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ORIGINAL PAPER

Supporting mathematics and science teachers in implementing intercultural learning

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Abstract

Our current multicultural societies require that education addresses diversity and promotes cultural awareness and intercultural learning. Mathematics and science education can also contribute to this aspect of citizenship education and create a culture of belonging for all students. Professional development that integrates intercultural learning with educational practices is still uncommon in the field of science and mathematics teacher preparation and support. This study explores the possibilities to support science and mathematics teachers in implementing intercultural learning through a professional development course. The course was developed in a European setting, based on a theoretical analysis, and tried out with 319 teachers from six participating countries. The impact of the course on teachers' take up of intercultural learning was measured with a pre-post questionnaire. We found that the course strengthened teachers' self-efficacy beliefs and extended their teaching practices with opportunities created by cultural diversity among their students or in their subjects. In addition to that, teachers' self-efficacy beliefs and the perceived cultural diversity in class appeared to be influencing factors for teachers' practices. Based on our findings we recommend that the combination of intercultural learning with educational practices of mathematics and science might be a suitable gateway to provide new intercultural learning opportunities for students.

Keywords Intercultural learning · Professional development · Diversity · Teaching competences · Multicultural approach to science education · Citizenship Education

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1 Introduction

Competences in mathematics and science are among the eight key competences listed by the EU that are needed for lifelong learning and active citizenship (European Commission, 2019). Through sufficient competences in mathematics and science individuals should be empowered to voice their opinions in societal debates and pursue their careers to their own fulfilment and therefore take an active role in our societies (see also Hoskins & Crick, 2010). However, based upon the PISA study in 2018, the European Union (2019) pointed out that more than one in five students among 15-year-olds do not reach the minimum proficiency level necessary to participate successfully in society. This minimum proficiency level is identified through the PISA assessment and includes, for example, the employment of basic algorithms and using everyday scientific knowledge (OECD, 2019). In addition to that, 13.7 million young people—those with migration backgrounds are particularly concerned here—are not in employment, education or training (European Union, 2016). We use 'migration' to include permanent as well as impermanent moves of people between countries or communities (Horevitz, 2009). In particular young people with low competences in science and mathematics and without access to education are less involved in social and political life and at risk of exclusion and marginalization (European Union, 2016). The recent refugee influx in Europe additionally enhanced the need for inclusive education that promotes learning in groups with different competence levels and cultural backgrounds.

A multicultural approach to science and mathematics can establish the dignity of all students by respecting their different cultural roots (e.g., Bishop, 1988; D'Ambrosio & D'Ambrosio, 2013) and also support students with migrant backgrounds (European Union, 2016). Additionally, the inclusion of multicultural perspectives in education promotes intercultural learning, an approach that fosters knowledge, understanding and respect for diverse cultural traditions and beliefs to the extent that these are consistent with social justice and human rights (Cummins, 2016). Moreover, mathematics and science themselves are culturally situated (Lemke, 2001). For example, there are many different methods for writing numbers and doing basic calculations (Orey & Rosa, 2004), and different countries refer to different roots of basic concepts (e.g. the Pythagorean theorem versus the Gougu theorem). As such mathematics and science can provide various opportunities to connect content with multicultural perspectives and, in turn, support a diverse and inclusive learning environment. Respecting diverse cultural backgrounds and supporting inclusion are also key aspects of citizenship education (Westheimer & Kahne, 2004).

Conventionally, science and mathematics instruction has focused on the learning of pure science and mathematics detached from societal implications as opposed to learning 'of and about science' (Osborne & Dillon, 2008; see also Hazelkorn et al., 2015). To support a shift towards the understanding of the nature, applications and implications of science and mathematics and, thus, competences vital in democratic, pluralistic and increasingly multicultural European societies, teachers need specific support. However, research has shown that teachers' beliefs about intercultural learning and teaching practices to support intercultural learning are not easy to change (e.g., Lee et al., 2007). In addition to that, only few specific learning opportunities exist which leave an incomplete picture on how to best support science and mathematics teachers in their turn towards intercultural learning (Romijn et al., 2021).

To provide science and mathematics teachers with the necessary support to shift their instruction towards intercultural learning, the goal of the project MaSDiV (Supporting mathematics and science teachers in addressing diversity and promoting fundamental values) was to design and investigate a professional development (PD) course on intercultural learning. To do so, partners from Cyprus, Germany, Malta, the Netherlands, Spain and Turkey set out to collectively develop and implement the PD course in this multinational context. In this way, we formulated key design features of a PD to support teachers' in implementing intercultural and collected empirical evidence on its effectiveness.

2 Theoretical background

2.1 Intercultural learning

Intercultural learning refers to a learning process in a multicultural setting in which students become aware of the subjective cultural context and get more competent to interact sensitively across those cultural contexts (Bennett, 2009). These competences include cultural self-awareness, knowledge of behaviors of people from diverse cultural communities, and abilities to shift cultural perspective and to bridge cultural differences (Hammer, 2012). In addition, more personal intercultural competences relate to the ability to show empathy, to reflect on one's emotions and to be able to relativize one's own views (Martorana et al., 2021). Intercultural learning is expected to promote social cohesion and respect across cultural groups, and to promote academic achievement for students of marginalized communities (Cummins, 2016).

