INCLUSIVE STEM LEARNING ENVIRONMENTS: CHALLENGES AND SOLUTIONS

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Abstract

While many believe all students should be taught equitably, in practice there are many barriers to achieving this goal, especially when it comes to inclusive Science, Mathematics, Engineering and Technology (STEM) learning environments. When considering such STEM environments, inclusiveness does not only refer to the education of students with disabilities, but also to those who are underrepresented in STEM due to ethnicity, gender or any other vulnerability factor. Scientix, the community for science education in Europe, organised an online Science Topics Networking Seminar (STNS) in collaboration with the projects SpicE – Special Education STEAM Academy[1] and Far Beyond the Barriers[2]. At the event, 15 experts representing various stakeholders in STEM education came together to discuss the challenges of supporting inclusive STEM learning environments. This observation paper outlines the key discussion points raised during the seminar. The main points to consider in achieving an inclusive STEM learning environment are: (1) creating a personalised strategy for each student; (2) organising teacher training programmes on how to promote inclusivity in STEM teaching; (3) eliminating barriers, such as gender inequality or socio-economic barriers; (4) implementing policies to support inclusivity; and (5) involving parents and local communities.

Keywords: inclusive STEM learning environments, accessibility, assessment, professional development, equity & inclusion, STEM education, gender equality, assistive technology.

[1] SpicE - https://spiceacademy.eu/objectives/
[2] Far Beyond the Barriers - https://www.farbeyondthebarriers.com/

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Introduction

As inclusive STEM seems to have a different meaning for different organisations and researchers, it is first necessary to define inclusiveness. There has been a shift from inclusive education, referring to the education of students with disabilities, to an inclusive learning environment which considers the possibility of equal education for all students, irrespective of their gender, ethnicity, disability, social status or any other (in)visible quality.

In March 2021, the European Commission launched its ambitious Strategy for the Rights of Persons with Disabilities 2021-2030[3] to ensure their full participation in society, in line with the Treaty on the Functioning of the European Union and the Charter of Fundamental Rights of the European Union, which establish equality and non-discrimination as cornerstones of EU policies. This strategy builds on its predecessor, the European Disability Strategy 2010-2020[4], which encouraged EU member states to provide inclusive and high-quality education for all children. The strategy also contributes to building a Union of equality, together with the LGBTIQ Equality Strategy 2020-2025[5], the EU Anti-racism Action Plan 2020-2025[6], the Gender Equality Strategy 2020-2025[7] and the EU Roma Strategic Framework[8].

The importance of gender equality is also recognised in the Education 2030 Agenda[9], which sees education as empowering all genders. Gender equality remains a policy priority for the European Research Area (ERA). Women's participation in STEM disciplines and professions is also highlighted in the Digital Action Plan (2021-2027)[10] Action 13: Women's participation in STEM careers and studies.

To promote the inclusion and diversity dimension, Erasmus+ and the European Solidarity Corps have also provided their Inclusion & Diversity Strategy[11], which adjusts to the specific

[3] Strategy for the Rights of Persons with Disabilities 2021-2030 - https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:52021DC0101
[4] European Disability Strategy (2010-2020) - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Aem0047
[5] LGBTIQ Equality Strategy 2020-2025 - https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2068
[6] EU Anti-racism Action Plan 2020-2025 - https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1654
[7] Gender Equality Strategy 2020-2025 - https://ec.europa.eu/commission/presscorner/detail/en/IP_20_358
[8] EU Roma Strategic Framework - https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1813
[9] Education 2030 Sustainable Development Agenda - https://unesdoc.unesco.org/ark:/48223/pf0000245656
[10] Digital Education Action Plan (2021-2027) - https://education.ec.europa.eu/focus-topics/digital-education/action-plan
[11] Erasmus+ and European Solidarity Corps Inclusion and Diversity Strategy - https://erasmus-plus.ec.europa.eu/document/implementation-guidelines-erasmus-and-european-solidarity-corps-inclusion-and-diversity-strategy

needs of participants by prioritising inclusion in the selection of projects, organising preparatory visits to support organisations and increasing support for young people through mentorships.

The need to make mainstream education more inclusive, equal and diverse is also promoted through the UN Sustainable Development Goals, with Goal 4 to: 'Ensure inclusive education and promote lifelong learning opportunities for all.'

