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From barriers to boosters: initial teacher education for inclusive science education

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The paper presents a literature review on current barriers and boosters in the context of initial science teacher education for inclusion. The authors argue that current science teacher education programs for prospective teachers could be improved by adopting a more conceptually grounded and sustainable approach toward inclusion. To this end, the paper proposes an approach based on inclusive values and evidence-based practices that would benefit all students. Firstly, the paper identifies several barriers that exist in current science teacher education programs, including the dominance of an *add-on approach*, separate teacher education tracks, and inadequate preparation for the topic leading to decreasing self-efficacy toward inclusion. Secondly, to overcome these barriers, the paper proposes the integration of evidence-based practices, collaboration, and knowledge-transfer in science teacher education programs. These boosters can equip prospective science teachers with the necessary skills and knowledge for effective inclusive science education. Overall, the paper provides valuable insights and recommendations for improving initial science teacher education programs in the context of inclusion.

KEYWORDS

inclusive education, science education, pre-service teacher, professionalization, inclusion, initial teacher education, scientific literacy, collaboration

1. Introduction

> *A young science teacher, named Sarah, has just begun teaching in school. Sarah faces several challenges in her science class. She struggles to create lessons that are accessible to all students. Some students have different learning styles and abilities, and Sarah finds it difficult to cater to all their needs. For example, some students[1] struggle with abstract concepts and aspire to hands-on activities to grasp the content. Sarah realizes that she needs to adapt her teaching to accommodate all her students. Sarah is aware that some of her students have additional needs, but she does not know how to support them. She is afraid of not being able to provide the necessary adjustments and changes that could enhance their learning. Sarah feels that she needs to acquire more knowledge and skills in inclusive education, and she feels overwhelmed with the additional burden.*

1 In this article the authors define the word "students" to describe pupils at school level. Higher educational students at universities are designated as "prospective teachers (PTs)" or "prospective science teachers (PSTs)" to avoid misunderstandings.

In recent years, there has been a growing recognition of the importance of providing high-quality education to prospective teachers (PTs) in the context of inclusive education (IE). Political and academic efforts have been made to improve the quality of teacher education, as reflected in initiatives such as the *European Agency's Teacher Education for Inclusion* (*TE4I*) project, which aims to support the development of inclusive policies and practices in teacher education. Moreover, there has been an intensification of research activities in this area, as evidenced by a recent bibliometric analysis conducted by Cretu and Morandau (2020). The need for high-quality teacher education is also reflected in the fourth goal of the United Nations' 2030 Agenda. However, despite the efforts being made, many teachers, like the fictional character Sarah, continue to face barriers in teaching when it comes to IE, particularly in subject didactics[2] such as science education (Troll et al., 2019). Science education involves more than just learning about scientific facts and concepts; it requires a specialized way of thinking and working that places complex demands on both teachers and students (Stinken-Rösner and Abels, 2021). This results in very specific barriers in teaching science education, some of which particularly connected to "doing science" (Hodson, 2014; Stinken-Rösner and Abels, 2021), that are rarely encountered in other subjects.

The implementation of an inclusive school system at all levels, as mandated by the *Convention on the Rights of Persons with Disabilities* (2006), has been hindered by various factors, one of which is the existence of multiple concepts and approaches to inclusion and their implementation in the curriculum (Florian, 2021). Consequently, many PTs do not feel adequately prepared for IE. In the field of science education, various studies have identified barriers to the implementation of inclusion in practice (Markic and Bruns, 2013; Menthe and Hoffmann, 2015; Schmitt-Sody et al., 2015; Pawlak and Groß, 2021; Stinken-Rösner and Abels, 2021; Sührig et al., 2021; Stinken-Rösner et al., 2023). For example, Essex et al. (2019) conducted two exploratory studies with prospective science teachers (PSTs) in England that aimed to investigate their understanding of inclusion and the connection between inclusion and teacher education. Their results indicate that traditional notions of ability are still prevalent, with ability-based differentiation being perceived as the primary teaching method for promoting inclusivity. Moreover, PSTs face the challenge of reconciling conflicting and contradictory perspectives on inclusion, diversity, and academic achievement. This highlights the need for a consistent, high-quality science teacher education that provides clear guidance and support for IE practices.