Intercultural learning includes the word 'culture', which refers to the social behavior and norms in a specific society or group of people. This term has a rather wide scope and various cultures such as city and rural culture and others can be distinguished. In this paper, we mainly refer to cultures from different countries that enter the classroom as a result of increased migration in the recent decennia in many societies. Awareness for culture in class refers to the 'iceberg of culture' (Hall, 1976) that uses the metaphor of the iceberg to make the complex concept of culture easier to understand. Like an iceberg, only the 'tip' of culture is visible (e.g., behavior, clothes), while the bulk of what makes up cultural identity (e.g., beliefs, values) is unobservable.

Various stages in attitudes towards intercultural learning can be recognized (Hammer, 2012). From the denial stage where teachers will claim that cultural differences do not exist, they can develop towards the adaptation stage where a teacher would see and take cultural differences as teaching opportunities in the classroom (Hammer, 2012). This final stage requires, for example, sensitivity for and the abilities to find contexts that can be used as problem situations in the classroom and that offer opportunities for students from different cultures to contribute and to create rich sources for learning (Booth & Ainscow, 2002). Awareness of these stages might prevent obstacles for teachers in implementing intercultural learning such as created by existing societal power relations (Cummins, 2016) or by tensions between culturally and linguistically diverse learners, and aiming for a unifying culture or monolingualism (Tualaulelei & Halse, 2022).

Intercultural learning requires attention to the sensitivity for and the ways to address cultural and ethnic differences in pre-service and in-service teacher education (Gay, 2009; Sleeter, 2001). Interculturally competent teachers should be able to address culturally relevant pedagogy in class that does not only focus on achievements but also helps to understand the own cultural identity and at the same time to develop a critical view of inequalities in society (Ladson-Billings, 1995). The need for such teachers has become increasingly relevant since societies are now facing growing cultural, linguistic and socio-economic diversity. An approach to PD that integrates intercultural learning requires a careful exploration of the relationship with mathematics and science education.

2.2 Intercultural learning in mathematics and science education

The importance of attention for home culture in science and mathematics education is already addressed for quite some years and highlights possible conflicts between the children's everyday culture and the school culture of mathematics and science. Both the school and the home cultures have overlapping language and strategies, but also divergent aims and purposes and might create moments of foreignness in school (Prediger, 2004). Lack of attention for the relationship between in-school and out-of-school experiences of students in learning mathematics and science can hinder conceptual development in those domains (de Abreu & Crafter, 2015; Ensign, 1998). More recent studies show the importance of connecting ''funds of knowledge'' that students can bring to the classroom, their science experiences and their future visions on science careers, and the development of a sustained interest in science in school (Basu & Barton, 2007). In mathematics education that could for instance refer to the use of various algorithms for calculations rooted in diverse cultures as a resource in classroom practice.

Intercultural learning in science and mathematics education requires to connect mathematical and scientific knowledge with cultural knowledge, i.e., facts, information, skills and familiarity with social processes (Lareau, 2015). Learning environments need to embrace both knowledge domains and promote explicit and inquiring discussions across them (Gondwe & Longnecker, 2015). In this way, it becomes possible to overcome differences between the learners' world and the school content they are supposed to acquire.

Several strategies for promoting intercultural learning have been advocated. Inspired by gender studies in mathematics and science education an option is focusing on *role models* that appeal to students of various cultures (e.g., include Nobel laureates Aziz Sancar and Jennifer Doudna in genetics education, or Florence Nightingale when teaching statistics). These appealing role models help to support a sense of belonging and to reduce (implicit) discipline and future career related biases such as the technological sector is not for women (McIntyre et al., 2003).

Ethnographic studies have advocated the use of *ethnomathematical contexts* in mathematics education, focusing on cultural dissonances of children of indigenous cultures who were supposed to learn "Western Mathematics" (e.g., Bishop, 1988; D'Ambrosio & D'Ambrosio, 2013). These studies have inspired many scholars to use indigenous patterns or traditional practices in mathematics education (e.g., Hunter & Miller, 2022; Wijaya et al., 2011). In addition, the embedding of ethnomathematics in teacher education for teachers of indigenous people appeared to be successful in overcoming language obstacles and changing conventional mindsets about mathematics (Greer & Mukhopadhyay, 2015).

A third strategy is by focusing the attention on dynamic shifts between *everyday language and the more technical language* of mathematics and science to support construction of meaning for learners with limited proficiency in the language of instruction (Prediger & Wessel, 2013). For instance, when learning about fractions you need to discuss in various verbal registers everyday situations and graphical representations to come to understand the part-whole relationships, their symbolic notations and how to reason and perform calculations with them (Prediger & Wessel, 2013).

Finally, connecting intercultural learning and *inquiry-based learning* (IBL) seems to have potential to allow students to explore phenomena from various cultural perspectives (Brown, 2017). IBL is a student-centred learning approach, in which students are involved in inquiry-related processes such as observing phenomena and creating their own questions, selecting mathematical or scientific approaches, creating representations to clarify relationships, interpreting and evaluating solutions as well as communicating those solutions (Dorier & Maass, 2014). This active stance that students take, as promoted in IBL, has been used to serve the purpose of citizenship education (Maass et al., 2022).