The STNS entitled Inclusive STEM Learning Environments: What are the key elements to ensure all students have equal opportunities to learn STEM? explored the challenges and good practices of inclusive STEM and how to create inclusive STEM learning environments. The seminar provided an opportunity to discuss and explore inclusive STEM teaching and students' engagement in different contexts. It also brought together a diverse group of stakeholders to exchange knowledge and to lay the foundations for new partnerships and collaborations. Attendees included representatives from Ministries of Education (MoEs) and industry, teachers, policymakers, researchers, teacher trainers and educational consultants, together with representatives from CSOs and NGOs.

This paper outlines the main conclusions from the STNS held online on 26 October 2022. It combines a literature review based on the research, projects and initiatives mentioned by the attendees in discussions during the seminar, as well as their observations from their experiences in inclusive STEM education. Therefore, by combining theory, research and practice, this paper gives an overview of some key STEM-related initiatives, projects and interventions to actions that could be taken to design and create supporting inclusive STEM learning environments.

Inclusive STEM learning environment

What is an inclusive STEM learning environment?

As mentioned, there has been a shift from inclusive education, referring to the education of students with disabilities, to an inclusive learning environment, which considers the possibility of equal education for all students. According to UNESCO, 'an inclusive approach to education means that each individual's needs are taken into account and that all learners participate and achieve together.'[12] It takes into consideration the diversity, unique characteristics and learning needs of each student.

[12] UNESCO - What you need to know about inclusion in education | UNESCO

Inclusive STEM learning environments could be defined as virtual or face-to-face learning spaces where all students feel included and where teachers can stimulate and create STEM-related activities. For each student to feel included, the STEM learning environment needs to be accessible, respectful, inviting and supportive, but also challenging enough to improve long-term retention (Bjork & Bjork, 2011). It needs to support the learning process. The flexibility and adaptability of a learning environment fits well with the STE(A)M approach and highlights the importance of connecting STEM to other disciplines.

The inclusive STEM learning environment can be recognised as a space where not only students', but also teachers' needs and involvement must be taken into consideration. It has been highlighted how teachers should pay more attention in encouraging 'failure' as a natural part of STEM learning, which always involves trial and error. An inclusive environment should promote collaboration to explore, analyse and discuss new ideas and then draw conclusions. In addition, teachers need to listen to students' ideas and find different ways of teaching students with different backgrounds and abilities so that they can express themselves and connect the knowledge acquired in the classroom to their daily lives. This is also reflected in the 'learning by doing' approach, where all students can carry out hands-on activities. As some argue, learning by doing is a concept which could be applied to all learning. It is a pedagogical approach in which teachers implement more hands-on and creative ways of learning to actively engage students, and to allow them to make sense of their experiences (Bruce & Bloch, 2012).

Moreover, in an inclusive STEM learning environment, all barriers – such as linguistic, technical and structural – need to be eliminated as it should be accessible and respectful towards different cultures. It should be an inviting place with proper technical equipment, such as in science laboratories, which should be accessible to students with disabilities. For example, the language of instruction needs to be relatable to students and applicable to their lives. To accomplish this, teachers could introduce conceptual change, a type of learning where students develop new concepts by realising what they already know and building on their existing knowledge.

Most importantly, in an inclusive STEM learning environment, all voices should be heard. Students need to understand the purpose of STEM learning and how it affects their everyday lives. Apart from eliminating barriers, it is necessary to ensure inclusive and equitable quality education, and promote lifelong learning opportunities.

How are teachers being prepared to deal with inclusivity?

An inclusive environment may be regarded as an environment which ensures that all participants can present observable progress in regards to concrete goals of STEM topics. To

achieve this, teachers play an important role. Teachers are usually more willing to engage in projects that bring them some kind of professional satisfaction as they are the ones who put these ideas into practice. However, they are usually overwhelmed and present feelings of being less effective or less satisfied with what they have achieved.

Inclusive teaching requires teachers to recognise the experiences and abilities of every student, to embrace the idea that each student's learning capacity is open-ended and to be open to diversity. This is also highlighted in the Teacher Education for Inclusion (TE4I) project[13], initiated by the European Agency for Development in Special Needs Education. The TE4I project investigated how teachers are being prepared for inclusive education and what kind of competencies they need to have to be 'inclusive'. Some of the main concerns which need to be reinforced at European policy level include developing an effective recruitment and selection process and improving teacher education systems to ensure the quality of teacher educators. Moreover, according to the TE4I project findings, it is necessary to improve teacher competencies, of which they have identified four as the basis of working in inclusive education: (1) valuing the diversity of learners, (2) supporting all learners, (3) collaborating with others, and (4) being responsible for own lifelong learning. To ensure teachers rise to this challenge, they require training. According to UNESCO's 2020 report on inclusive teaching[14], the availability of such training sessions varies depending on the country, and for those with fewer resources, it is more challenging to organise teacher training for inclusive education.

