

Integrating Inclusive Practices in Science, Technology, Engineering, and Mathematics Education: Rethinking the Curriculum for Teachers' Professional Development

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ABSTRACT

Despite the global emphasis on Science, Technology, Engineering, and Mathematics (STEM) education, the field is still marked by systemic disparities that restrict the participation of underrepresented groups. While the necessity of inclusive practices is widely recognized, European educators frequently lack context-specific professional development (PD) tailored to their unique educational landscapes. This study explores how STEM teachers reflect on their identities, classroom practices, and school environments in relation to inclusion. Data were collected from 63 STEM teachers across 16 European countries who participated in a targeted blended training program, using a questionnaire-based self-reflection tool adapted from the American Psychological Association's (2021) considering diversity self-reflection tool and comprising Likert-scale items on teacher identity, classroom practices, curriculum/materials, and school environment. The study employed descriptive statistics to assess teacher perceptions and Kruskal–Wallis tests to examine the impact of training duration. Key findings indicate that while teachers hold strong positive beliefs regarding the importance of inclusion ($M = 4.6$), they report significantly lower confidence in practical applications, such as constructively addressing diversity-related conflicts ($M = 3.9$) and selecting inclusive curriculum materials. Crucially, the analysis revealed that the duration of training significantly impacts teachers' self-awareness, specifically regarding how their own cultural identities influence their professional judgment ($p = 0.008$). These results highlight a critical gap between inclusive intent and pedagogical practice. The study concludes that to move beyond superficial awareness, future STEM PD curricula in Europe must be redesigned to prioritize sustained, critical reflection and provide concrete strategies for conflict resolution and material adaptation.

KEY WORDS: European education, inclusive practices, professional development, science, technology, engineering, and mathematics education, teacher identity

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education plays a significant role in preparing students for the future workforce and fostering innovation (OECD, 2021). The need to promote STEM education is linked to its interdisciplinary nature which involves multiple skills, competencies, and dispositions that the students can gain, as well as the growing need for workers in STEM in the future (OECD, 2021). Historically, STEM disciplines have been dominated by certain demographic groups, leading to the underrepresentation of women, minorities, and individuals with disabilities (Avraamidou, 2020; Duncan et al., 2023; Evagorou et al., 2024). This lack of diversity in STEM not only limits the potential talent reservoir but also perpetuates systemic inequities. The importance of equipping STEM teachers with the knowledge and skills necessary to challenge and dismantle inequities within their spheres of influence has been highlighted by many scholars (Gorski, 2016). In-service teacher training and professional development (PD) programs for educators are essential in supporting them to address these challenges. Such programs can equip teachers

with the knowledge and skills necessary to create inclusive STEM classroom environments that support diverse learners. By focusing on inclusive practices, PD can help educators implement strategies that promote equity and access (Darling-Hammond et al., 2017). Teachers require specialized training to implement inclusive practices in their classrooms effectively. This includes understanding the unique challenges faced by underrepresented groups, developing culturally responsive teaching strategies, gender-inclusive and gender-sensitive strategies, and creating an inclusive curriculum (Forde, 2014; Wright and Delgado, 2023). Without such tailored PD, teachers may struggle to adapt their practices to support all students effectively (Gay, 2018). Consequently, addressing this gap is critical for fostering an inclusive STEM education system.

By promoting inclusivity, educators can help ensure that all students, regardless of their background, have equal opportunities to succeed in STEM. This approach not only benefits individual students but also can potentially enrich the STEM community by bringing diverse perspectives and ideas. Nevertheless, despite the widespread belief that education should be equitable, numerous obstacles hinder

the establishment of this objective, particularly in developing inclusive learning environments for STEM which involves not only accommodating students with disabilities but also addressing the needs of those who are underrepresented due to factors such as ethnicity, gender, or other vulnerabilities (Milanovic et al., 2023). As educational settings become increasingly diverse, it is imperative for STEM educators to actively engage in dialogs concerning diversity, equity, and inclusion.

Most of the studies related to inclusive practices in STEM education originate from the USA (i.e., Palid et al., 2023), with a strong emphasis on preparing university faculty members for STEM inclusive practices (i.e., Dewsbury, 2017); supporting minorities (i.e., Charity Hudley and Mallinson, 2016); and promoting gender-sensitive approaches (Wright and Delgado, 2023). The aforementioned aspects of STEM PD in the USA have been important in addressing systemic inequities within the American educational context with its specificities. However, in Europe, research on inclusive practices and teacher PD in STEM remains limited, except for some recent projects (i.e., Spice Academy) that have created educational frameworks for STEAM in Special Education (Agaliotis and Kartasidou, 2023). While the findings from the USA provide important information, the socio-cultural and educational contexts within Europe differ significantly, making it difficult to transfer inclusive STEM professional-related strategies within the European contexts. Unlike the US context, which often focuses on specific racial demographics, the European educational landscape is characterized by “super-diversity” arising from intra-European mobility and multilingualism, requiring distinct pedagogical approaches. Therefore, what we argue in this paper is the need to design PD programs tailored to teachers, which will take into account the contextual situation related to STEM education, the diverse educational systems, and the unique challenges faced by educators in fostering inclusivity within STEM education within a changing landscape. Accordingly, this paper positions inclusive STEM teacher PD at the intersection of three strands: (a) Equity literacy and culturally responsive pedagogy (Gay, 2018; Gorski, 2016), (b) universal design for learning (UDL) as a design frame for accessibility and representation, and (c) PD design principles (e.g., active learning, coherence, duration, and follow-up) associated with changes in teacher beliefs and practices (Darling-Hammond et al., 2017; Desimone, 2009; Desimone and Garet, 2015). We take as a starting point that teachers’ identities and positionalities shape instructional judgment and that sustained, structured reflection is necessary to translate inclusive intent into classroom practice.

To address the gap and tackle the aforementioned needs for teacher PD, this paper aims to explore how teachers from different disciplines understand STEM education and to examine how they reflect on their own identities related to inclusion. More specifically, the research questions guiding this study are (a) How do teachers reflect on their identities related to inclusion when it comes to themselves and their

practices? (b) How do teachers reflect on their identities related to inclusion when it comes to their students and classrooms? (c) How do teachers reflect on their identities related to inclusion when it comes to the curriculum and classroom materials they teach? and (d) How do teachers reflect on their identities related to inclusion when it comes to their school environment?

By focusing on European contexts and examining whether teachers’ self-awareness and practices differed according to the duration of PD, this study contributes empirical evidence for designing STEM PD that moves beyond superficial awareness toward sustained reflection, conflict-responsive pedagogy, and concrete strategies for adapting curriculum materials to diverse learners. In what follows, we outline related scholarship, describe the training program and instruments, and report analyses that inform a design-oriented agenda for inclusive STEM PD in Europe.

LITERATURE REVIEW

Inclusive Pedagogies and Practices in STEM Education

Inclusive practices in STEM education have been a focal point of research and policy discussions, as they are crucial for fostering diversity and equity in these fields. Inclusive practices in STEM education ensure that all students have equitable access to learning opportunities. This is done by enhancing student learning and decreasing social disparities in STEM education, which in turn increases the diversity of the student population entering and completing STEM majors (Johson, 2019; Sanders O’Leary et al., 2020). Despite the recognized significance of inclusive practices in STEM, there is a notable gap in PD programs specifically tailored to address these needs as most existing PD initiatives focus broadly on improving teaching practices or enhancing subject matter knowledge, but they often lack a targeted emphasis on inclusivity, especially targeted at STEM-related subjects. Furthermore, a significant number of educators exhibit reluctance to participate in these discussions, often due to a perceived deficiency in knowledge or training. This hesitancy can impede the creation of inclusive learning environments essential for fostering student success (Johnson, 2019).