2.3 Teaching competences for intercultural learning in mathematics and science education

A culturally competent science or mathematics teacher has the ability to understand and effectively interact with students from different cultures, and successfully engage them in science or mathematics learning with meaningful activities that incorporate their own culture, skills, experiences and prior learning (Santiago, 2017). Several studies have recommended that a responsive attitude of teachers to students' diverse characteristics is needed. This responsive attitude is characterized through an interest in and awareness of characteristics of the diverse backgrounds of the students (Brown, 2003; Wubbels et al., 2006). Moreover, teachers need to become knowledgeable about the cultures and communities in which their students live (Weinstein et al., 2003). In addition to interest in and knowledge about students, teachers also need to develop competences for choosing relevant, up-to-date contexts and to learn to embed them with an active-oriented pedagogy such as IBL in their classrooms (Romero-Ariza et al., 2018).

For teachers to implement all these ideas in their classrooms, their self-efficacy beliefs serve as a necessary foundation (e.g., Zee & Koomen, 2016). Teachers' self-efficacy beliefs are understood as beliefs about the own capabilities to execute a certain action despite possible challenges (Tschannen-Moran & Woolfolk Hoy, 2001). As such teachers' self-efficacy beliefs are directed towards the future and specific to certain teaching situations such as supporting intercultural learning (Bong & Skaalvik, 2003; Siwatu, 2007). However, while teachers' self-efficacy beliefs are among the most important factors for teachers' actions, several contextual factors also impact how a teacher might enact specific teaching practices. Buehl and Beck (2015), for example, identified several characteristics on the school level that influence the transition of beliefs into practice. Time constraints has been identified numerous times in the literature as a possible hindering factor for implementing student-oriented instruction (e.g., Skaalvik & Skaalvik, 2010; Teig et al., 2019). In addition to that, school support can be seen as a major supporting factor for teachers' everyday challenges (e.g., Crawford, 2007). Ways to support teachers to implement intercultural learning such as PD programs should therefore not only take into account teachers' knowledge and self-efficacy beliefs but ways to deal with contextual challenges as well.

2.4 Teachers' professional development

Supporting teachers in implementing intercultural learning with a (limited) PD program still has many challenges. While Romijn et al. (2021) as well as Parkhouse et al. (2019) provided reviews on PD in the context of intercultural learning both reviews still relied on a relatively small database, which led Parkhouse et al. (2019) to conclude that the literature base had too much variation to draw specific conclusions about factors for PD effectiveness. The effectiveness of such a PD program is also not self-evident since Lee et al. (2007), for example, found that elementary science teachers' beliefs as well as their practices on intercultural learning remained relatively stable across a 2-year PD program (see also Parkhouse et al., 2019). Still, Romijn et al. (2021) were able to identify the explicit support of reflection and fostering of enactment as key aspects that a PD on intercultural learning should incorporate. Those features are in line with general guidelines on effective PD that they should combine phases of learning in seminars with phases of learning at school (Lipowsky & Rzejak, 2015; Maass et al., 2019) and initiate cooperation between teachers in a local context (McLaughlin & Talbert, 2006). However, these types of PD are still relatively uncommon as Romijn et al. (2021) concluded and their success to transform the actual teaching practices is not secured (see Lee et al., 2007).

Based on these theoretical considerations, we developed a new PD course on intercultural learning for mathematics and science teachers and answered the following research questions to provide evidence for its effectiveness:

1. How do science and mathematics teachers' self-efficacy beliefs and practices for supporting intercultural learning change across a professional development program?
2. What are the main influencing factors for mathematics and science teachers' practices prior and after the professional development program?

3 The project MaSDiV and its professional development courses

3.1 The project MaSDiV

The project MaSDiV (Supporting mathematics and science teachers in addressing diversity and promoting fundamental values) followed the approach of connecting mathematics and science education with citizenship education. Within the project, partners from six countries designed a PD course to support teachers in connecting mathematics and science education with inquiry-based learning (IBL), real life contexts and intercultural learning. In this way, science and mathematics teachers receive support in designing lessons in such a way that students of every level of competence and with different cultural backgrounds can benefit (see https://icse.eu/international-projects/masdiv/). The PD course was structured into three modules: First, a general module on IBL in mathematics and science. The second module focussed on using real-life contexts and the third and last module specifically addressed intercultural learning. The complete PD program required at least 14 in-person hours to complete, which were spread over several sessions with the number of sessions and the times in between varying from country to country (three to six months). Between the sessions, the participants were asked to implement the content of the PD course into their own teaching practice. In this work, we report on the module about intercultural learning.