Furthermore, the European Association of Distance Teaching Universities (EADTU)[15], a university network for open higher education, has also set the topic of diversity and inclusion as a priority in their new strategies. They have established the Task Force Diversity and Inclusion (2021-2022), which consists of 22 experts from 12 EADTU member institutions. Their task includes 'organising education for disadvantaged groups of students by offering them easily accessible learning paths made fit for a great diversity of students.'[16]

In Italy, according to the latest laws and guidelines[17] from the Ministry of Education to support inclusive STEM, didactic plans that consider the characteristics of the individual student will be devised. Groups for Territorial Inclusion, formed on a provincial basis, or groups of expert teachers, will support schools in drafting the Individualised Education Plan (IEP) and managing

[13] Teacher Education for Inclusion - https://webbutiken.spsm.se/globalassets/publikationer/filer/te41-policy-paper-pdf/
[14] Inclusive teaching: preparing all teachers to teach all students - https://unesdoc.unesco.org/ark:/48223/pf0000374447
[15] EADTU - https://eadtu.eu/
[16] https://diversity-inclusion.eadtu.eu/about
[17] https://www.miur.gov.it/-/inclusione-approvato-il-decreto-in-via-definitiva-nuove-norme-a-favore-degli-alunni-con-disabilita

disadvantaged students. At school level, the operational working group for inclusion will draft the IEP. Furthermore, in Italy, students with learning disabilities are fully integrated in the class. They often have specially trained and dedicated teachers. At a local level, inclusion is facilitated through the promotion of stable multi-professional teams in schools which support and co-plan the necessary educational interventions with the teachers. In addition, numerous projects for inclusion in STEM are in place at both national and local levels; for example, IN2STEAM – Inspiring Next Generation of Girls through Inclusive STE(A)M Learning in Primary Education[18], led by the European study and initiative centre CESIE[19].. The aim of the IN2STEAM project is to foster an innovative STE(A)M learning approach in primary education by using gender-inclusive methods to promote non-stereotyping choices.

In Portugal, educational systems prepare teachers to teach in specific areas, and inclusion is an integral part of the whole curriculum. Currently, there is concern about STEM because the approach has not yet been included in undergraduate courses for future teachers. It has only been included in postgraduate courses. For example, to tackle inequality when it comes to students with different socio-economic background, Teach for Portugal[20], a non-governmental organisation, organises 5-week, intensive summer courses before admitting interested university graduates and young professionals to their programme. The aim of the programme is that those teachers admitted collaborate for two years in schools in under-resourced communities across Portugal. Another initiative in Portugal that aims to promote gender inclusivity in engineering and technology – fields which are mainly male-dominated – is called Engenheiras Por Um Dia[21] (Engineers for a day). It was piloted in 2017 as an initiative from the Secretary of the State for Citizenship and Equality of the Portuguese Government. Since its start, it has reached more than 10 000 students in primary and secondary schools and its main goal is to increase the number of girls and women going into Information and Communication Technology (ICT) subjects, as well as to reduce inequality.

According to a recent press release by UNICEF[22], before the COVID-19 pandemic in North Macedonia, more than half of all fifteen-year-olds failed to meet basic proficiency levels in maths, which is below the Western Balkan and the EU average. To provide equal opportunities to each student in North Macedonia, teachers should have regular professional development

[18] IN2STEAM - https://in2steam.eu/
[19] CESIE (it. Centro Studi ed Iniziative Europeo) – a European study and initiative centre, https://cesie.org/en/
[20] Teach for Portugal - https://teachforportugal.org/o-programa
[21] Engenheiras Por Um Dia - https://digital-skills-jobs.europa.eu/en/inspiration/good-practices/engineers-day-engenheiras-por-1-dia-portugal
[22] https://www.unicef.org/northmacedonia/press-releases/national-and-local-authorities-agree-need-optimize-primary-school-resources-more

courses, especially for secondary school teachers since in primary schools there are more special education teachers. In addition, the New Concepts for Inclusive Education[23], which North Macedonia adopted in 2020, introduces new methods of supporting students and schools. With the new Law on Primary Education[24], special schools will be transformed into primary schools with resource centres that will provide professional assistance and support those municipal primary schools where students with disabilities are enrolled.