Institutional policies and practices are crucial for sustaining inclusive environments. For example, the Interagency Working Group on Inclusion in STEM (2021) outlines best practices for diversity and inclusion for students across educational levels. This working group emphasizes the need for strategic partnerships, targeted recruitment, and retention efforts. These practices include engaging minority-serving institutions, providing financial support for internships, and developing leadership opportunities for underrepresented groups. Promoting representation and access in STEM education is crucial for advancing gender equity and increasing the participation of underrepresented groups, such as women and girls, in STEM fields. Initiatives aimed at reducing gender gaps and fostering participation of females in STEM education and careers are essential for achieving equitable outcomes

(UNESCO, 2020; World Bank, 2020). Collaborative programs and policies that support gender parity and provide role models and mentorship opportunities are vital for encouraging girls and women to pursue STEM careers (UN Women, 2016; UNESCO, 2017).

Furthermore, literature highlights several strategies and interventions aimed at creating more inclusive environments for underrepresented groups in STEM, including women, racial and ethnic minorities, and individuals with disabilities. A systematic review by Palid et al. (2023) found that diversity-focused STEM intervention programs that create a welcoming environment and focus on the successes of minoritized students are effective in improving student outcomes. These programs often include multiple components, such as mentorship, academic support, and community-building activities, which collectively contribute to a more inclusive atmosphere. By implementing these strategies, educational institutions can create more equitable and inclusive environments that support the success of all students in STEM fields. On a systemic level, such practices involve the adaptation of pedagogical strategies, new curricula, and resources to address the varied needs of the student population. By fostering inclusivity on a systemic or school level, educators can facilitate the provision of equitable opportunities for all students, irrespective of their backgrounds, to achieve success in STEM (LaForce et al., 2019). Nevertheless, teachers often need support within their own classrooms, as well as examples of practices and pedagogies that can be used to support the diversity of students within their classes (Evagorou and Mousoulides, 2019).

One of the pedagogies that has been used to support diverse teaching is the culturally responsive pedagogy. This pedagogy is highlighted as a key approach to addressing social justice, diversity, equity, and inclusion in education, recognizing and valuing students' cultural backgrounds and integrating these into the curriculum (Gay, 2002). In culturally sensitive or culturally responsive pedagogies, cultural and linguistic practices of minoritized groups are integrated into the curriculum, thereby promoting learning and achievement outcomes for all students (Hernandez et al., 2013). In STEM education, studies support that some of the main difficulties students are facing are linked to their diverse cultures and languages and how these compare to the dominant school culture (Xenofontos, 2015). Research evidence supports that learning in STEM subjects can be facilitated through social interaction and student dialog (Herrenkohl and Guerra, 1995), as such experiences help students listen, think, and share their reasoning. This underscores the importance of language in science education, as well as the significance of understanding cultural context.

Duncan et al. (2023) highlight the importance of cultural competency in creating equitable and inclusive STEM classrooms. According to Meyer and Crawford (2011), students face significant cultural challenges in science education and STEM education classes. For some students, science and STEM are a second culture, and the cultural aspects of

STEM subjects may be unfamiliar to them, necessitating their inclusion in teaching. STEM subjects are more accessible to students with a Western cultural background, as STEM in general is a Western construct (Aikenhead, 1996). Thus, even in the absence of language barriers, STEM lessons pose difficulties for students from cultures different from the dominant ones (Settlage and Southerland, 2012).

Despite efforts over the last decade regarding culturally responsive science teaching, most of these initiatives come from countries like the U.S., where classrooms often have large populations of students sharing a common language and culture (e.g., Latinx students who speak Spanish in predominantly English-speaking classrooms). Such efforts also focus on the teacher's use of the second language (e.g., Spanish) to better support students. However, the demographic shifts observed across the world in recent years have resulted in classrooms with students from diverse cultural backgrounds who speak multiple languages (Author, 2019). Consequently, the examples from the U.S., while useful, cannot be directly applied across all contexts.

Sanders O'Leary et al. (2020) emphasize the need for teachers to engage in culturally responsive teaching workshops, which can raise awareness of social identities and barriers to learning, such as implicit bias and stereotype threat, hence leading to increased knowledge and motivation to adopt inclusive teaching practices and consequently develop equitable learning environments. In addition to culturally responsive teaching, differentiated instruction and UDL are recommended strategies to support diverse learners in STEM classrooms. These approaches emphasize flexibility and inclusiveness, allowing for the accommodation of various learning needs and promoting equitable access to STEM education (Basham and Marino, 2013). Specifically, the UDL offers a comprehensive framework for designing instructional goals, assessments, and materials that accommodate the needs of all learners. As Meyer et al. (2014) emphasize, this framework provides multiple means of representation, expression, and engagement, ensuring that all students can access and participate in learning activities. Moreover, differentiated instruction plays a crucial role in meeting the diverse needs of students. This strategy involves tailoring teaching methods to differentiate content, processes, products, and learning environments based on students' readiness levels, interests, and learning profiles (Tomlinson, 2014). Collaborative learning is also an effective approach that fosters an inclusive classroom environment. Through group work and peer learning, students are encouraged to share their diverse perspectives and learn from one another, thereby fostering a sense of community and belonging (Johnson and Johnson, 2021). The use of assistive technologies significantly supports inclusive practices. Technologies such as screen readers, speech-to-text software, and adaptive learning platforms can help remove barriers to learning for students with disabilities, thereby enhancing their educational experience (Burgstahler and Cory, 2010). LaForce et al. (2019) sought to derive a theoretical model for inclusive

STEM high schools by employing a “component approach.” According to their study, critical components of STEM school models include personalization of learning, problem-based learning, rigorous learning, and the development of career, technology, and life skills. These components contribute to the common goals and strategies employed by these schools to support student success.

Another significant aspect of inclusive practices is the development of STEM identity among students. Singer et al. (2020) discuss how authentic learning experiences, coupled with a focus on diversity and inclusion, can help students develop a sense of belonging and positive STEM identities. This is particularly important for underrepresented students, who often face challenges in seeing themselves as part of the STEM community due to a lack of representation and role models.

Finally, mentorship and support networks also play a critical role in promoting inclusivity in STEM education. The literature suggests that mentoring programs, such as those described by Palid et al. (2023), can provide essential support and guidance for students from underrepresented groups, helping them navigate academic and professional challenges. These programs often include peer mentoring, faculty mentoring, and professional networking opportunities, which can enhance students’ confidence and persistence in STEM fields. An example of working with students and mentoring them comes from Calabrese Barton, who works with students from low-income areas, homeless students, or students with immigrant backgrounds. Barton promotes engagement with science and STEM through after-school activities, outside of school. As part of their effort to support students and mentor them, they organize after-school science clubs in challenging environments as part of social justice programs, aiming to keep children away from abusive substances through educational activities. Based on her interactions with these children, Barton concludes that: (a) Students with low academic performance and no interest in science excel in after-school activities, where the questions and investigations stem from their own needs (for example, using alternative energy sources to reduce electricity bills); (b) the investigations they propose relate to how they imagine themselves in the future, thus connecting STEM to their personal needs; and (c) parental involvement in these activities leads to better learning outcomes (Basu and Barton, 2007). Therefore, students’ needs and ideas should also be considered as part of the inclusive practices.

In conclusion, an inclusive teacher in STEM education should exhibit the following characteristics: (a) Recognize that there are multiple ways of understanding reality, and these ways are connected to each individual’s social position, (b) Hold positive views and attitudes toward students with diverse characteristics (gender, culture, abilities) and be able to identify students’ strengths in learning rather than focusing solely on their weaknesses, (c) See themselves as responsible for and capable of bringing about social change that will improve the school environment for all students, (d) Understand how

students construct knowledge, particularly in the context of STEM education, (e) Have knowledge about their students’ lives outside of school, and (f) Use this knowledge to design lessons that build upon students’ existing knowledge while pushing them beyond the familiar (Villegas and Lucas, 2002). To prepare teachers with these characteristics, there is a need for the development of professional training programs that focus on cultivating pedagogical content knowledge, specifically in the area of inclusive STEM teaching.