3.2 The module on intercultural learning

One of the pre-conditions for the intercultural learning module *Teaching science and mathematics in multicultural settings* was that time needed should be 4 to 5 in-person hours. We used an iterative, cyclic process of design, consultation, re-design and try-out (Gravemeijer & Cobb, 2006) to ensure the module being theory-based, robust, and flexible. This approach was adapted to involve all partners in the design process and to ensure adaptability and usability for an international audience (Maass et al., 2019). The design process consisted of three phases: an initial design phase, a screening by consortium members, and a phase including improved design and final feedback from an international expert panel. The experts reviewing the designed materials took different perspectives varying from a geographical perspective, a disciplinary perspective, and an implementation perspective involving various stakeholders (e.g. teacher educators and policy makers).

The theoretical starting points for the PD module helped to identify topics or activities related to addressing and developing teaching skills, knowledge, and beliefs for intercultural learning integrated in science and mathematics education. The initial list consisted of the following topics and activities for the module:

1. Is your discipline (e.g., mathematics) a neutral discipline? (awareness and beliefs)
2. Addressing multicultural aspects of your discipline in your teaching with history or by asking students to bring their parents' (multicultural) strategies for solving problems (e.g., algorithms for simple calculations) (knowledge and skills)
3. Dilemmas in intercultural learning and school development from multicultural differences seen as a challenge to seen as an opportunity (awareness, knowledge and beliefs)
4. Role models: who are they, who can inspire our students? (awareness and knowledge)
5. Use of multicultural contexts in your teaching (e.g., car number plates in various countries) (skills)
6. Language in multicultural science and mathematics classrooms (awareness and skills).

We are aware that each of these topics is on itself rich and complex enough to be dealt with during an individual course. However, with this module we tried to raise awareness for the need of intercultural learning, what it entails, and how it can be addressed in science and mathematics classrooms. With the course, we provided teachers with initial teaching strategies that they can try out with their students. These experiences are sources for reflection in follow-up meetings. We were interested whether such a course would already change teachers' self-efficacy beliefs and practices for intercultural learning in mathematics and science for citizenship education.

Organize a debate about one or more of the following statements or questions:

- Mathematics is an objective discipline
- Science and mathematics have nothing to with culture, society or politics
- Which aspects of diversity are particularly important for mathematics and science education and why?
- Can you give an example of 'intercultural situations' from your own mathematics and science teaching practice?
- How would you define cultural diversity?

Fig. 1 Statements for challenging the neutrality of your discipline

An example activity for discussing the teachers' assumptions about their disciplines was to confront them with statements about the neutrality (or not) of these disciplines (Fig. 1). This activity was inspired by Cockrell et al. (1999).

Participants may think that mathematics and science are mainly of Western origin and may not be aware of contributions from other cultures and older civilizations. If this is the case the course provider should provide some (more) examples from indigenous science (like traditional medicine, celestial navigation, number systems). The discussion should lead to the understanding of the importance to recognize and incorporate multicultural roots of the disciplines in teaching practices. In the module, we also added example tasks for day-to-day practice by the teachers (Fig. 2).

Moreover, we included a focus on the role of language in teaching and learning science and mathematics (e.g., Fig. 3).

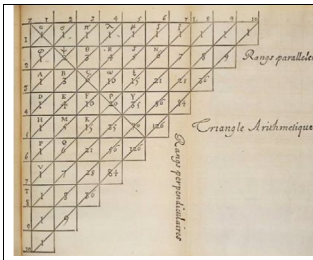
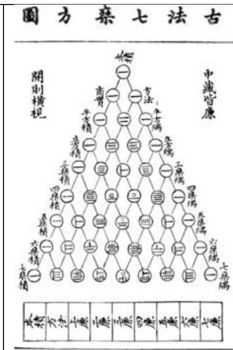
4 Design of the study

Based on our considerations of the importance of intercultural learning for students and the subsequently identified elements in mathematics and science to promote intercultural learning, this study is designed as an exploratory proof of concept study (see also Lyon et al., 2018). In this way, we set out to investigate (i) to which degree it is possible to implement a newly developed PD on intercultural learning in a multi-national context and under the restrictions of the different PD systems, and (ii) the impact of the course on beliefs and practices of the participating teachers. To allow for this implementation, our PD course had to be adaptable to the local contexts and easy to facilitate. At the same time, it is critical that even though certain restrictions in the local contexts apply, the general effectiveness of the PD course should be ensured.

4.1 Implementation of the course and data collection

Based on the design process of the PD modules, a set of MaSDiV course materials were developed. Those materials included the explicated aims of the modules, a description

Fig. 2 The various roots of what in the Western world is called the Pascal triangle

		
In 1665 the French mathematician Blaise Pascal drew this version of the triangle, that later was named after him, at least in the	Study the picture above that comes from a Chinese mathematical work by Zhu Shijie, dated 1303.	Write at least five aspects you find interesting about the picture above. What is the language? Is it easy to recognize the numbers?
Western world. Find out how it works.	What do you notice? What is the system used to write the numbers?	What patterns do you see? This figure is a page from a work by the Moroccan Mathematician and medical doctor named Ahmad al-Ad'dari ibn Mun'im who lived around 1200.

Provide participants with a word cloud that include words like area, force, gradually, reaction, square, function, rise and fraction. Create small groups and have them discuss the following questions:

- Which of these words are also part of your everyday language? How is the meaning different in your discipline and in daily life?
- Write down two typical expressions or sentences using one of these words. One in daily language and one for your discipline.
- What problems do you expect that students may have regarding this 'shift of' meaning?
- Discuss ways to help your students to acquire the 'language of mathematics/science'.