In Turkey, both in-service and pre-service teacher training is provided by the Ministry of National Education, Directorate General for Innovation and Educational Technology. Teachers are also guided by research centres that involve experts who provide training to teachers and their expertise to the schools. According to UNICEF[25], Turkey is also working on making their education system more inclusive, especially for students with disabilities and for refugees. Since 2003, Turkey has implemented Conditional Cash Transfers for Education (CCTE)[26], a social policy tool to facilitate enrolment and regular attendance in schools. With this support, families receive an allowance when their children regularly attend school. In 2017, this policy was expanded to cover school-age refugee children residing in Turkey under temporary protection. This programme is funded by the EU, together with the governments of Norway and the US.

To conclude, according to UNESCO's 2020 report on inclusive teaching mentioned above, many countries have made some progress in preparing teachers to support all students and to promote inclusion. The issue remains when it comes to changing attitudes towards inclusivity and adequately supporting teachers with the skills needed to promote inclusive environments. It is still necessary to include pre-service education and high quality in-service professional development to tackle prejudice and discrimination. In addition, when it comes to STEM teachers, they should learn more about different strategies for promoting inclusivity in their STEM lessons, and conversely, special needs teachers should be equipped with the requisite STEM knowledge.

[23] North Macedonia: New concepts for inclusive education and primary education - https://eurydice.eacea.ec.europa.eu/news/north-macedonia-new-concepts-inclusive-education-and-primary-education-part-european
[24] North Macedonia: Law on Primary Education - https://mon.gov.mk/stored/document/Zakon%20za%20osnovnoto%20obrazovanie%20-%20nov.pdf
[25] Quality inclusive education in Turkey - https://www.unicef.org/turkiye/en/quality-inclusive-education
[26] Conditional Cash Transfers for Education (CCTE) - https://www.unicef.org/turkiye/en/conditional-cash-transfer-education-ccte-programme

Barriers to inclusive STEM teaching

When trying to determine the barriers to inclusion, the focus should be on different target groups, such as students with learning disabilities and students who are underrepresented in STEM due to ethnicity, gender, social status or any other vulnerability factor.

Bias against inclusivity

One of the barriers is the political barrier, along with bias and prejudice against certain groups of students. Creating an inclusive environment and having personalised education cannot be achieved without inclusive policy strategies and plans, as well as the appropriate resources to implement them. Inclusive education policies should be developed and strengthened in different countries to guarantee that good practices at local and national levels are not discontinued due to political changes.

Aside from policies, preventing biases and stereotypes in the classroom is also something teachers should work on. The prevalent stereotypes need to be understood in order to promote and facilitate inclusivity in education. According to a study by Pit-ten et al. (2017) on stereotypes and attitudes towards students with special educational needs, it was found that although teachers expressed positive attitudes towards the benefits of inclusion, they reported negative attitudes regarding their ability to teach students with special educational needs.

Gender barriers

According to UNESCO[27], only 35% of women pursue STEM topics in higher education, while only 30% of scientific researchers worldwide are women. As STEM projects are mainly led by male researchers, it is important to understand how this is translated into the classroom and educational materials. The ratio of female STEM students is growing, but the number of women as STEM professors is still low. In the report 'She Figures 2021' (European Commission, 2021), it was underlined that in Europe women represent 32% of doctoral graduates in physical sciences and mathematics, and that only a quarter of self-employed professionals in STEM are women.

Although there is visible progress when it comes to increasing women's interest and involvement in STEM, women continue to be underrepresented in some STEM fields. Schmader (2022) mentions that gender stereotypes might likely constrain women's relatively lower interest in male-dominated STEM careers. Dismantling these barriers requires a multi-

[27] Gender-responsive STEM education - https://unesdoc.unesco.org/ark:/48223/pf0000366803/PDF/366803eng.pdf.multi

level approach, from changing the organisational and educational cultures to changing those on the interpersonal and individual levels.

According to the Council of Europe Strategy for the Rights of the Child (2022-2027)[28], in order to promote a gender-sensitive approach, girls need to be empowered to access education and STEM careers, and they need to be introduced to the use of different technologies. For example, the EQUALS-EU project[29] aims to promote gender equity in social innovation through capacity building and creating smart, sustainable and inclusive social innovation ecosystems in local communities and cities in Europe and the Global North and South. Another project which is in support of increasing the participation of women in STEM is the EU-funded project – Girls Go Circular[30]. Its aim is to equip schoolgirls aged 14-18 with digital and entrepreneurial skills through an online learning programme about the circular economy. More than 20 000 girls have been involved as the project has been ongoing for two years.