The *3H Framework* proposed by Sharma (2018) emphasizes the importance of developing beliefs, knowledge, and skills in teacher education for IE, referred to as the heart, head, and hands of inclusion. Teachers must possess inclusive beliefs as the foundation for the development of knowledge and practical skills required to become effective inclusive educators. Without proper professionalization, teachers may inadvertently perpetuate existing inequalities and limit students' opportunities to succeed (Jordan and Stanovich, 2003; Jordan et al., 2010). Teachers' beliefs and practice are hindering or supporting students to fulfill their potential and achieving academic and social goals (Hart et al., 2004). Initial teacher education can help acquire appropriate beliefs and practices for IE (Forlin et al., 2009; Sosu et al., 2010).

Achieving effective and inclusive science education (ISE) requires an interweaving of the perspectives of inclusive pedagogy and science education (Stinken-Rösner et al., 2020). This involves the careful differentiation and elaboration of inclusive pedagogical aspects within science education, which, in turn, places unique demands on science teachers. They must possess both the necessary knowledge and practical skills to combine inclusive pedagogical approaches with science-specific content. However, there are some barriers in teacher education that need to be overcome to achieve this goal. Firstly, there is a lack of agreement on what content should be included in science teacher education and professional development programs for inclusion. Thus, it is crucial to establish a shared and transparent understanding of what ISE should look like to promote the base of best practices. Secondly, there are systemic barriers such as the distinct study programs for regular and special education teachers that make it difficult to combine the aspects of subject-specific knowledge and IE. Therefore, thirdly, combined approaches are rarely integrated into teacher education of prospective teachers. For example, science teacher education only rarely includes competences such as observing and diagnosing learning needs, differentiating or individualizing (Abels and Schütz, 2016; Abels, 2019).

The purpose of this article is to present those barriers in initial science teacher education for inclusion and, based on that, to derive boosters, which are potential strategies and solutions that can contribute to successful initial science teacher education. The article first establishes an understanding of ISE that is located within a broad, reflective understanding of inclusion as a process. The article argues for a feasible teacher education approach that can be easily implemented in practice through evidence-based practice and skills, without being overly simplistic. Building on this, the article identifies potential strategies, content and solutions for initial teacher education programs in ISE. By examining the potentials and barriers identified in initial science teacher education for inclusion research, this article aims to contribute to the ongoing discussion about what constitutes good ISE and how to promote it with proper and adequate teacher education. There is a wealth of knowledge that can contribute to successful initial teacher education in the field of ISE and therefore a synopsis of current research findings and good-practice concepts was done and is presented in this article. Furthermore, this literature review contributes to the understanding of current barriers and boosters in initial science teacher education for inclusion in Germany.

2. Inclusive science education: exploring key terms

2.1. Inclusion as a normatively shaped reflection process

Since the *Salamanca statement* (UNESCO, 1994) as well as the ratification of the *UN Convention on the Rights of Persons with Disabilities* (2006), the provision of education for all children in a school within their local community has been recognized as a fundamental human right in most countries worldwide. Consequently, the question of whether IE should be realized has been supplanted by the question of how it can be effectively implemented across all levels

2 Term to describe the science of teaching and learning.

(Booth and Ainscow, 2002). This topic is extensively explored in the academic literature, where IE is viewed as an ideology that promotes respect for the right of all students to quality education (Florian and Black-Hawkins, 2011). IE is considered normative in nature due to its grounding in the human rights context and the values and imperatives associated with it. However, there is a broad corpus of literature which shows evidence that IE contributes to quality education and social inclusion for all (Kefallinou et al., 2020). The focus of IE is to increase participation for all students, value all individuals equally, promote equity, anti-discrimination, and respect.