Fig. 3 Addressing the role of language in science and mathematics education

of the overall structure and workflow as well as a detailed description of each activity including possible examples that could be used to facilitate discussion. Furthermore, a set of slides were produced that can be used by the PD leaders.

To ensure an intended and consistent implementation in all partner countries, several steps were undertaken. First, all members from the varying partner countries conducted an in-depth analysis of the current curricula as well as the modules and subsequently developed an adaption of the PD course for their local context. Second, all consortium members agreed to minimum standards for implementation which include a total of 14 h of learning off-job for the whole course and dedicated phases for try-out and reflection on the job. Third, the course materials were discussed among all project partners during the biannual international project meetings. The PD course was then carried out directly from project partners or colleagues of involved consortium members.

To investigate to which degree the MaSDiV course change mathematics and science teachers' practices for intercultural learning and its influencing factors, a mixed-method study was implemented. At the beginning of each course, all participating teachers answered a questionnaire on their current self-efficacy beliefs and teaching practices addressing cultural diversity to support intercultural learning. At the end of the last session of the course, the same questionnaire was answered again. We omitted to use a control group for this study since the PD systems in the participating countries would not have allowed for teachers to sign up for a waiting control group. Furthermore, in all partner countries, case studies were implemented. From each PD course at least three teachers that represented diverse backgrounds were invited to participate in the case study. Data collection included classroom observations and a subsequent semi-structured interview about the lesson and the PD course.

4.2 Design of the questionnaire

To assess science and mathematics teachers' change in self-efficacy beliefs and practices as well as possible

Table 1 Distribution of participants across countries and subjects

	CY	GE	MT	NL	SP	TR
N	44	35	81	56	53	50
Mathematics	33%	100%	51%	31%	29%	56%
Science	67%	0%	49%	69%	71%	44%

influencing factors as an outcome of the MaSDiV PD course, we employed a questionnaire. The questionnaire first asked for teachers' professional background such as their subject, teaching experience and current job situation. Among the factors describing the current job situation were the perceived diversity at school, time constraints, and school support. All three of these factors could have an influence on teachers' teaching practices (Buehl & Beck, 2015) and were assessed with single items in order to ensure feasibility of implementation in a large-scale, multi-national context.

Science and mathematics teachers' self-efficacy beliefs about addressing cultural diversity in order to support intercultural learning were assessed with a newly developed three-item scale. While there are a diverse range of self-efficacy instruments (e.g., Skaalvik & Skaalvik, 2010; Tschannen-Moran & Woolfolk Hoy, 2001), teachers-self-efficacy beliefs are specific to a certain teaching practice and context (Bong & Skaalvik, 2003). Tschannen-Moran and Woolfolk Hoy (2001), for example, assessed three different dimensions of teaching with four items each. Therefore, we developed three new items focussing on assessing teachers' confidence to cope with designing specific learning activities situated in different cultural contexts, adapting instruction to students' different cultural backgrounds, and building on students' diverse experiences. The complete instrument can be found in the Appendix. To ensure the content validity of the scale, a similar process compared to the PD development was implemented. The scales were iteratively developed and discussed with teacher educators from multiple countries in the project consortium to establish a consensus on the construct. Similar developed instruments have also shown convergent validity (e.g., Maass et al., 2022). For the sample under investigation, the scale was highly reliable (Cronbach's $\alpha = 0.82$ for the pre-test).

Teachers' practices were assessed through self-reports on three items with a four-point Likert scale. The scale was designed to assess the frequency of certain teaching practices from "never or hardly ever" to "almost every lesson". The teaching practices under investigation were using contexts from various cultures, addressing cultural values and expectations explicitly, and relate the content to the cultural background of the students. As such, the practices were aligned with the content of the PD course. The items can be found in the Appendix as well. Cronbach's alpha of this scale during the pre-test was satisfactory with $\alpha = 0.78$.

4.3 Sample

After analysing the national PD systems, a call for participation in the PD was formulated and distributed through national and local policy institutions for education in the six participating countries Cyprus, Germany, Malta, the Netherlands, Spain, and Turkey. Accordingly, all teachers who took part in the MaSDiV PD program were volunteers and needed to apply for participation. A total of $N = 467$ mathematics and science teachers participated in the PD program and provided information in the pre-test. From those teachers, we were able to successfully match $N = 319$ teachers from the post-test via a personal code. These 319 mathematics and science teachers are the prime focus of investigation. 66% of the teachers were female and overall had a mean age of 39 years ($SD = 11$ years). The mean teaching experience was 11 years ($SD = 9$ years). An overview of the distribution of the sample across countries and subjects can be found in Table 1. In total, 48% of the participants were mathematics teachers and 52% taught different science subjects.