Moreover, an example of how teachers can assess how gender-fair their teaching practices are is by using an online self-assessment tool called Gender4STEM Teaching Assistant[31]. This tool was developed as part of the e-learning platform for the Gender4STEM project, an Erasmus+ project whose main aim is to spark interest in STEM among girls. After using the self-assessment tool, teachers obtain a personalised recommendation of materials which might help them find ways of introducing more gender-fair teaching practices. Finally, other ways to reduce the gender gap across STEM topics have also been explored in one of the previous STNS Scientix Observatory papers entitled 'STEM Female Leaders' (Bilgin et al., 2022).

Socio-economic barriers

There is also a low participation rate of STEM students from low-income backgrounds[32], and first-generation (FG) students, i.e. students whose parents did not obtain a college or university degree. Pearson et al. (2022) analysed programmes that enhance the participation of these groups of students. It was found that if students are considered both low-income and FG, they are up to four times more likely to drop out of higher education after their first year than those without these risk factors. It also needs to be considered that depending on the area, or country, students might have less access to STEM education. For example, research shows

[28] European Council Strategy for the Rights of the Child - https://rm.coe.int/council-of-europe-strategy-for-the-rights-of-the-child-2022-2027-child/1680a5ef27
[29] EQUALS-EU - https://equals-eu.org/
[30] Girls Go Circular - https://eit-girlsgocircular.eu/
[31] Gender4STEM Teaching Assistant https://edu.gender4stem-project.eu/
[32] Why Low-income Kids Are Nowhere to be Found in STEM - The Edvocate (theedadvocate.org)

that in high-poverty areas, there are fewer science resources and less access to advanced mathematics (Sawchuk, 2017). The main barriers for students from low-income backgrounds and FG students include negative stereotyping and a lack of the sense of belonging, but these students also have a fear of being incompetent and might feel as intellectually inferior to their peers (Pearson at al., 2022).

The social climate also affects students belonging to ethnic minorities. For example, a study in Flanders by Korkmaze & Agirdag (2015) analysed ethnic inequality in education, especially in STEM subjects. The research shows that students belonging to ethnic minorities consistently had lower scores than native students, irrespective of the social status of their parents. One of the reasons mentioned is that the students did not have a sense of school belonging and were subject to negative stereotypes accompanied with lower teacher expectations.

Language barriers

According to Oyoo (2012), the science-language barrier is often related to translating scientific information from English to other languages. This is common for students whose first language is not English, but research shows that even students whose native language is English have difficulties understanding scientific information (Boyle et al., 2020). This factor has an impact on the development of scientific literacy among students.

The language barrier arises also in the context of teaching STEM to refugee students. For example, Delen et al. (2020) argue that the main barrier to STEM teaching for refugee students in Turkey is the lack of language skills. Teachers should know Arabic or English to communicate with students, or students should know Turkish or English to communicate with others.

In Germany, for example, to facilitate the integration of refugee students, 'Welcome classes' are organised where aside from learning the German language, students learn about STEM. The project is called MINTegration[33] and it includes a five-day programme for refugee students to learn about STEM through practical activities and experiences. All in all, when discussing inclusivity, teaching in a multilingual environment should be taken into consideration.

Structural barriers

When creating inclusive STEM environments, there is a lack of support and assistive technologies. For example, in Portugal, there are generally no barriers for students with physical disabilities when one considers the school infrastructure, but there is a lack of

[33] https://slidetodoc.com/mintegration-stem-activities-for-refugee-kids-martin-lindner/

inclusive materials and assistive technologies in the science labs. This presents an issue particularly for those teachers who are usually not trained on how to use the existing technologies. Another barrier is that teachers do not have enough time to include STEM education as there is a lot of pressure to comply with the curriculum. Teachers would feel more motivated if they were properly trained on how to introduce new technologies and given more time to do so. Another important point when it comes to structural barriers is that a lot of buildings, labs and materials are still not accessible to students with disabilities. As the first step to making STEM learning inclusive, physical barriers should be eliminated.

How to ensure inclusive STEM environments?

Achieving a personalised strategy for each student

One size does not fit all students. However, ensuring a personalised STEM approach for each student is difficult to achieve if there are many students in a classroom and only one teacher. A smaller class size might have a positive impact, but before implementing such an approach it's best to analyse the context[34]. Perhaps some might even benefit from occasional one-to-one interventions or smaller group teaching within a class[35]. Aside from the size of the class, it is important that teachers have adequate support. For example, it could be some students who excel in maths but the students' physical disabilities prevent them from using computers. With proper assistance, these students can participate in the classroom with their peers and keep achieving great results.