Although these goals form the basis of academic discourse, the discussion around IE is neither uniform nor uncontroversial. Göransson and Nilholm (2014) conducted a literature review that revealed four distinct interpretations of IE: (a) the inclusion of students with disabilities in regular classrooms, (b) addressing the social and academic needs of students with disabilities, (c) catering to the social and academic needs of all students, and (d) fostering the development of inclusive communities. The definitions reflect different perspectives and dimensions of inclusion. While (a) is more commonly used in a legal context (e.g. United Nations, 2006), the other definitions refer to content-oriented goals. (b) reflects the concept of "education for some," while (c) refers to "education for all" (Leijen et al., 2021). The relation between these two perspectives has been widely discussed in the literature by authors such as Florian (2019) or Leijen et al. (2021). While "education for all" places emphasis on accommodating all students, there is a risk of overlooking the unique needs of certain students (with special educational needs). Conversely, focusing solely on special educational needs ("education for some") runs the risk of stigmatization and highlighting disability. This delicate balance between categorizing students for individualized support while avoiding stigmatization is a vital consideration. Also, considering only individual aspects is not enough; inclusion also refers to processes of participation in community (UNESCO, 2009), resulting in the need for promoting social learning and community at a school level as incorporated in (d). The discourse on inclusion is therefore very multifaceted and complex. Limiting it to disability is not productive. Therefore, this paper adopts a reflective understanding of inclusion that views inclusion as a normatively shaped reflection process, adapting a value based, "thick" concept (Norwich, 2022) of inclusion:

> *"Inclusion is seen as a* ***process*** *of addressing and responding to the diversity of needs of all learners through increasing participation in learning, cultures and communities, and reducing exclusion within and from education. It involves changes and modifications in content, approaches, structures and strategies, with a common vision which covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children"* (UNESCO, 2005, p. 13, original emph).

To sum up, inclusion refers to the practice of creating educational environments that are welcoming, accessible, and promotive for all students, regardless of their abilities, backgrounds, or individual learning prerequisites. This involves creating classrooms and school environments that are physically, emotionally, and intellectually accessible to provide students with the necessary support and accommodations they need to succeed. Moreover, inclusion invites to embrace diversity as valuable asset, using everyone's strengths for personal and collective growth, rather than seeing differences as obstacles (Fränkel and Kiso, 2021). However, current school systems often hinder IE due to conflicting political decisions, resource allocation, and societal demands. However, the focus of this paper is not on systemic barriers that prevent inclusion in practice. Rather, it focusses on the academic dimension of IE. It explores how higher education teaching can be designed to prepare PTs to appropriately develop ISEfor all learners.

2.2. Science education for all as a prerequisite for the development of 21st century skills

"Science for all" refers to the concept of providing equal and inclusive access to science education and opportunities for individuals of all backgrounds and abilities, regardless of race, gender, socio-economic status, or any other factor that may create barriers in teaching and has been highlighted in reform documents for several decades [e.g., American Association for the Advancement of Science (AAAS), 1989, 1993; National Research Council (NRC), 1996].

This objective is becoming even more important considering current global social and economic challenges. To succeed in today's rapidly changing and technology-driven world, students need to develop a set of abilities and competencies that are deemed as essential: the 21st century skills [Bybee, 1997; Bybee and Fuchs, 2006; Trilling and Fadel, 2009; Organisation for Economic Co-operation and Development (OECD), 2013]. 21st century skills can be clustered in four main domains namely digital age literacy, inventive thinking, effective communication and high productivity (Turiman et al., 2012). Since many of today's and tomorrow's issues are related so science and technology, scientific literacy is a key component of digital age literacy and, thus, of 21st century skills (Ananiadou and Claro, 2009; Turiman et al., 2012). Accordingly, scientific literacy is not only important for students who may go on to careers in science, technology, engineering, and mathematics. Scientific literacy is also crucial for those who will be citizens and consumers in a world where science plays an increasingly important role. Consequently, science education needs to address all students, regardless of their background or future career plans, and provide them with multiple opportunities to develop 21st century skills. By fostering these, students are equipped with the tools they need to succeed not just in the science classroom, but also in the workforce and in their personal lives.