4.4 Analysis

In order to investigate to which degree, the developed PD course changed mathematics and science teachers' self-efficacy beliefs as well as their self-reported practices to address cultural diversity, we first analysed the change between pre- and post-test scores using paired t-tests. Paired t-tests allow to test the hypothesis that the difference between a pre- and a post-test score are zero. For our research, the results of a paired t-test indicate whether teachers' self-efficacy beliefs or self-reported practices changed from the beginning of the PD course to the end of the PD course. In a second step, we utilized multiple regression analysis to determine which factors influence the occurrence of practices for supporting intercultural learning. More specifically, we computed a multiple regression model at the beginning and another multiple regression model at the end of the PD course. These two multiple regressions allow us to compare to which degree the influencing factors for teachers' self-reported practices changed across the PD course. The standardized regression coefficients will be used to compare the effect sizes of the different influencing factors. All statistical analyses were done using the software R.

After analysing the answers to the questionnaires, we used open coding to find possible supporting and contradicting

Table 2 Teachers self-efficacy beliefs and self-reported teaching practices from the pre- and post-test including t-values from paired t-tests and Cohen's d

Scale	Pre	Post	t	D
Self-efficacy beliefs on supporting intercultural learning	2.44 (0.56)	2.69 (0.60)	7.07***	.40
Self-reported teaching practices	1.91 (0.69)	2.16 (0.74)	6.68***	.38

***$p<.001$

quotations from the teachers in the semi-structured interviews to further illustrate our findings and to allow the teachers' own voices to tell their experiences. In this way, the focus of our data analysis is on the quantitative data while using the qualitative data as additional evidence in our mixed-method design.

5 Results

We developed a PD course to support teachers in productively attending to the cultural diversity in mathematics and science classrooms. In our analyses, we investigated first to which degree teachers feel more confident to support intercultural learning in their classroom and also apply these teaching practices more frequently after attending the PD course. In a second step, we focussed on possible influencing factors for teachers' self-reported practices before and after the PD course.

5.1 Change in teachers' self-efficacy beliefs and practices

To investigate changes in teachers' self-efficacy beliefs and self-reported teaching practices for supporting intercultural learning, we first compared the respective mean values from the pre- and the post-test (see Table 2). On a four-point Likert scale, teachers indicated below average self-efficacy beliefs at the beginning of the PD course ($M=2.44$, $SD=0.56$). Similarly, teachers also stated that they seldomly address cultural diversity in their mathematics and science classrooms ($M=1.91$, $SD=0.69$). Both values increased significantly until the end of the PD course (self-efficacy beliefs: $M=2.69$, $SD=0.60$; teaching practices: $M=2.16$, $SD=0.74$). Both, the change in teachers' self-efficacy as well as the change in self-reported teaching practices were significant and showed a medium effect size of Cohen's $d=0.40$ (self-efficacy beliefs) and $d=0.38$ (teaching practices), $t(312)=7.07$, $p<0.001$ (self-efficacy beliefs), $t(309)=6.68$, $p<0.001$ (teaching practices). More specifically, 10% of the participating teachers' self-efficacy beliefs decreased, 55% remained stable, and for 35% the self-efficacy beliefs increased. Similarly, 9% of the teachers reported less frequent, 57% similarly frequent, and 34% more frequent use of teaching practices supporting intercultural learning. These changes in self-efficacy beliefs and self-reported teaching practice were nearly equal for science and mathematics teachers. While the change in self-efficacy beliefs was 0.21 for mathematics teachers, science teachers' self-efficacy beliefs increased by 0.26 on average. For self-reported teaching practices, mathematics teachers changed by 0.25 and science teachers by 0.23 on average. Overall, teachers felt more confident and also reported to use teaching strategies more often to support intercultural learning in their classrooms.

This change in teachers' confidence to teach and practice was also evident for observed case study teachers. For example, one teacher from Cyprus concluded:

> *"IBL is the, the way I teach anyway. What was missing was taking into account the culture, the social context is most of the times there. The fact that I started thinking and taking notes on social issues or on experiences from diverse societies. And coming again to, for example, the sessions on space: How humanity works on that, which countries and why they made such a huge progress, differences and similarities. We all have similar question about space that bother people and scientists all around the world. We all observe the sky and the stars, the moon is one for all of us, the sun too. Wherever you live.“ (Teacher from Cyprus)*

In this quote, it becomes apparent that the teacher from Cyprus already had some background knowledge around IBL but not with a focus on intercultural learning. The PD course helped her to connect both ideas and expand her confidence and repertoire around multicultural issues.

In the observed lessons, however, only few teachers directly utilized contexts that incorporated perspectives from different cultures. For example, one teacher from Cyprus used a crime scene activity to discuss science practices but also the uniqueness of fingerprints. Another teacher from Germany discussed an old court case using mathematical argumentation but also allowed the students to highlight societal and cultural arguments. The other teachers mainly used contexts that are not directly related to multicultural learning such as the shape of wax cells or noise measure robots or focussed more on the inquiry-process in general through challenging mathematical tasks. The few instances where we were able to observe intercultural learning highlights that even after the PD course teachers only implemented this type of lesson rather seldomly.