To achieve an inclusive STEM learning environment, classrooms also need to be adequately equipped. For example, the School 4.0[36] plan in Italy will allow schools to use the funds of Next Generation Italia, the National Recovery and Resilience Plan to create next generation classrooms and labs. The investment aims to accelerate the digital transition of Italian schools by making their facilities more technologically advanced, flexible and suited to greater digitalisation of teaching.

Moreover, the students should be at the centre of the learning process. When students participate in teamwork and peer learning, they realise they are capable of working with STEM topics and have great results when motivated to learn. To achieve this, teachers could have

[34] Reducing class size | EEF (educationendowmentfoundation.org.uk)
[35] https://d2tic4wvo1iusb.cloudfront.net/eef-guidance-reports/send/EEF_Special_Educational_Needs_in_Mainstream_Schools_Recommendations_Poster.pdf?v=1670931554
[36] School 4.0 - https://www.italiadomani.gov.it/en/Interventi/investimenti/scuola-4-0-scuole-innovative-nuove-aule-didattiche-e-laboratori.html

students tinker various materials. Tinkering is built on inquiry-based pedagogy and implements a hands-on learning approach to help develop students' skills, such as critical thinking, collaboration and problem solving, and boost their self-confidence[37]. During a tinkering activity, the student is presented with tools and materials needed to explore a specific STEM phenomenon. This could be a way for the teacher to evaluate students' work, and also to show the community the contribution of each student.

Recently, the SpicE – Special Education STEAM Academy[38] project was launched to promote visibility and inclusion for primary education students with mild disabilities, and to promote STEAM strategies in Special Education (SE) at a European level. The project is co-funded by the Erasmus+ programme and one of the main goals of the project is to develop a Competence and Education Framework for STEAM in SE, as well as to develop a STEAM training programme for SE. Another goal is to create a community of practice platform for teachers to exchange knowledge. SpicE will also design a self-assessment tool for STEAM competencies. Regarding self-assessment and STEM strategies at the school level, Scientix also offers a service called the STEM School Label[39] (SSL). The aim of the SSL is to support schools in improving their STEM activities and help develop their STEM strategy through a free self-assessment tool including seven key areas of development, and to provide training and resources for applicant schools.

Another example of a project that is helping students with specific learning disabilities is the LEAD![40] project, funded by the Erasmus+ programme. It aims to increase their social inclusion by encouraging them to acquire new skills to improve their school performance. In addition, based on the analysis of the project implementation, a set of policy recommendations[41] has also been set to emphasise how local, regional and national level policies could support the inclusion of students with special needs and create learner-centred schools. A project that also aims to eliminate barriers which students with disabilities face is Far Beyond The Barriers, an Erasmus+ funded programme. The main objectives are to promote awareness about students with learning difficulties, to promote positive attitudes in the language used in school and to achieve a more inclusive classroom by ensuring necessary assistance for the teachers. It is important that each teacher feels able to teach and understand a student's individual needs.

[37] https://www.museoscienza.org/en/education/tinkering
[38] SpicE - https://spiceacademy.eu/
[39] Scientix STEM School Label - https://www.stemschoollabel.eu/
[40] LEAD! - https://lllplatform.eu/news/lead-specific-learning-disorders-no-more/
[41] LEAD! Policy recommendations - https://lllplatform.eu/lll/wp-content/uploads/2022/11/LEAD_Policy-recommendations.docx.pdf

It is also necessary to highlight different ways of making the STEM learning environment more accessible to underrepresented groups. For example, Lynch et al. (2018) analysed inclusive STEM high schools which have been established in the United States to enhance the participation of students underrepresented in STEM. It is important to note that students in such schools are not enrolled based on their prior achievements, but are there based on their interest[42]. These structures could create opportunities for shaping a learning environment where such students may further develop their STEM knowledge to be successful later in STEM careers.