The challenge for science teachers and other stakeholders in the field is to understand the diverse needs and characteristics of students and to provide a learner-centered pedagogy that meets those (UNESCO, 1994). Teachers play a crucial role in promoting science education for all: 'the quality of an education system cannot exceed the quality of its teachers' (McKinsey Report, 2007 p. 16). Florian and Rouse (2009) state: 'The task of initial teacher education is to prepare people to enter a profession which accepts individual and collective responsibility for improving the learning and participation of all children' (p. 596). PSTs thus need to be equipped to teach in inclusive classrooms and diverse learning groups, acquiring knowledge and confidence about ISE in practice (Mumba et al., 2015). To do so, PSTs require support in developing their competencies in science and IE, which is still an area that lacks research and practice (Egger et al., 2020).

The subsequent sections of this paper will delve into the current state of research by analyzing key barriers (Section 3) and offering potential strategies to tackle these in the context of initial teacher education at the university (Section 4).

3. Barriers in initial teacher education programs for inclusive science education

3.1. The add-on approach and subject-specific elaboration

The diversity of students in the classrooms, due to demographic changes and globalization, is becoming increasingly apparent. This diversity in the classroom is reflected, among other things, in students' language, motivation, interest and prior knowledge, which, in turn, directly influences subject learning. Therefore, initial teacher education programs at universities must prepare PTs by showing them how to adapt their respective subject teaching to diverse groups of students.

To date, however, there is no agreement on how inclusive pedagogical principles should be implemented in initial subject teacher education programs. Most of the existing approaches, such as the *add-on* or the *integrated approach* (Bricker, 1995), have been described either by general or special educators and, accordingly, are only partially oriented toward the specifics of science education.

One example, the *add-on approach* for IE in schools, refers to a method of providing support for students with disabilities or other special needs in regular classrooms. This involves adding on additional services or resources to meet the needs of individual students without fundamentally changing the existing teaching methods. Not only does the *add-on approach* contradict the broad understanding of inclusion (as outlined in Section 2.1), it also can be difficult for subject teachers, who teach limited hours in various classes and lack the resources to assess individual learning needs and to adapt content and methods accordingly. However, it is what some researchers and lecturers belief should be done (see Section 3.3; Essex et al., 2019; Fränkel, 2019).

This article argues for a more feasible approach toward IE at school, adapting and modifying lesson planning rather than adding on to traditional structures. Inclusive subject education should thus not focus on individual students with special needs but rather on teaching and learning subject-specific concepts and practices in ways that are accessible and relevant to all students (see Section 4.1; Florian, 2021).

One approach that meets this normative demand is the universal design approach (Florian and Black-Hawkins, 2011). The authors suggest implementing inclusive pedagogical methods instead of special needs approaches, which prioritize uniform instruction with content differentiation for some students, in classroom practice. Based on the *Universal Design for Learning (UDL)* (National Center on Universal Design for Learning, 2010), the universal design approach aims to provide students with multiple means of representation, of action and expression as well as of engagement. These multiple means to the respective content allow, in contrast to homogeneous instruction, for natural differentiation (Wittmann, 2010) according to students' individual learning requirements. Also, it is in line with the understanding of inclusion as defined by the UNESCO in 2005 (see Section 2.1).

Regardless of the approach and underlying understanding of inclusion, PSTs face the challenge of applying it to their own subject. Since most approaches arise from general or special education, they do not adequately consider the specifics of individual subjects. For example, science education is characterized by four central aspects: reasoning about scientific issues, learning scientific content, doing science, and learning about science (Hodson, 2014; Stinken-Rösner et al., 2020) which incorporate the concept of scientific literacy (see Section 2.2; Ananiadou and Claro, 2009; Roberts and Bybee, 2014). It is imperative to adapt existing inclusive pedagogical principles to these science-specific goals. Next to the establishment of an evidence-based, shared, and/or transparent understanding of what ISE should look like in practice, the topic itself needs to be anchored in the science-didactic components of initial science teacher education programs. Although there are already first considerations as to how this could be (legally) implemented, there is not yet a uniform procedure, let alone common content.

3.2. Separate education tracks for prospective science and special education teachers

Three models of inclusion-oriented teacher education programs have been identified by Stayton and McCollum (2002). The *Infusion Model* integrates inclusion-related elements into subject (e. g. science) teacher education programs through individual courses, without fundamentally challenging the basic structure that separates subject and special education teacher education. The *Collaborative Training Model* involves joint training on inclusion-related issues for prospective subject and special education teachers, with only partial supplementation of specific special education content. The *Unification Model* eliminates the separation between subject and special education PTs, making inclusion-related content an essential component of a common curriculum for all PTs.