Table 3 Multiple regression models of teachers' self-reported practices for supporting intercultural learning at the beginning and the end of the PD course

	Practices Pre	Practices Post
Self-Efficacy Beliefs Pre / Post	.39***	.53***
Cultural Diversity in Class	.16**	.10*
Time Constraints	.12*	.04
School Support	.19***	.04
R^2	.25	.31

***$p<.001$; **$p<.01$; *$p<.05$

5.2 Influences on teaching practices

To investigate possible influencing factors for teachers' self-reported practices for intercultural learning, we specified a multiple regression model using the pre- and post-test data separately (see Table 3). Before the MaS-DiV PD course, teachers were significantly more likely to facilitate intercultural learning, when they experienced a higher cultural diversity in class (β = 0.16, $p < 0.01$) and also felt that, overall, an emphasis was placed on dealing with diversity at their school (β = 0.19, $p < 0.001$). In addition to that we found that teachers also reported a significant more frequent use of teaching practices for cultural diversity with a small effect size, when they experienced higher time constraints (β = 0.12, $p = 0.02$). In addition to those factors from the classroom and school environment, the frequency of self-reported teaching practices was also significantly influenced by teachers' self-efficacy beliefs with a medium effect size (β = 0.39, $p < 0.001$). Teachers' who feel more confident to support intercultural learning in mathematics and science classrooms also reported to implement the respective teaching practices more frequently. Based on these influencing factors, we were able to explain 25% of the variance in self-reported teaching practice at the beginning of the PD course.

For the post-test teaching practices, we also found that teachers' self-efficacy beliefs were significant predictors of the self-reported teaching practice with an even higher effect size (β = 0.53, $p < 0.001$). Beyond, teachers' self-efficacy beliefs, only the perceived cultural diversity in class remained a significant predictor for teachers' self-reported practices after the PD course with only a small effect size (β = 0.10, $p = 0.03$). Teachers' perceived time constraints and the reported school support did no longer significantly predict teachers' self-reported practices for supporting intercultural learning. The final model from the post-test showed a high $R^2 = 0.31$. Comparing both regressions, it seems that the professional development reduced the importance of contextual features for supporting intercultural learning in mathematics and science classrooms.

In terms of the cultural difference, we also observed differences between teachers from countries with higher migration rate like Cyprus and Malta and countries with lower migration rates like the Netherlands. A teacher from Cyprus, for example, explained afterwards:

> *"For me IBL was not new. I needed more to see how it correlates with issues of diversity. I did not want that to come at the end separately. I was anxious for the module 3 session to learn how to deal with my refugee students." (Teacher from Cyprus)*

In her comment, she stressed that there is a need for intercultural learning especially for classes with students from different backgrounds. Many case study teachers talked about their limited time for preparing instruction that supports intercultural learning. A teacher from Germany, for example, said:

> *"So, above all, [the module] about cultural diversity, I found it incredibly helpful, because it's just stuff that makes perfect sense as soon as you hear it, but I just did not think about it in my hectic everyday teaching. And it is also interesting for the students to see which social values mathematics has (…). Also, for the historical context, this is actually interesting for students." (Teacher from Germany)*

While the initial problems of time constraints were very apparent in the teacher interviews, the interviews did not focus on school support structures and teacher did not come up about this topic by themselves.

6 Discussion

6.1 Interpretation of findings

We found that the PD could indeed strengthen teachers' confidence for addressing cultural diversity and, in turn, teachers reported to implement the corresponding teaching practices more frequently in their classrooms. We also found a strong connection between teachers' self-efficacy beliefs and their self-reported teaching practices, which increased throughout the PD course. Contextual factors such as the perceived diversity in class, time constraints or a supportive school environment were not as important anymore after the completion of the PD course. This indicates that the MaSDiV PD course allowed the participating mathematics and science teachers to support intercultural learning more frequently regardless of the classroom and school context.

While Lee et al. (2007) reported that it is quite challenging to alter teachers' beliefs and practices for addressing linguistic and cultural diversity, our analysis showed that through the course, both teachers' self-efficacy beliefs and self-reported teaching practices increased significantly. In accordance with Lee et al. (2007) though, teachers felt only partially confident and implemented intercultural learning in some of their lessons. Yet, it must be noted that the module on intercultural learning was the last module in the overall PD program and, as such, teachers only had limited time for try-out and reflection. An increase in the duration of the PD course and subsequent try-out and coaching phases could have an even stronger impact on teachers' self-efficacy beliefs and teaching practice and should be considered in the future (see Maass et al., 2022; Romijn et al., 2021).

In addition to an increase in time dedicated specifically to the PD, we also found that prior to attending the PD a supportive school environment was among the significant predictors of a frequent implementation of intercultural learning. Therefore, another way to support the change in classroom culture is through a collective effort on the level of the school and the educational system as a whole (Cummins, 2016). Interestingly, we also found that teachers who reported higher time constraints also reported teaching practices to address cultural diversity more frequently. This result is contradictive to the established finding that time pressure reduces the likelihood of incorporating student-oriented teaching such as IBL (e.g., Teig et al., 2019). One possible explanation could be that teachers who teach in high-need schools with a high cultural diversity experience both the time pressure in accounting to the diverse needs of students and at the same time the need to implement respective teaching strategies.