Preparing teachers

According to the OECD's report 'Changing the Odds for Vulnerable Children' (2019), the main point of their inclusive growth agenda is the well-being of children. To detect an individual student's needs, especially in a diverse classroom setting, education systems need to build on the teachers' capacity to close the well-being gap. As an example, the report mentions that schools should be provided with specialised teachers and training to identify students at risk, and to foster self-esteem and positive attitudes. Considering the different definitions of inclusive STEM education, different challenges arise when trying to achieve an inclusive STEM learning environment. Implementing Continuing Professional Development (CPD) for teachers and other educators, who consider the different requirements for inclusivity, entails a complex process. When taking into consideration the CPD programmes available, they are usually mitigated due to the students' diversity; therefore, the most effective CPD might be that provided in-house which targets the specific audience of the school, college or university. In addition, teachers should also be aware of each student's needs and background and take them into account for a personalised approach. For example, the INSCHOOL[43] project, funded by the Erasmus+ programme, aims to train both in-service and pre-service teachers to develop inclusive education practices. In 2020, European Schoolnet also ran a massive open online course called Designing for Personalisation and Inclusion with Technologies[44] (DEPIT). The aim of DEPIT[45], an Erasmus+ project, was to develop an effective working method for teachers and students. The DEPIT APP[46] that was developed is useful to teachers in general for planning their classroom work, but it's also important for students as they have a clear overview of their own learning path.

[42] https://inclusivesteminsights.sri.com/index.html
[43] INSCOOL - https://www.inclusiveschools2.net/article/id/4.html
[44] https://www.europeanschoolnetacademy.eu/courses/course-v1:DEPIT+design_personalisation_technologies+2020/about
[45] DEPIT - http://depit.eu/the-project/
[46] DEPIT APP - http://depit.eu/the-depit-app

Without clear and achievable goals, whatever infrastructure exists may not help us achieve our objectives. To be inclusive in STEM education, it is important that teachers can assess the students' needs, and this should be included in schools when organising training sessions. It should also be highlighted that lower outcomes may stem from using standardised texts and categorising students with disabilities, while it would be better to introduce the personalised strategy for each student as mentioned above.

Moreover, teachers need to learn how to develop critical thinking skills with their students. This is a difficult challenge that requires a radical change not only connected to the way teachers think, but also to the way curricula are built. When choosing the teaching materials, teachers need to be mindful of the images and voices represented, and provide diverse historical and contemporary role models (Ivey et al., 2012). Many teachers also do not have access to appropriate teaching materials, so they would benefit from having free resources to include in their lessons. For example, Scientix offers various teaching materials for free as part of its online Resource Repository[47].

For teachers to remove barriers in STEM learning environments, according to some researchers, it is necessary to sequence instruction so that it fits the needs of each student. Klimaitis and Mullen (2021) mention the importance of grouping both students with and without disabilities in STEM lessons as they can then receive support from their peers. In addition, to promote inclusivity, students might benefit from having a mentorship experience. An example of a project that involves teachers, students and role models representing companies and higher education institutions is CHOICE[48]. Its goal is to create innovative open education resources. By including role models, the project aims to ensure that the resources correspond to the current skills challenge that is perceived in both higher education and in the labour market. As part of the project, a set of policy and advocacy recommendations[49] has been devised to support the reform of the school curricula on regional, national and European levels by shifting to a practice-oriented and a more interdisciplinary approach of STE(A)M education. Finally, a crucial point raised by Sarju (2021) is to involve students and scientists with disabilities when consulting on decisions which affect them, because they are the experts of their own disabilities and know what the best approach for them is.

[47] Scientix Resource Repository - http://www.scientix.eu/resources
[48] CHOICE - https://lllplatform.eu/what-we-do/eu-projects/choice/
[49] CHOICE Policy and advocacy recommendations - https://lllplatform.eu/lll/wp-content/uploads/2022/12/D4.7-Policy-and-advocacy-recommendations_EN-final-layout.pdf

Using assistive technology

Klimaitis and Mullen (2021) highlight the usefulness of assistive technologies and artificial intelligence (AI) that could help students with disabilities access educational materials more easily. For example, such students would benefit from having adaptive products such as the ones Key2Enable[50] produces. For example, they have developed a smart keyboard, Key-X, which helps people with motor impairment to access any computer or smartphone. For people with severe motor disabilities, Key2Enable has developed a-blinX, which picks up the blinking of the eyes to write and vocalise sentences or use any computer.

Key2enable developed a hybrid solution comprising of plug-and-play hardware (innovative 9-button keyboard, Key-X, and its accessories) and a fully customisable online learning platform that integrates seamlessly with the keyboard, and facilitates alternative communication, cognitive stimulation and engagement between children with and without disabilities in an inclusive/adaptive learning environment.