Several countries, including Germany, the United Kingdom, and the United States, offer teacher education programs falling under the *Infusion Model* category (European Agency for Development in Special Needs Education, 2012; Allday et al., 2013). Such programs may offer standalone courses on inclusion, rather than integrated components in the curriculum. Even in countries with fewer types of teacher education programs, specialized courses are usually available for those pursuing higher education in specific areas, such as special education needs (Florian, 2021). This approach reinforces the belief that different teacher education programs are necessary for different groups of students, resulting in a fragmented approach toward diversity (Winn and Blanton, 2005).

Fragmented approaches to teacher education can lead to subject teachers feeling that they are only responsible for "regular students" and special education teachers only responsible for "students in need of support" due to their specialist qualification (Florian and Rouse, 2009). This can leave teachers feeling unprepared to teach a diverse student population (Young, 2008). The *UNESCO International Conference on Education (ICE)* report "Inclusive Education: The way of the future" (2009) supports the idea that separate study programs for prospective subject and special education teachers are not effective.

Rather than pursuing a narrow specialization early on, it is advantageous for all PTs to cultivate general education skills and gain multiple experiences. Therefore, many researchers argue that effective preparation for IE at school can only be achieved through curricular offerings that are developed interdisciplinary and responsibly, as seen in the *Collaborative Training Model* and the *Unification Model* (Pugach et al., 2019).

To gain a better understanding of further deficits of the *Infusion Model*, we will examine the example of university curricula in Germany. First, we will provide some contextual information about inclusive education in Germany. The ratification of the UN Convention on the Rights of Persons with Disabilities in 2009 is the most crucial legal framework in Germany. Since then, the inclusion rate (students with special educational support needs at regular schools) has been consistently increasing, while the exclusion rate is decreasing at a slower pace (Scheer and Melzer, 2020). This suggests that the increasing inclusion rate of students with special educational support needs in regular schools in Germany is not due to more students returning from special needs schools to regular schools, but rather due to a higher labeling of students with special needs in regular schools. Furthermore, the German Institute for Human Rights (2022) criticizes Germany's inadequate fulfillment of its legal obligation to implement an inclusive education system. A significant challenge in Germany is the federal system and the absence of a nationwide overarching strategy for inclusive education implementation. Consequently, there are no uniform concepts within the federal states, and the implementation of inclusion remains fragmented, even in a broader understanding of inclusion. Germany is an immigrant country, but the link between qualifications and origin poses a problem, leading to the need for Germany to adjust its policies on educational equity (Autorengruppe Bildungsberichterstattung, 2020). Fortunately, the federal government offers funding programs such as the current program "Integration through Education" by the Federal Ministry of Education and Research (2023).

In terms of science education, the challenge in Germany is that it is typically structured and implemented through the subjects of biology, chemistry, and physics. Cross-curricular education, as defined by the science subject, is more of an exception than a rule. Consequently, university-trained teachers specialize in individual subjects rather than interdisciplinary science education. Moreover, the fact that science subjects are considered minor subjects in Germany exacerbates the lack of (special educational) resources in the German education system, which already faces the challenge of a massive teacher shortage. Finally, multiprofessional cooperation in schools is particularly rare in minor subjects in Germany due to these and other factors (Fränkel et al., 2020).

IE implementation in German university curricula is still in its early stages (Frohn and Moser, 2021). In 2015, a joint effort between *the German Rectors' Conference (GRC)* and *the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (CMC)* resulted in the issuance of recommendations for the integration of inclusion-oriented content within subject-specific didactics modules of initial teacher education programs. These recommendations call for higher education institutions (HEIs) to implement an inclusive overall concept through additive and integrated concepts in the next ten years (CMC and GRC, 2015). Parallel to this, changes have been made within laws. For instance, the *School Act of the state North Rhine Westphalia* mandates at least 5 ECTs for inclusion-oriented issues in subject-education modules (LZV, 2016: § 1, para. 2, sentence 2). However, the legal framework varies from state to state and is described as a "patchwork" (Frohn and Moser, 2021). Universities are thus legally required to offer suitable study programs.