Teachers’ Perceptions on Inclusive Practices in STEM Education

Teachers’ perceptions of inclusive practices directly influence the implementation and success of such educational strategies. Through a comprehensive analysis of existing literature, Margot and Kettler (2019) reveal that educators value the interdisciplinary approach inherent in STEM education which facilitates students’ ability to integrate knowledge across various subjects and apply it to real-world problems, while they recognize its significance in enhancing critical thinking and student engagement as well as preparing them for future careers. Nevertheless, this positive attitude is often tempered by significant challenges such as a lack of resources, curricular rigidity, insufficient training, and structural issues along with a lack of confidence, highlighting the need for PD, collaboration, and support to effectively implement STEM education. In addition, teachers often feel overwhelmed by the additional demands of differentiating instruction to meet the needs of all students, particularly in subjects that are already perceived as challenging (Sungur Gul et al., 2023).

Teachers’ beliefs about inclusion also play a significant role in their practices. Specifically, teachers who hold strong beliefs in the value of inclusion are more likely to employ strategies that support diverse learners. These strategies include using multiple representations of content, providing hands-on learning experiences, and fostering a collaborative classroom environment (Dignath et al., 2022). Teachers’ perceptions of inclusivity are shaped by their PD experiences and the interventions they participate in which aim at enhancing teachers’ understanding of integrating inclusive strategies into their STEM teaching (Zhang et al., 2023). Freeman et al.’s (2014) highlight that teachers’ attitudes toward inclusive STEM education are shaped by their experiences and the support they receive. Specifically, teachers who have access to PD opportunities and collaborative networks are more likely to adopt inclusive practices and integrate them into their teaching. This is echoed by the findings of Shernoff et al. (2017), who emphasize the importance of ongoing training and support for teachers to effectively implement STEM education that is inclusive and accessible to all students. Moreover, the study by Nguyen et al. (2020) suggests that teachers’ perceptions of inclusive STEM education are influenced by their understanding of the benefits it offers, such as fostering critical thinking, creativity, and problem-solving skills among students. Teachers who perceive these benefits are more inclined to embrace inclusive practices and adapt their teaching

methods to accommodate diverse learners. However, the study also notes that teachers often feel unprepared to address the specific needs of students with disabilities in STEM subjects, highlighting the need for targeted training and resources. Inclusive practices in STEM education also involve addressing the specific needs of underrepresented groups. A case study on teachers' perceptions of inclusive practices for students with disabilities in STEM education indicates that teachers who received specialized training in inclusive education were more confident in their ability to support students with disabilities. These teachers were more likely to use assistive technologies and adapt their instruction to meet the needs of all students (O'Leary et al., 2025; Fernández-Batanero et al., 2022).

The impact of teachers' perceptions on student outcomes is another important consideration. A meta-analysis study aiming at improving teachers' perceptions of STEM education revealed that positive changes in teachers' perceptions were associated with improved student engagement and achievement in STEM subjects, suggesting that efforts to enhance teachers' perceptions of inclusive practices can have a direct impact on student success (Zhou et al., 2023).

PD for Inclusive STEM Education

PD is effective in improving teachers' perceptions of their ability to implement inclusive practices in STEM education, ensuring that all students, regardless of background and abilities, have equal opportunities to succeed in STEM fields. Such programs, which often include collaborative learning opportunities, not only help teachers share best practices and develop a community of practice but also enhance teachers' content knowledge and pedagogical skills, enabling them to better support students with diverse learning needs (Darling-Hammond et al., 2017). As Zhang et al. (2023) claim, teachers who engage in sustained PD are more likely to develop a deeper understanding of how to create inclusive STEM classrooms, enabling them to adapt their teaching methods to meet the needs of all students, thereby promoting equity in STEM education.

Effective PD is characterized by several key features, including active learning, a focus on student learning-oriented teaching practices, subject-specific content, collaboration, coherence with curriculum and standards, and sustained duration with ongoing support (Bates and Morgan, 2018; Darling-Hammond et al., 2017; Desimone, 2009; Desimone and Garet, 2015). These elements are crucial for influencing teacher beliefs and classroom practices, ultimately improving student achievement (Desimone et al., 2005). By incorporating these key features, PD programs not only enhance general teaching practices but also specifically empower teachers to implement inclusive strategies in STEM education. This alignment ensures that PD initiatives are not only effective in a broad sense but also tailored to foster inclusivity and equity in STEM classrooms.

Martins and Baptista (2024) explore the impact of integrated STEAM education on the development of PCK among physics teachers. They emphasize that effective PD in STEAM education not only enhances teachers' content knowledge but

also equips them with the skills to integrate arts into STEM subjects, thereby enriching the learning experience and promoting creativity. This approach aligns with the findings of Conradty and Bogner (2020), who demonstrate that STEAM PD positively influences students' creativity and motivation. By incorporating arts into STEM education, teachers can create more engaging and dynamic learning environments that cater to diverse student needs.

Moreover, the review by Boz (2023) highlights the importance of evaluating PD effectiveness through rigorous methods, including formative and summative assessments, and involving multiple stakeholders such as teachers, administrators, and students (Guskey, 2014). This comprehensive approach ensures that PD initiatives lead to meaningful changes in teaching practices and student outcomes. Building on this, Sanders O'Leary et al. (2020) highlight that effective PD for inclusive STEM education focuses on developing educators' self-awareness regarding their social identities, privileges, and biases, which can impact student learning experiences. It also equips educators with tools and resources to adopt inclusive and culturally responsive teaching strategies, addressing barriers to student learning such as stereotype threats, microaggressions, and fixed mindsets. Furthermore, it incorporates activities that foster interaction, collaboration, and engagement, presenting diversity and inclusion from an asset-based perspective to enhance participant learning and understanding.

In addition to these strategies, implementing interactive exercises that allow educators to explore their perspectives on diversity, inclusion, and equity is also important. These exercises should be complemented by practical examples of inclusive practices that align with active learning pedagogy to enhance student learning outcomes and reduce disparities in STEM education (Johnson, 2019). However, challenges and considerations in PD must be addressed to ensure its effectiveness. Addressing power dynamics and disparities between educators and students is crucial in PD sessions to create a safe and inclusive learning environment for all participants. Providing flexibility and support for participants, such as accommodating childcare needs and balancing workshop sessions with social interactions, can further enhance the effectiveness of PD initiatives in inclusive STEM education (O'Leary et al., 2025).

METHODS

Context

This study focuses on data from a training program that was developed as part of an EU-funded project which aims to reduce the number of low-performing STEM learners by offering PD for both in-service and pre-service STEM teachers. The training program was offered multiple times across two academic years, either as an online training or a face-to-face summer school training. For the purposes of the training program, four theme clusters were created, each consisting of three 2-h sessions. Cluster 2, which is the emphasis of this research, focused on

diversity and inclusion in STEM education. In addition to providing participants with helpful resources for putting inclusive practices into practice in their own settings, this cluster aimed to increase awareness and understanding of the critical roles that diversity and inclusion play in STEM education. Participants became familiar with (re)design strategies for selecting and developing tasks and adapting them to their specific educational environments. It covered various task formats, pedagogical approaches, and their connections to role models in STEM. In addition, participants prepared an example activity, including a lesson plan, along with expectations regarding diversity and inclusion. Teachers also had opportunities to inquire into and reflect on their enacted lessons, drawing on theoretical constructs and tools from research on inclusive classroom practices. This reflective process helped them to gain a deeper understanding of the strategies needed to implement and evaluate inclusive STEM lessons, as well as recognize the affordances, constraints, and challenges involved. In addition, guidance was provided on future practices, and participants were asked to identify two key takeaways from the cluster that they would continue to apply in their classrooms.

The cluster's goal was to assist educators in developing a body of knowledge and strategies for promoting inclusive STEM education. Small group reflections, discussions, problem-solving, and creating materials for posters and brief presentations were among the many collaborative tasks in which participants took part. Short plenary lectures and plenary sharing conversations were also beneficial to them. Participants completed follow-up activities and preparatory tasks on the learning platform to support asynchronous learning.

Online training sessions

During the online training sessions, the subject of diversity and inclusion in STEM education was introduced. The 2-h session's objective was to broaden the participants' awareness of how STEM education could promote diversity. Discussions on important topics, including the gender gap in STEM disciplines, the under-representation of students with disabilities, and racial and ethnic minorities, were facilitated by interactive collaborative tasks. Participants were asked to critically evaluate the current under-representation concerns and actively promote equality, diversity, and inclusion in their educational practices by the end of the session.

