	2018	International Journal of Bilingual Education and Bilingualism	Taylor & Francis Online	School of Education and Human Development, University of Colorado Denver, Denver, CO, USA
28	Alvarez, Laura	Reconsidering Academic Language in Practice: The Demands of Spanish Expository Reading and Students' Bilingual Resources.	2012	Bilingual Research Journal	Taylor & Francis Online	WestEd Teacher Professional Development Program
29	Lee, Okhee and Luykx, Aurolyn and Buxton, Cory and Shaver, Annis	The Challenge of Altering Elementary School Teachers' Beliefs and Practices Regarding Linguistic and Cultural Diversity in Science Instruction.	2007	Journal of Research in Science Teaching	Wiley	(1) School of Education, University of Miami, Coral Gables, FL 33146.; (2) College of Education, University of Texas at El Paso, El Paso, TX 79968; (3) School of Education, University of Miami, Coral Gables, FL 33146; (4) Cedarville University, Cedarville, OH 45314
30	Luykx, Aurolyn and Lee, Okhee and Mahotiere, Margarette and Lester, Benjamin and Hart, Juliet and Deaktor, Rachael	Cultural and Home Language Influences on Children's Responses to Science Assessments.	2007	Teachers College Record	Sage	(1) University of Texas at El Paso; (2), (3) and (4) University of Miami; (5) College of William and Mary; (6) ???
31	Di Stefano, Marialuisa and Villanueva Alarcón, Idalis and McEneaney, Elizabeth and Marte Zorrilla, Edwin and Esquinca, Alberto	Exploring Bilingual and Dual Language Teachers' Perspectives on Asset-Based Professional Development in Science and Engineering.	2022	Bilingual Research Journal	Taylor & Francis Online	(1) and (3) University of Massachusetts, USA; (2) and (4) University of Florida, USA; (5) San Diego State University, USA
32	Kiramba, Lydiah Kananu	Heteroglossic Practices in a Multilingual Science Classroom.	2019	International Journal of Bilingual Education and Bilingualism	Taylor & Francis Online	University of Nebraska–Lincoln
33	Harden, Karon and Punjabi, Maitri and Fernandez, Maricel	Influences on Teachers' Use of the Prescribed Language of Instruction: Evidence from Four Language Groups in the Philippines.	2022	Education Quarterly Reviews	Elsevier	RTI International
34	Symons, Carrie	Instructional Practices for Scaffolding Emergent Bilinguals' Comprehension of Informational Science Texts.	2021	Pedagogies: An International Journal	Taylor & Francis Online	Department of Teacher Education, Michigan State University, East Lansing, MI, USA
35	Ünsal, Zeynep and Jakobson, Britt and Wickman, Per-Olof and Molander, Bengt-Olov	Jumping Pepper and Electrons in the Shoe: Using Physical Artefacts in a Multilingual Science Class.	2020	International Journal of Science Education	Taylor & Francis Online	(1), (2), (3) and (4) Department of Mathematics and Science Education, Stockholms Universitet, Stockholm, Sweden
36	Ünsal, Zeynep and Jakobson, Britt and Molander, Bengt-Olov and Wickman, Per-Olof	Language Use in a Multilingual Class: a Study of the Relation Between Bilingual Students' Languages and Their Meaning-Making in Science.	2018	Research in Science Education	Springer	(1), (2), (3) and (4) Department of Mathematics and Science Education, Stockholm University, SE-106 91, Stockholm, Sweden
37	Karlsson, Annika and Nygård Larsson, Pia and Jakobsson, Anders	Multilingual Students' Use of Translanguaging in Science Classrooms.	2019	International Journal of Science Education	Taylor & Francis Online	(1), (2) and (3) Faculty for Education and Society, Malmö University, Malmö, Sweden

38	Tian, Zhongfeng	Challenging the 'Dual': Designing Translanguaging Spaces in a Mandarin-English Dual Language Bilingual Education Program.	2022	Journal of Multilingual and Multicultural Development	Taylor & Francis Online	Department of Bicultural-Bilingual Studies, The University of Texas at San Antonio, San Antonio, USA
39	Grapin, Scott E. and Pierson, Ashlyn and González-Howard, María and Ryu, Minjung and Fine, Caitlin and Vogel, Sara	Science Education with Multilingual Learners: Equity as Access and Equity as Transformation.	2023	Science Education	Wiley	(1) Department of Teaching and Learning, University of Miami, Coral Gables, Florida, USA; (2) Department of Teaching and Learning, The Ohio State University, Columbus, Ohio, USA; (3) Department of Curriculum and Instruction, The University of Texas at Austin, Austin, Texas, USA; (4) Department of Chemistry, University of Illinois Chicago, Chicago, Illinois, USA; (5) Department of Elementary Education, Metropolitan State University of Denver, Denver, Colorado, USA; (6) Computing Integrated Teach
40	Mohan, Bernard and Slater, Tammy	A Functional Perspective on the Critical "Theory/Practice" Relation in Teaching Language and Science.	2005	Linguistics and Education: An International Research Journal	Elsevier - Science Direct	(1) and (2) Department of Language and Literacy Education, University of British Columbia, Vancouver, Canada V6T 1Z4
41	Pierson, Ashlyn E. and Grapin, Scott E.	A Disciplinary Perspective on Translanguaging.	2021	Bilingual Research Journal - The Journal of the National Association for Bilingual Education	Taylor & Francis Online	(1) The Ohio State University; (2) University of Miami