Despite efforts by education policymakers to anchor inclusion in initial teacher education, there remains a lack of comprehensive data on its implementation (Laubner and Lindmeier, 2017). The Monitor Lehrerbildung (2015) conducted a survey of higher education institutions (HEIs) in Germany, revealing that less than half of the HEIs offered compulsory courses or modules on inclusion, with almost a third having plans to implement such courses in the future, mainly in the field of educational sciences and less in subject didactics or subject sciences. Current data shows that courses on inclusion are offered on a small scale, usually less than 10 ECTs (Frohn and Moser, 2021). The interim assessment by GRC and CMC (2020) is primarily anecdotal and lacks a systematic analysis of the implementation process (Frohn and Moser, 2021). Furthermore, the methodology used (self-reporting by university locations) has been criticized for potentially leading to the "re-declaration" of existing courses and content from special needs education as inclusive without reframing or modifying courses (Merz-Atalik, 2017; Frohn and Moser, 2021).

Slee (2007) argues that this approach may not be enough to address broader inclusive pedagogical and curriculum principles. He suggests that teachers need to learn and apply a more inclusive approach that considers the needs of all students, not just those with disabilities. This argument is supported by a study in the Western Balkans which found that restricting on children with disabilities as the sole focus of IE could hinder social and educational inclusion (Pantic et al., 2011). To address this issue, projects like the *UNESCO Special Needs in the Classroom* was introduced (Ainscow, 2004). The project aimed to remove barriers to learning and enhance participation for all, instead of focusing on specific disability categories. However, the project has faced criticism for not having enough knowledge about human differences (see also Section 2.1). Consequently, it is essential to ensure that teacher education programs address the broader principles of IE and offer effective strategies for all students to learn and participate in the classroom without ignoring differences. It is important to stress that simply re-labeling existing courses without fundamentally changing their content or structure leads to maintaining the status quo and thus cementing existing separate structures. This could become one of the greatest barriers for change in initial teacher education.

Linking subject-specific aspects and inclusive aspects is necessary to meet the needs of all students in ISE (as discussed in Section 2.2). However, the implementation of inclusion-oriented content in subject didactics, including science education programs, is currently deficient (Frohn and Moser, 2021). In courses where IE is implemented, the focus tends to be on general inclusive aspects such as attitudes and beliefs, rather than on subject-specific content knowledge (Cretu and Morandau, 2020). It is also important to note that, although curricular changes have been made, they may not necessarily translate into what is actually taught by the lecturers since lecturers themselves do not feel prepared to teach IE content (Symeonidou, 2017). This could be attributed to the traditional separate structures in universities, where lecturers are trained as subject specialists and may feel inadequately prepared to teach inclusive aspects in subject didactics

(Moser and Kipf, 2015). It is unreasonable to expect lecturers to teach topics for which they have not received adequate education.

3.3. Teachers feel unprepared for inclusion

The barriers to prepare for ISE in initial teacher education, as previously discussed, are significant. These include fragmented, and disability-oriented approaches, which hinder the adequate preparation of PTs for inclusive classrooms. The lack of quality education in ISE has serious implications for PTs, who face the challenge of teaching in inclusive classrooms without adequate preparation. Consequently, because they aren't adequately prepared, they feel unprepared and not ready for ISE, as indicated by a vast corpus of literature (Cretu and Morandau, 2020).

A recent meta-analysis conducted by Dignath et al. (2022) summarizes the research on the topic throughout the past two decades. The researchers examined teachers' beliefs about IE and factors that contribute to variation in their beliefs, including the point in their career, training in special versus subject education, and the effects of specific programs and interventions. The review of 102 papers from 40 countries found that, on average, teachers' cognitive appraisals, emotional appraisals, and self-efficacy toward inclusion were in the mid-range of scales. Self-efficacy beliefs were higher for prospective than for in-service teachers, and teachers with special education training held more positive views about inclusion. Development programs and interventions enhanced teachers' attitudes, emotions, and confidence in inclusive practices, particularly when teachers gained practical experience in inclusive classrooms (also Lautenbach and Heyder, 2019). The length of the intervention did not affect the outcomes. However, the presented values are solely indicative of the mean and do not capture the full spectrum of attitudes exhibited by distinct PT cohorts. It is important to acknowledge the presence of varying attitude patterns among these groups and to account for them in any intervention measures (Specht et al., 2022).