Still, after attending the MaSDiV course neither the supportive school environment nor the perceived time constraints had a significant influence on teachers' self-reported teaching practices for supporting intercultural learning. Instead, only the actual perceived diversity in class and the self-efficacy beliefs remained important determinants for self-reported teaching practices supporting intercultural learning. This shift in predictors indicates that the participating teachers now have the personal or material resources themselves and do not have to rely too much on systemic resources (see e.g., Navy et al., 2020). During the course, the teachers adapted presented examples to their own teaching material, which were then to be implemented between the course sessions and discussed afterwards. Through these activities of discussing possible gateways for intercultural learning and reflections, teachers were able to expand their own personal resources that are expected to establish inclusive classrooms with attention for multicultural elements of their disciplines that support *all* students to participate in science and mathematics practices.

6.2 Limitations and directions for future research

Yet, our study is also subject to some limitations. First, we only used a rather small number of items to assess teachers' self-efficacy beliefs and teaching practices. An increase in the number of items could help to also increase the reliability of the findings. Still, due to the limited in-person hours in the PD course to complete the questionnaires, we settled for this economic approach. However, while teachers' general self-efficacy beliefs are often assessed with more items, specific dimensions of teachers' self-efficacy such as planning or implementing a specific type of instruction or task has been assessed with a small set of items as well (Tschannen-Moran & Woolfolk Hoy, 2001).

Second, we focussed our investigation on teachers who volunteered to participate in a PD on dealing with diversity and can therefore expect that those teachers already had a general interest in that topic. Broadening the scope of teachers and increase access to the course could provide additional meaningful insights. In a similar vein, we only included teachers from European countries in our study. The promising first findings can encourage other teacher educators to implement this PD approach in other countries as well.

Third, we also did not recruit a control group for this study due to the PD systems in the participating countries. Because of that, we cannot assume that the PD was the only factor driving the change in teachers' self-efficacy beliefs and teaching practices. However, since explicit learning opportunities to strengthen teachers' self-efficacy beliefs and additional support for altering teaching practices was provided during the PD, it can be concluded that the PD had an impact on those teacher characteristics. Future research should continue this work by comparing the presented PD approach with other PD approaches that, for example, focusses more explicitly on students' language as a way to address cultural diversity (e.g., Prediger et al., 2022). With our study, we were not able to explore which elements of the PD course were successfully and sustainably taken up by the teachers. Further research is needed to investigate possible changes in teaching practices in relation to the teachers' backgrounds and the contexts in which they work.

6.3 Conclusion

While Lee et al. (2007) showed that it is difficult to change teachers' teaching practices for intercultural learning, our results provide promising evidence that it is indeed possible to support science and mathematics teachers to develop competencies to include intercultural learning in their classroom. Therefore, our proposed design principles for a PD on intercultural learning such as discussions around the multicultural origins of mathematics and science, alternative approaches to teaching mathematics (e.g., not as a fixed set of routines, using diverse role models) and a focus on language should be incorporated in other PD courses. Especially the combination of practices such as IBL and an intercultural lens proved to be a fruitful addition to initiatives for citizenship education. By implementing and evaluating this newly developed PD approach in multiple countries throughout Europe, we expanded the previously limited understanding about PD focussing on intercultural learning (e.g., Parkhouse et al., 2019; Romijn et al., 2021). In addition to this, we were also able to identify possible influencing factors on the school level that should be attended to beyond the PD context. With the importance of a supportive school environment, we provide an additional route for supporting mathematics and science teachers in implementing intercultural learning.

The examples included in this paper illustrate a variety of opportunities for mathematics education to foster intercultural learning. We argued that it is important and possible to have teachers experience and reflect on ways to connect in-school practices with out-of-school experiences of students, and to use a variety of role models, contexts and roots of their discipline for creating a culture of belonging for all. Providing multiple entry points for students to connect and engage with mathematics should reduce experiences of foreignness in school and, in turn, provide meaningful opportunities for learning (Prediger, 2004). This approach is in line with the sustainable development goal to ensure inclusive and equitable quality education[1] as well as part of the key competences for lifelong learning of the EU (2019). In such a way, students should not only become more competent in science and mathematics but also respective of diverse cultural backgrounds. This instructional approach is needed and maybe even fundamental for preparing teachers to contribute to citizenship education for all students in our currently changing and multicultural societies.

Appendix

Self-efficacy beliefs

To what extend do you agree with the following statements?

I feel confident that …	Strongly disagree	Disagree	Agree	Strongly agree
…I can design learning activities situated in different cultural contexts	❑	❑	❑	❑
…I can adapt my teaching to suit students' different cultural background	❑	❑	❑	❑
…I can build on students' cultural background in my teaching	❑	❑	❑	❑

[1] https://sdgs.un.org/goals/goal4.

Teaching practices

How often do the following activities take place in your lessons?

In my teaching …	Never or hardly ever	Some lessons	Most lessons	Almost every lesson
…I relate to the cultural background of my students	❑	❑	❑	❑
…I address cultural values and expectations of students	❑	❑	❑	❑
…I use contexts from different cultures	❑	❑	❑	❑

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