Assistive technologies can help students to have a more hands-on experience in science labs. However, such technologies may not be accessible to all, but there are a number of low-cost adaptations that could be implemented in the lab (Rule et al., 2009). For example, students could use a notched plastic syringe with Braille labels or a submersible audible light sensor for the detection of light intensity and color changes. Finally, according to Sukhai et al. (2014), teachers could use AI to create complex visuals and graphs to make educational materials more accessible for students with disabilities.

Involving parents

Teachers need to be aware of students' attitudes and know how to approach each student. Besides knowing the students' needs, it is crucial for them to also communicate with parents. To achieve an inclusive environment, additional resources in the classroom may be needed, but to achieve this goal, schools need to involve parents. They have their own expectations, but they also must understand the challenges and problems that arise when dealing with inclusivity and try to work together to resolve them. It could be useful to create positive attitudes by introducing people with different STEM career profiles and having real examples in the classroom. This way parents can also be informed of future STEM career opportunities. Issues may arise with adolescents who might not want their parents to be too involved, but a solution could also be to teach parents about the importance of STEM. For example, schools could organise events and group work to include parents and also give them the opportunity to learn

[50] Key2Enable - https://key2enable.com/

about STEM, especially about the use of technologies. If the teacher uses various technologies in the classroom, it would be useful for the parents to also learn and understand how these affect them. Another example of including parents is when teachers allow them to join their children in the classroom to be there as support, but also to set an example for their child. It is best if they include hands-on activities, so for example, a parent might bring some materials to school, and together with the teacher they could organise science-related activities to explain the importance of STEM. Most importantly, parents need to keep all doors of the future open for their children.

Conclusion

Whether it is virtual or face-to-face, every student must feel included. The inclusive STEM learning environment must be accessible, respectful, inviting and supportive, but also challenging enough. The flexibility and adaptability of such a learning environment fits well with the STE(A)M approach, which is flexible and inspiring enough to tackle individual needs and motivations. Regarding the means to create inclusive learning environments, there is a need to emphasise progress. When students exhibit progress, teachers also feel professional satisfaction. They see that their efforts are being effective. Moreover, peer learning is key in STEM education. However, cooperation should not only be between students but also between educators, families and external education stakeholders. Teacher training sessions should also include how to tackle the issue of language used in the classroom, as well as address teachers' own biases as many categorise students with disabilities, instead of implementing a personalised approach. Future teachers and in-service teachers require not only STEM content training, but also pedagogical knowledge to be able to create safe and interesting spaces for every student.

Regarding the challenges in creating inclusive STEM learning environments, one of the issues that persists is how female students do not have adequate support to choose STEM careers and continue pursuing them, because they tend to drop out due to a lack of support. Gender equality is difficult to achieve when there are no policies or budgets that encourage it. In addition, as STEM projects are often led by male researchers, this also translates into materials and resources created for teachers. Such materials do not adequately address the importance of STEM role models with different backgrounds. Furthermore, another barrier to inclusivity in STEM is structural, as many buildings, laboratories and tools are still not accessible to all. More importance should be given to this barrier as well. Apart from structural, there are socio-economic barriers, especially for students who come from other countries and/or from underprivileged backgrounds. When taking into consideration students who come from

different countries, language presents another barrier. For students who are not able to communicate effectively, it is difficult to progress in STEM education as this generates frustration.

All the above-mentioned barriers can be seen, but there are invisible barriers that need to be addressed because everything starts from our mindset. Changing the mindset of policymakers, school directors, educators and families is key to being able to take advantage of the possibilities that STEM education brings. Teachers should also assess their mindset when it comes to inclusivity, and include hands-on and challenging activities which motivate all students. If done with the appropriate tools and means, no student will be left behind.

Furthermore, different solutions and strategies can be identified by education policymakers at national and regional levels. The importance of evaluation, and how teachers require guidance to plan clear and achievable goals also needs to be highlighted because without this, STEM inclusive education will not be successful. New methods and approaches in STEM education will open many doors for all students, especially when having the teacher guide a student's learning by creating a safe and motivating environment. It is imperative that all systems and institutions, as well as individual schools and teachers, try to achieve observable concrete progress because without progress, the movement for inclusion will soon lose its dynamic, and there is a risk of going back to traditional approaches to education.

Finally, the role of families is very important in creating an inclusive STEM learning environment. Parents should regularly be involved in school activities and schools need to keep them informed about future STEM career possibilities. Together, the schools and families might find solutions to personalise the learning of the students and create a supportive community that is enriching and brings diversity and role models to the students.

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