Building on the first session's conclusions, the second session examined how diversity and lesson design relate to STEM education. Participants in this 2-h session explored methods for choosing and creating assignments that take into account differences in gender, culture, and cognitive ability. Participants in cross-country groups developed sample lesson plans and activities that they were supposed to test out and consider. The goal of this session was to provide participants with the tools they need to develop inclusive learning activities that consider the varied backgrounds of their students.

In the third and last 2-h session, teachers were encouraged to use tools and theoretical constructs from research on inclusive

classroom practices to reflect on their enacted lessons. The purpose of this reflective approach was to increase instructors' understanding of inclusive STEM class implementation and assessment techniques. Participants engaged in discussions to share experiences and insights, linking research findings with their teaching practices. By the end of the session, teachers were expected to design and enact inclusive teaching approaches informed by existing research. Table 1 provides an overview of the online training sessions conducted on inclusion and diversity in STEM, highlighting the focus, learning objectives, and outcomes associated with each session.

Face-to-face training

The face-to-face training was conducted as part of a summer school in Prague, consisting of two 2-h sessions. This format allowed for a more interactive and dynamic exploration of the topics covered in the online sessions, with adaptations to meet the specific needs of the participants and the objectives of the summer school. The workshop presented the idea of critical postmodern science pedagogy and integrated UDL principles (Ash and Wiggan, 2018). To plan strategies for moving toward more inclusive educational environments, participants engaged in thoughtful conversations. The workshop aimed to empower educators to foster diversity and promote inclusivity within their respective STEM educational contexts by combining theoretical insights with practical applications. Table 2 offers a summary of the face-to-face training session.

Sample and Procedure

Initially, the training was conducted twice during the academic year 2023–2024 and delivered online in a blended format, utilizing both synchronous and asynchronous methods. 88 STEM teachers participated in the blended sessions, but for the purposes of this research, responses to the self-reflection tool were collected only during the second iteration and the summer school. The study protocol was reviewed and approved by the Cyprus National Bioethics Committee. Before participation, all teachers received written information about the study aims and procedures, the voluntary nature of participation, and their right to withdraw at any time without consequences, and they provided informed consent. No direct personal identifiers were collected. Questionnaires were anonymized at source and any potentially identifying information was removed before analysis. All data were stored securely in password-protected files on access-restricted systems and were accessible only to the research team, in accordance with applicable data-protection requirements. A total of 63 STEM teachers from 16 European countries completed the questionnaire.

Data Collection Tool

The data collection tool was a questionnaire that was administered to the STEM teachers. The questionnaire was adapted from the Considering Diversity Self-Reflection Tool for Psychology Teachers developed by the American Psychological Association (APA, 2021). The aim of the tool was to help teachers make their classrooms and schools more inclusive and diverse. Teachers' demographics such as

Table 1: Summary of training sessions on inclusion and diversity in STEM

Title	Description	Learning objectives	Outcomes
1. Diversity and inclusion	This introductory session focused on raising awareness about diversity and inclusion in STEM education. It explored STEM's role in teaching diversity and discussed the underrepresentation of specific groups. Critical postmodern science pedagogy was introduced as a strategy to address these issues.	- Raised awareness of diversity and inclusion in STEM education. - Explored STEM's potential in teaching diversity. - Discussed the underrepresentation of certain groups. - Introduced critical postmodern science pedagogy.	- Participants became active in pursuing equality, diversity, and inclusion. - They appraised the role of STEM in teaching diversity. - They criticized underrepresentation and the potential of critical pedagogy for awareness.
2. Analyzing and designing STEM tasks for diversity and inclusion	This session built on previous insights, focusing on task design to foster inclusion and diversity. Participants became familiar with designing tasks that consider classroom diversity and prepared an example activity for try-out, including a lesson plan with expectations for inclusion and diversity.	- Understood how tasks could organize activities utilizing classroom diversity.	- Participants prepared an example activity for try-out and were expected to report on and reflect on pedagogical practices in the following session.
3. Analyzing inclusive classroom practices	Teachers reflected on their lessons using tools derived from research on inclusive practices. The session aided in implementing and evaluating inclusive lessons and discussed future practices. Participants indicated two key messages they wished to continue practicing in their classrooms.	- Became aware of research findings on diversity and inclusion. - Shared and justified teaching decisions. - Developed reflection strategies linking research and teaching.	- Teachers designed and enacted inclusive approaches linked to existing research. - They collectively inquired into teaching and became more aware of their teaching choices.

Table 2: Overview of the face-to-face summer school session on inclusion and diversity in STEM

Title	Description	Focused areas	Outcomes
Face-to-face session	Conducted during a summer school, this session consisted of two 2-h face-to-face training modules. It allowed for an interactive exploration of topics from the online sessions, adapting to participants' needs. The workshop focused on critical postmodern science pedagogy (CPSP) and Universal Design for Learning (UDL) principles.	- Presented and discussed critical postmodern science pedagogy (CPSP). - Integrated Universal Design for Learning (UDL) principles. - Engaged participants in planning strategies for inclusive educational environments.	- Participants were empowered to foster diversity and inclusivity in their STEM educational contexts. - They combined theoretical insights with practical applications to create more inclusive educational strategies. - Participants engaged in meaningful discussions and collaborations.

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teaching experience, level of education in which they teach, subject they teach, their gender, and country were collected. Four categories of questions are included in the self-reflection tool, namely questions about the teachers' perceptions of diversity and inclusion; questions about their students and classroom; questions about the curriculum and instruction, and questions about the school. Finally, the self-reflection tool included a question asking teachers if they plan to take steps to further enhance inclusion in their STEM practices, followed by an open-ended question asking them to indicate their steps. Teachers had to indicate their agreement with these statements on a five-point scale (1 = I strongly disagree, to 5 = I strongly agree).

Data Analysis

The data from the reflection tool were analyzed using descriptive statistics to summarize participant responses, allowing for an assessment of trends in participants' reflections. Means were calculated for each item to identify central tendencies. These results provide insights into participants' perceptions of STEM and inclusion and can be used to inform the design of PD. To further examine differences across groups, non-parametric inferential tests were conducted. Kruskal-

Wallis tests were used to assess whether teachers' responses differed according to levels of prior PD duration, as the data did not meet the assumptions required for parametric tests. In addition, Mann-Whitney U tests were conducted where comparisons involved two independent groups (e.g., teachers expressing willingness versus uncertainty regarding future inclusion efforts).

RESULTS

Table 3 presents the gender distribution, level of instruction, and STEM specializations of the teacher sample. From the 63 teachers who responded to the reflection tool, 77.8% (n = 49) taught at the secondary level, making this the most common level of instruction among the participants. Meanwhile, 19% (n = 12) worked at the primary level, and only a small proportion, 3.2% (n = 2), taught at the pre-primary level. Among these teachers, the most common STEM specializations were science and mathematics, particularly at the secondary level where 26 teachers specialized in science and 22 in mathematics. The sample also included smaller numbers of teachers specialized in technology (n = 6), chemistry (n = 3), and various other subjects such as physics and maths, and computer science,

each with one teacher. Furthermore, two teachers declared that they were specialized in all disciplines as primary teachers.

Table 4 summarizes the teaching experience and the level of training that participants previously had in inclusion and diversity. First, the teaching experience of the sample was varied. Twelve teachers were indicated with no experience and 1–5 years, respectively. Most of the teachers had 10–20 years ($n = 22$), some of them had 6–10 years ($n = 9$), and a few had more than 30 years ($n = 8$) of teaching experience. Furthermore, a significant portion ($n = 18$) have had no training in the area of Inclusion and Diversity. While half of the sample ($n = 33$) had undertaken 1–10 h of training and only a few had more than 10 h of training ($n = 12$).

How do teachers reflect on their identities related to inclusion when it comes to themselves and their practices?

Table 5 presents the descriptive statistics related to teachers' identity when it comes to themselves. The high averages

(ranging from 4.5 to 4.6) for statements like modeling respect for diverse individuals, recognizing diversity within and between groups, and valuing inclusion in STEM education show that STEM teachers generally exhibit strong awareness and commitment to diversity and inclusion. However, areas with comparatively lower averages (ranging from 4.1 to 4.3) suggest specific domains where further training and support may be needed. For instance, there is potential for improvement in actively seeking opportunities to learn about diversity and form new relationships, even if teachers report modeling inclusion of people from diverse backgrounds in their personal lives ($M = 4.3$, standard deviation $[SD] = 0.951$). Furthermore, the categories with the lowest averages were teachers' recognition of assumptions about individuals from other cultures or groups ($M = 4.1$, $SD = 0.729$) and their awareness of how their own identity and cultural perspectives affect their judgment ($M = 4.2$, $SD = 0.734$).

How do teachers reflect on their identities related to inclusion when it comes to their students and classrooms?

The findings of the descriptive statistics (Table 6) also show that STEM educators generally demonstrate a great dedication to creating inclusive and respectful classroom environments. For instance, educators acknowledge the influence of their privilege and power on their relationships with students from various backgrounds ($M = 4.4$, $SD = 0.766$) and describe

Table 3: Demographic characteristics of participants

Characteristic	Number of teachers (n)	Percentage
Gender		
Female	43	68.3
Male	19	30.2
Prefer not to say	1	1.5
Level of instruction		
Secondary	49	77.8
Primary	12	19.0
Pre-primary	2	3.2
STEM specializations		
Science	26	41.3
Mathematics	22	34.9
Technology	6	9.5
Chemistry	3	4.8
Physics and maths	1	1.6
Computer science	1	1.6
Other	4	6.3

STEM: Science, technology, engineering, and mathematics

Table 4: Teaching experience and training in inclusion and diversity

Characteristic	Number of teachers (n)	Percentage
Teaching experience (years)		
No experience	12	19.0
1–5	12	19.0
6–10	9	14.3
10–20	22	34.9
More than 30	8	12.7
Inclusion and diversity training (hours)		
No relevant training	18	28.6
1–10 h	33	52.4
11–20 h	4	6.3
More than 20 h	8	12.7

Table 5: Descriptive statistics for teachers' self-reported identity, awareness, and inclusion beliefs

Statements	Average	SD
In my own life, I model respect for people who are different from me in gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.	4.6	0.745
I believe that inclusion and diversity in the context of STEM education are important	4.6	0.767
I recognize there is diversity between groups of individuals based on gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.	4.5	0.829
I recognize there is diversity within groups of individuals with the same gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.	4.5	0.780
In my own life, I model inclusion of people who are different from me in gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.	4.3	0.951
I take opportunities to put myself in places or situations where I can learn about differences and create new relationships.	4.3	0.841
I am aware of how my identity and cultural perspective influence my judgment.	4.2	0.734
I am aware of the assumptions that I hold about people of cultures and groups different from my own.	4.1	0.729

SD: Standard deviation, STEM: Science, technology, engineering, and mathematics

Table 6: Descriptive statistics for teachers' classroom practices and awareness related to diversity and inclusion

Statements	Average	SD
I am careful not to prejudge a student's performance based on cultural or identity differences.	4.5	0.754
I recognize how my power and privilege as a teacher impact my relationships with students of differing backgrounds and identities.	4.4	0.766
My students feel comfortable being themselves in my classroom.	4.3	0.861
I understand how my power and privilege as a teacher impact my relationships with students of differing backgrounds and identities.	4.3	0.863
I recognize conflicts based on differences between individuals and groups.	4.2	0.880
I actively facilitate community building in my classroom.	4.1	0.908
I am knowledgeable about the diverse backgrounds (gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.) of my students and their families.	4	0.856
My students know each other's names, backgrounds, and interests.	4	0.898
My students share personal examples reflective of their differing backgrounds in the classroom.	3.9	0.999
I constructively address conflicts based on differences between individuals and groups.	3.9	1.031
I am knowledgeable about the diverse interests (gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.) of my students and their families.	3.8	0.878

SD: Standard deviation

being cautious not to make assumptions about students based on cultural or identity differences ($M = 4.5$, $SD = 0.754$). A generally positive and encouraging classroom climate is also suggested by the teachers' perception that their students feel free to be who they are in the classroom ($M = 4.3$, $SD = 0.861$). However, descriptive statistics also point to areas where teachers' capacity for addressing diversity and inclusion might be improved with more training and PD. For example, teachers report recognizing conflicts based on differences between individuals and groups ($M = 4.2$, $SD = 0.880$), although their ability to constructively address such conflicts received a lower average ($M = 3.9$, $SD = 1.031$). This suggests a potential gap between recognizing issues and taking reasonable steps to resolve them, indicating a need for further training in conflict resolution and mediation strategies.

Similarly, there is also space for improvement in teachers' understanding of the diverse backgrounds of their students ($M = 4.0$, $SD = 0.856$) and interests ($M = 3.8$, $SD = 0.878$). These relatively lower averages imply that PD aimed at enhancing cultural awareness and expanding teachers' comprehension of the unique identities and experiences of their students may be beneficial. In addition, the finding that students have opportunities to share personal examples reflective of their differing backgrounds received a lower average ($M = 3.9$,

Table 7: Descriptive statistics for teachers' Inclusive curriculum and instructional practices

Statements	Average	SD
I respect diverse behaviors, values, communication styles, and languages in my classroom.	4.4	0.799
I acknowledge diverse behaviors, values, communication styles, and languages in my classroom.	4.3	0.854
I ensure that classroom responsibilities, activities, and interactions are inclusive (e.g., an equitable system for calling on students; gender neutral language).	4.2	0.979
I prepare students for future environments that may be different from their current experiences (e.g., college, work).	4.1	1.017
The materials I use in class are accessible and appropriate for students with varying educational needs.	4	0.904
My classroom materials are inclusive, diverse, and non-stereotypical.	3.9	0.900
The materials I use in class are accessible and appropriate for students with varying physical disabilities.	3.8	1.070
When attempting controversial or sensitive diversity-related lessons and things get uncomfortable, I persevere.	3.8	1.002

SD: Standard deviation

$SD = 0.999$), highlighting the necessity to create more inclusive classroom practices that encourage students to express their identities and perspectives.

How do teachers reflect on their identities related to inclusion when it comes to the curriculum and classroom materials they teach?

According to the findings (Table 7), STEM educators often work to establish inclusive and respectful learning environments through their lesson plans and teaching strategies. For instance, in their classes, instructors feel that different behaviors, values, communication styles, and languages are respected and acknowledged ($M = 4.4$, $SD = 0.799$ and $M = 4.3$, $SD = 0.854$, respectively). In addition, STEM teachers indicate that they ensure classroom responsibilities, activities, and interactions are inclusive, such as using equitable systems for calling on students and gender-neutral language ($M = 4.2$, $SD = 0.979$). These results reflect a strong dedication to fostering diversity in everyday classroom activities.

However, the data also highlight areas where further PD could enhance teachers' ability to address diversity and inclusion more effectively. For instance, the accessibility and appropriateness of classroom materials for students with varying educational needs ($M = 4.0$, $SD = 0.904$) and physical disabilities ($M = 3.8$, $SD = 1.070$) received lower averages, despite teachers reporting that they are preparing students for future environments that may differ from their current experiences ($M = 4.1$, $SD = 1.017$). These findings point to the necessity of further training in the creation and selection of inclusive and accessible learning materials and resources for all students, especially those with disabilities.

In addition, there is potential for improvement in making sure that instructional resources reflect the diversity of students' identities and experiences, as evidenced by the lower average ($M = 3.9$, $SD = 0.900$) for the finding that classroom materials are perceived as inclusive, diverse, and non-stereotypical. Guidance on selecting or creating materials that are impartial and culturally sensitive may be helpful to educators.

Finally, teachers' persistence with addressing sensitive or controversial diversity-related lessons when discomfort arises had the lowest average in this part ($M = 3.8$, $SD = 1.002$). This implies that even though educators may recognize the importance of discussing sensitive topics, they might not have enough confidence or coping mechanisms to do so. This gap might be filled with PD centered on establishing safe spaces for conversation and supporting challenging dialogs in their settings.

According to the descriptive statistics in Table 8, STEM teachers generally try to incorporate diverse and inclusive resources into their lessons. One example of a commitment to portraying diversity in visual teaching aids is the perception of the images and visual displays used in the classroom (e.g., PowerPoint slides, posters) as inclusive, diverse, and non-stereotypical ($M = 4.2$, $SD = 1.025$). The averages, however, are marginally lower for other categories of materials, including general classroom resources ($M = 3.9$, $SD = 0.938$), names and examples in handouts and assessments ($M = 3.9$, $SD = 0.973$), and textbooks and readings ($M = 3.9$, $SD = 1.074$). The consistent averages across these areas ($M = 3.9$) highlight a potential gap in the availability or selection of diverse and non-stereotypical materials. These results suggest that although educators are making progress in integrating diversity into visual aids, more may be done to guarantee that all teaching materials – textbooks, readings, and tests – are equally inclusive and free of stereotypes.

How do teachers reflect on their identities related to inclusion when it comes to their school environment?

In addition, according to the descriptive statistics of the last section of the self-reflective tool (Table 9), STEM teachers believe that their schools are receptive to family input on diversity issues ($M = 4.0$, $SD = 1.198$) and are typically aware of the diversity of their school community ($M = 4.2$, $SD = 0.879$). The analysis does, however, also point out a few areas in which schools might not be doing enough to embrace and celebrate diversity. For instance, the averages for public areas, committees, programs, and support services are significantly lower ($M = 3.7$, $SD = 1.227$ – 1.254), even though schools are thought to encourage diversity in these areas. This implies that although attempts are being made, they might not be strong enough or obvious enough to establish an environment that is truly inclusive. In addition, the belief that students from diverse origins and identities are disproportionately negatively impacted by school policies (such as scheduling and prerequisites) ($M = 3.3$, $SD = 1.322$) draws attention to structural obstacles that could sustain inequalities. Similarly,

Table 8: Descriptive statistics for the self-reported inclusivity of instructional materials used by the participants

Statements	Average	SD
The images and visual displays used in the classroom (e.g., PowerPoint, posters) are inclusive, diverse, and non-stereotypical	4.2	1.025
The textbooks and readings used in the classroom are inclusive, diverse, and non-stereotypical	3.9	1.074
The resources used in the classroom are inclusive, diverse, and non-stereotypical	3.9	0.938
The names and examples in handouts and assessments used in the classroom are inclusive, diverse, and non-stereotypical	3.9	0.973

SD: Standard deviation

Table 9: Descriptive statistics for teachers' perceptions of school-level diversity and inclusion

Statements	Average	SD
I am aware of my school community's diversity.	4.2	0.879
My school is open to feedback from families to share insights and experiences related to diversity concerns.	4	1.198
My school supports diversity in: Public spaces (e.g., inclusive signage, accessibility, representation in displays and decorations)	3.7	1.232
My school supports diversity in: Programs, committees, and student groups	3.7	1.254
My school supports diversity in: Support Services	3.7	1.227
The demographics of my STEM classes match the demographics of my school.	3.7	1.254
My school celebrates diversity.	3.6	1.203
The membership of the parent groups (e.g., PTA or PTO) reflects the demographics of the school community.	3.5	1.313
My school policies (e.g., scheduling and/or prerequisites) disproportionately negatively impact students of differing backgrounds and identities.	3.3	1.322
The demographics of the teaching staff reflect the demographics of my school.	3.3	1.301

SD: Standard deviation

the lower average for schools celebrating diversity ($M = 3.6$, $SD = 1.203$) indicates that although diversity is recognized, it is not often or significantly honored. Teachers may be more equipped to design and carry out activities that genuinely celebrate the diverse identities and cultures present in their school communities if they receive training that emphasizes inclusive practices and cultural competency.

To further examine whether teachers' perceptions and practices differed according to their level of prior training in inclusion and diversity, participants were categorized into four groups based on the number of hours of training in Inclusion and Diversity in STEM education that they self-reported having undertaken in the past (0 h, 1–10 h, 11–20 h, and 20+ h). The grouping was based exclusively on teachers' retrospective self-reports of prior PD experience. Additional statistical analyses were conducted. In particular, it was investigated

whether there were statistically significant differences in instructors' responses according to their degree of training using the Kruskal–Wallis test, a non-parametric method. The Kruskal–Wallis test was selected because it can be used to compare several independent groups (such as training levels) when the data does not satisfy the homogeneity of variance or normality assumptions needed for parametric tests like analysis of variance. The results of these tests are presented below.

The results (Table 10) revealed a statistically significant difference in teachers' awareness of how their identity and cultural perspective influence their judgment across the four self-reported training groups ($H[3] = 11.718$, $p = 0.008$). This finding suggests that teachers' self-reported awareness differs according to their level of prior training. More specifically, teachers who reported higher numbers of prior training hours demonstrated different levels of self-awareness compared to those reporting little or no prior training.

For the remaining items, no statistically significant differences were found across the four self-reported training groups ($p > 0.05$).

Dunn's test with a Bonferroni correction for multiple comparisons was used to perform *post hoc* pairwise comparisons to determine whether particular training groups had different opinions about how identity influences judgment. According to the results, there was a statistically significant difference ($p < 0.05$) between the groups that received 1–10 and 11–20 h of training. Statistical significance was not reached by any other pairwise comparisons.

Table 10: Kruskal–Wallis test results for differences in diversity and inclusion views across training levels

Item	Kruskal–Wallis H	df	p-value
I am aware of how my identity and cultural perspective influence my judgment.	11.718	3	0.008*
I am aware of the assumptions that I hold about people of cultures and groups different from my own.	7.188	3	0.066
I recognize there is diversity between groups of individuals based on gender identity, religion, race, etc.	4.141	3	0.247
I recognize there is diversity within groups of individuals with the same gender identity, religion, race, etc.	5.844	3	0.119
In my own life, I model respect for people who are different from me in gender identity, religion, race, etc.	2.285	3	0.515
In my own life, I model inclusion of people who are different from me in gender identity, religion, race, etc.	3.292	3	0.349
I take opportunities to put myself in places or situations where I can learn about differences.	0.646	3	0.886
I believe that inclusion and diversity in the context of STEM education are important.	2.835	3	0.418

The significance level was set at $p < 0.05$. Bolded row indicates a statistically significant result. STEM: Science, technology, engineering, and mathematics

The Kruskal–Wallis test was also used to examine whether teachers' perceptions related to diversity and classroom dynamics differed across the four self-reported training levels. The results (Table 11) revealed statistically significant differences in two key areas: Teachers' self-reported knowledge about the diverse backgrounds ($H[3] = 11.127$, $p = 0.011$) and interests ($H[3] = 9.521$, $p = 0.023$) of their students and families, encompassing aspects such as gender identity, religion, race, ethnicity, language, abilities, sexual orientation, and socioeconomic status. These findings indicate that teachers' self-reported awareness of student diversity differed according to their level of prior training, particularly in relation to students' backgrounds and interests.

For the remaining items, no statistically significant differences were found across training groups ($p > 0.05$).

A Kruskal–Wallis test was also conducted to examine whether teachers' perceptions and practices related to inclusivity and classroom preparation differed across the four self-reported training levels. The results (Table 12) revealed no statistically significant differences across the training groups for any of the items evaluated ($p > 0.05$). This suggests that STEM teachers' practices and attitudes toward creating inclusive, diverse, and prepared classroom environments remain consistent regardless

Table 11: Kruskal–Wallis test results for differences in classroom diversity perceptions across training levels

Item	Kruskal–Wallis H	df	p-value
I am knowledgeable about the diverse backgrounds of my students and their families.	11.127	3	0.011*
I am knowledgeable about the diverse interests of my students and their families.	9.521	3	0.023*
I am careful not to prejudge a student's performance based on cultural or identity differences.	3.238	3	0.356
I actively facilitate community building in my classroom.	4.211	3	0.240
My students know each other's names, backgrounds, and interests.	1.294	3	0.731
My students feel comfortable being themselves in my classroom.	1.241	3	0.743
My students share personal examples reflective of their differing backgrounds in the classroom.	6.147	3	0.105
My students share personal examples reflective of their differing interests in the classroom.	5.502	3	0.139
I recognize conflicts based on differences between individuals and groups.	0.337	3	0.953
I constructively address conflicts based on differences between individuals and groups.	6.469	3	0.091
I recognize how my power and privilege as a teacher impact my relationships with students of differing backgrounds and identities.	6.754	3	0.080
I understand how my power and privilege as a teacher impact my relationships with students of differing backgrounds and identities.	7.042	3	0.071

The significance level was set at $p < 0.05$. Bolded row indicates a statistically significant result

Table 12: Kruskal–Wallis test results for differences in inclusive classroom practices across training levels

Measure	Kruskal-Wallis <i>H</i>	df	p-value
My classroom materials are inclusive, diverse, and non-stereotypical.	3.899	3	0.273
I ensure that classroom responsibilities, activities, and interactions are inclusive.	6.032	3	0.110
I acknowledge diverse behaviors, values, communication styles, and languages in my classroom.	1.805	3	0.614
I respect diverse behaviors, values, communication styles, and languages in my classroom.	2.933	3	0.402
The materials I use in class are accessible and appropriate for students with varying physical disabilities.	1.650	3	0.648
The materials I use in class are accessible and appropriate for students with varying educational needs.	4.186	3	0.242
I prepare students for future environments that may be different from their current experiences.	2.307	3	0.511
When attempting controversial or sensitive diversity-related lessons and things get uncomfortable, I persevere.	1.968	3	0.579
The significance level was set at $p < 0.05$			

of the level of training received. This finding highlights the need for further investigation into the factors that influence teachers' inclusivity practices and how training programs might be refined to address these areas more effectively.

Finally, a series of Mann–Whitney *U* tests were conducted to examine whether teachers who expressed a stronger willingness to take future steps toward enhancing diversity and inclusion differed from those who were unsure across measures of awareness, practices, and perceptions (Table 13).

Participants were divided into two groups based on their response to the item “I plan to take steps to further enhance inclusion in my STEM practices” (Yes vs. Unsure). The analysis revealed that teachers with higher willingness reported significantly greater awareness of the assumptions they hold about members of groups and cultures different from their own ($U = 131.00$, $z = -4.53$, $p < 0.001$, $r = 0.56$). Significant differences were also observed in teachers' knowledge of students' diverse interests ($U = 131.00$, $z = -3.57$, $p < 0.001$, $r = 0.47$) and diverse backgrounds ($U = 260.00$, $z = -2.30$, $p = 0.021$, $r = 0.29$).

In addition, teachers reporting stronger future willingness differed significantly in actively facilitating community building in the classroom ($U = 85.00$, $z = -3.37$, $p < 0.001$, $r = 0.47$), encouraging students to share personal examples reflective of their differing backgrounds ($U = 61.00$, $z = -3.93$, $p < 0.001$, $r = 0.54$), and constructively addressing conflicts based on differences ($U = 113.00$, $z = -2.77$, $p = 0.006$, $r = 0.37$). Significant differences were also found in the use of classroom materials that are accessible and appropriate for students with

varying educational needs ($U = 79.50$, $z = -3.22$, $p = 0.001$, $r = 0.45$), as well as in ensuring that names and examples used in handouts and assessments were inclusive, diverse, and non-stereotypical ($U = 93.50$, $z = -3.45$, $p < 0.001$, $r = 0.46$).

Overall, these findings indicate that teachers who express greater readiness to advance diversity and inclusion initiatives also report higher levels of diversity-related awareness and inclusive classroom practices, with effect sizes ranging from small to moderate to large.

In the final questions of the reflection tool, 43 teachers indicated that they plan to take further steps for enhancing inclusion in their STEM practices, whilst none of the teachers indicated a negative stance toward further steps.

DISCUSSION

The findings of this study offer important insights into how STEM teachers across multiple European contexts reflect on issues of diversity, inclusion, and classroom practice. Because the sample covered 16 European countries, teachers' responses may also have been shaped by national differences in inclusion policies, curriculum requirements, teacher preparation traditions, and resource availability. Overall, teachers reported strong beliefs in the importance of inclusion and a high level of awareness of diversity within and across groups. These positive orientations are consistent with the broader literature showing that teachers often value inclusive principles (Margot and Kettler, 2019; Johnson, 2019). At the same time, teachers expressed lower confidence in practice-proximal behaviors, most notably, addressing diversity-related conflicts and selecting or adapting inclusive instructional materials. This pattern mirrors research indicating that while teachers may endorse inclusive goals, translating them into everyday practice remains challenging in the absence of concrete strategies and targeted support (Sungur Gul et al., 2023).

Teachers' reflections also revealed differing levels of confidence across dimensions of classroom climate and interpersonal practice. High ratings related to equitable norms, non-judgmental interactions, and student comfort suggest that many educators are establishing classroom environments that support belonging and respect. However, areas such as conflict facilitation and the integration of diverse student perspectives received lower ratings. Prior research highlights that facilitating difficult dialogs and managing identity-linked conflict require specialized pedagogical tools and structured opportunities for practice (Johnson, 2019; Sanders O'Leary, et al., 2020). The present findings reinforce the ongoing need for professional learning opportunities that help teachers build practical and context-specific skills in these areas.

With respect to curriculum materials and accessibility, teachers viewed visual resources as more inclusive and diverse than textbooks, readings, and general instructional materials. Lower confidence in the accessibility of materials for students with physical disabilities further indicates gaps in universal access.

Table 13: Differences in diversity-related awareness and inclusive practices by level of future willingness (Mann–Whitney U tests)

Item	Group 1 (willing) n	Group 2 (unsure) n	U	z	p-value	r
I am aware of the assumptions that I hold about people of cultures and groups different from my own.	45	20	131.00	−4.53	<0.001*	0.56
I am knowledgeable about the diverse backgrounds (gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.) of my students and their families.	46	18	260.00	−2.30	0.021*	0.29
I am knowledgeable about the diverse interests (gender identity, religion, race, ethnicity, language, abilities, sexual orientation, socioeconomic status, etc.) of my students and their families.	42	16	131.00	−3.57	<0.001*	0.47
I actively facilitate community building in my classroom.	40	12	85.00	−3.37	<0.001*	0.47
My students share personal examples reflective of their differing backgrounds in the classroom.	41	12	61.00	−3.93	<0.001*	0.54
I constructively address conflicts based on differences between individuals and groups.	45	11	113.00	−2.77	0.006*	0.37
The materials I use in class are accessible and appropriate for students with varying educational needs.	40	11	79.50	−3.22	0.001*	0.45
The names and examples in handouts and assessments used in the classroom are inclusive, diverse, and non-stereotypical.	45	12	93.50	−3.45	<0.001*	0.46

Two-tailed Mann–Whitney U tests. Effect size (*r*) calculated as $z/\sqrt{N}$. $p < 0.05$ indicates statistical significance

This aligns with scholarship emphasizing the importance of UDL and the use of assistive technologies to ensure that STEM learning experiences are accessible to all students (Basham and Marino, 2013; Meyer et al., 2014). Inclusive STEM school models also emphasize the centrality of high-quality, equitable materials to support personalized and rigorous learning pathways (LaForce et al., 2016; Lynch et al., 2018). Hence, the findings suggest that while teachers may incorporate inclusive imagery or examples, deeper work is needed to ensure that core instructional materials are representative, non-stereotypical, and accessible for diverse learners.

Teachers also described inadequate support at the school level. Although many perceived their schools as open to feedback and aware of community diversity, they reported comparatively lower support across institutional programs, services, and public spaces. They also expressed concerns that some school policies may disproportionately affect students from different backgrounds. These perceptions resonate with broader policy analyses identifying school-level structures, such as tracking, prerequisites, and administrative procedures, as influential factors shaping equitable participation in STEM (UNESCO, 2017; World Bank, 2020; Interagency Working Group on Inclusion in STEM, 2021). The findings therefore suggest that individual teacher efforts toward inclusion must be complemented by supportive organizational structures and coherent policy environments to sustain meaningful change.

Notably, most teacher perceptions did not vary according to the number of training hours completed. This is consistent with prior research suggesting that short- or moderate-duration PD may lead to initial awareness gains without immediately producing shifts in practice, particularly when follow-up coaching, observation, and collaborative inquiry are limited (Boz, 2023; Demetriou, 2020; Owens et al., 2018; Shernoff et al., 2017). The use of self-report measures may also contribute

to ceiling effects, especially on attitudinal items, limiting the ability to detect finer-grained differences (Guskey, 2014; Desimone, 2009). Within this context, it is plausible that early developments, such as increased identity awareness or recognition of student diversity, emerge before more complex, practice-linked changes, including material adaptation or conflict-responsive pedagogy.

Finally, associations observed between teachers' willingness to take future action and their current levels of awareness and inclusive classroom practices suggest that reflective understanding may be linked to motivation for continued growth. This interpretation is aligned with PD theories highlighting the importance of coherent learning experiences, active engagement, and collaborative processes in supporting sustained instructional improvement (Desimone, 2009; Darling-Hammond et al., 2017). Evidence from STEM and STE(A) M professional learning similarly indicates that collaborative design and active learning approaches can strengthen teacher self-efficacy and disciplinary practice (Freeman et al., 2014; Conrady and Bogner, 2020; Martins and Baptista, 2024). The present study contributes multi-country European evidence underscoring persistent challenges in teachers' confidence related to inclusive materials, conflict management, and school-level supports, while also highlighting the potential role of reflective practice in fostering continued professional growth.

Limitations and Future Research

The study relied on self-report through a reflection tool, which is vulnerable to social desirability responding and common-method bias (Polas, 2025), risks that are especially salient when items concern equity, diversity, and identity. Furthermore, even though the sample spans 16 countries, it is relatively small and unevenly distributed across national

systems and levels, constraining external validity and limiting representation of Europe's super-diverse STEM teaching ecologies. Contemporary measurement reviews in STEM education caution that scale use without comprehensive validity evidence (beyond internal structure and alpha) can compound generalizability issues, reinforcing the need for broader, better-documented samples and instruments. The methodological design did not include classroom observations or longitudinal follow-up, which prevents assessing whether reflections translated into observable practice change or student outcomes over time. Validated observation protocols can capture instructional enactment in STEM (and related disciplines) and advocate longitudinal designs to track trajectories of teacher change. These limitations indicate the need for future research employing more rigorous, multi-method, and multi-level designs that can more accurately capture how inclusive STEM PD translates into practice. Namely, future research should also adopt longitudinal, mixed-methods designs that link PD participation to observed classroom practice, student experience, and learning outcomes, addressing well-documented limitations of short-term, self-report-heavy evaluations (Boz, 2023; Zhou et al., 2023). Given the distinct linguistic, policy, and demographic landscapes across Europe, comparative studies are needed to examine how these contextual factors interact with PD to facilitate or constrain inclusive STEM implementation (Evagorou et al., 2024; Palid et al., 2023). Building on established PD design principles, future work should test which specific design features, such as identity work, UDL-anchored materials adaptation, conflict-responsive facilitation, and co-design cycles, most strongly predict sustained change. Early evidence suggests that STE(A)M-integrated PD can improve student creativity/motivation and teacher pedagogical content knowledge (Martins and Baptista, 2024), but larger, longitudinal studies are needed to assess effects on equitable participation.

CONCLUSION

This study explored how STEM teachers from diverse European contexts reflect on their identities, practices, and school environments in relation to diversity and inclusion after participating in a targeted PD program. The results reveal a strong commitment among teachers to the principles of inclusive STEM education, particularly in terms of attitudes toward diversity and recognition of the importance of equitable practices. At the same time, the results highlight persistent gaps between teachers' inclusive intentions and their confidence in implementing concrete strategies such as conflict resolution, selection of inclusive materials, or sustained reflective practice. Importantly, the analysis demonstrated that the duration and depth of PD play a meaningful role in shaping teachers' self-awareness, particularly regarding how their own identities and assumptions influence their professional judgment. These results emphasize the necessity of designing STEM PD programs that go beyond surface-level awareness and

instead foster critical reflection, collaborative sense-making, and repeated opportunities to connect theory with practice.

This study contributes empirical evidence to the limited European literature on inclusive STEM education by emphasizing the need for context-responsive PD models that account for the linguistic, cultural, and structural diversity characteristic of European educational systems. As STEM fields continue to confront persistent inequities, the findings underscore the importance of supporting teachers through sustained, reflective, and practically oriented PD to advance more inclusive and socially just STEM learning environments. In light of these needs, the results of the study have several important implications for the design of inclusive STEM teacher PD in Europe. First, extended duration and sustained support should be prioritized, as concrete evidence links PD duration, coherence, and active learning with shifts in teacher beliefs and practice (Darling-Hammond et al., 2017). Second, PD should deliberately scaffold structured critical reflection on teachers' identities, positionalities, and implicit assumptions, given the association between reflective work and more equitable instructional judgment (Dignath et al., 2022; Sanders O'Leary et al., 2020). Third, PD should include explicit skill-building in (a) conflict resolution and facilitation of difficult dialogs, particularly around diversity-related tensions (Wright and Delgado, 2023), and (b) selection/adaptation of inclusive curriculum materials using frameworks such as UDL and differentiated instruction to ensure accessibility for learners with diverse needs (Meyer et al., 2014). For example, STEM educators could be supported to adapt materials by: (1) revising textbook problems, worksheets, and assessment items so that names, contexts, images, and STEM role models represent diverse genders, cultures, languages, abilities, and socioeconomic backgrounds; (2) redesigning diagrams, slides, laboratory instructions, and digital resources to improve accessibility through captions, alt text, larger fonts, high-contrast visuals, simplified language, tactile or printable diagrams, and screen-reader-compatible formats; and (3) developing differentiated versions of the same STEM task, such as adding bilingual vocabulary support, worked examples, manipulatives, simulations, sentence starters, or alternative ways for students to demonstrate understanding through oral explanations, annotated drawings, models, or short videos. Importantly, these strategies are not discipline-specific and can be readily adapted across STEM subject areas and educational levels, making them applicable within a wide range of classroom contexts. Embedding collaborative, practice-proximal activities, such as co-design, trial, and iterative revision of inclusive STEM tasks, can strengthen the translation of inclusive principles into classroom routines (Owens et al., 2018). PD should incorporate subject-specific and context-responsive exemplars (e.g., integrating STE[A] M to enhance engagement and creativity) so that teachers can adapt across European settings marked by super-diversity and multilingualism (Martins and Baptista, 2024). Providing ready-to-use tools (rubrics for inclusive materials, observation

protocols for equitable participation, lesson “access checks”), micro-cases for conflict mediation, and peer-mentoring structures can also help sustain changes after formal PD concludes (Shernoff et al., 2017).

At the policy level, the results emphasize the need for national and European initiatives that support PD with follow-up coaching, collaborative inquiry, and local adaptation time, rather than one-off workshops (Darling-Hammond et al., 2017; Guskey, 2014). Inclusion should be embedded as a core dimension of STEM quality, supported through standards, procurement guidance, and curation mechanisms that prioritize inclusive, non-stereotypical, and accessible instructional materials (LaForce et al., 2016; Wright and Delgado, 2023). Policies should audit and reform structural barriers, such as tracking, prerequisites, and scheduling, which can shape access to advanced STEM pathways and disproportionately affect minoritized learners (Lynch et al., 2018; Dignath et al., 2022). Given the heterogeneity of European educational systems, policies should promote context-responsive frameworks and cross-country knowledge exchange focused on inclusive pedagogies in multilingual and super-diverse settings (Evagorou et al., 2024; Palid et al., 2023). Furthermore, ministries and authorities should incentivize evaluation of PD impact using mixed-methods designs that assess changes in teacher practice and student participation/achievement, not only satisfaction (Boz, 2023; Zhou et al., 2023).

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