In the context of science education, research indicate that science teachers generally have neutral to positive attitudes and are willing to adapt their teaching methods to create an inclusive classroom environment (Spektor-Levy and Yifrach, 2019; Stinken-Rösner et al., 2023). Science teachers recognize that natural sciences are an essential component of students' literacy and citizenship education (Villanueva and Hand, 2011). However, several studies (Mutch-Jones et al., 2012; De Sousa et al., 2018; Spektor-Levy and Yifrach, 2019) suggest that science teachers lack support and guidance in identifying the appropriate pedagogy, methodologies, and technological resources to cater to the needs of all students. As a result, science teachers find it challenging to prepare lessons that are inclusive (Egger and Abels, 2022). They find it especially challenging to make abstract concepts accessible to all students (Buxton et al., 2019) as well as dealing with low interest among students (Potvin and Hasni, 2014).

Furthermore, PSTs may have problematic views on their students and inclusive teaching. Essex et al. (2019) conducted two case studies on inclusive practice in science teacher education programs at two universities in England. While PSTs recognized the value of inclusion as an academic concept, they expressed concerns about its implementation in practice, believing it could limit opportunities for high-achieving students. PSTs held a positive view of inclusion conceptually, but in the classroom, inclusion was primarily associated with low ability and limitations in learning. Most PSTs found differentiating students by ability necessary to meet individual needs, but only a small number recognized the issues of teaching according to perceived abilities. Those who did were studying Physics and Mathematics and had taught the same students in both subjects, leading them to realize that ability is not a fixed property. PSTs' understanding of inclusion as a teaching approach that allows for a shared experience for all students was limited. Differentiation was seen as a marker of inclusive practice, but there was little discussion on what forms it should take and what is a valid basis for differentiation. Differentiation by outcome was commonly used, assuming a direct link between ability and attainment. Essex and colleagues conclude that it would be beneficial for PSTs to have a more comprehensive understanding of students by observing them in different environments or creating a learning profile with them. A qualitative study by Fränkel (2019) found similar deficit-oriented and limiting ability beliefs as well as practices in in-service biology teachers.

The way teachers view inclusion depends not only on their belief system, but also on their perceived resources, such as prior knowledge, time, or support at their school, especially in subjects like science (Dignath et al., 2022; Egger and Abels, 2022). Teachers have expressed a range of questions and concerns regarding inclusion, including confusion about its purpose and target group, frustration with policy demands that hinder implementation, guilt about potentially failing students and parents, and exhaustion from current conditions (Allan, 2008). One example for the current challenges is sketched in a study by Chiner and Cardona (2013). In this research, the aim was to investigate how inclusion is perceived by teachers in primary and secondary schools in Spain, and whether these perceptions varied depending on the level of teaching experience, skills, and the availability of resources and support. The findings indicate that while the principles of inclusion were accepted, teachers believed that their skills, resources, time, and personal supports were inadequate. The study also found that teachers with more resources and personal support had more positive perceptions than those with fewer supports and resources.

Research suggests that the quality of initial teacher education plays a significant role in the feeling of unpreparedness experienced by PTs. Mintz et al. (2020) conducted a panel study of PTs in the Republic of Ireland to examine changes in their perceptions of inclusion from prospective to novice teacher years. The study found that the transition resulted in a significant decrease in attitude, perceived knowledge, and self-efficacy in relation to inclusion. They argue that teacher education programs should prioritize knowledge of effective strategies to include students with special educational needs in mainstream classrooms in their evaluation and practice. Arnaiz-Sánchez et al. (2023) found that limitations in the acquisition of competencies related to paying attention to diversity, limited relevance of theoretical learning to practical intervention, and a deficit-oriented approach to students' learning are significant barriers in initial teacher education.

Consequently, the issue at hand is not the concept of inclusion *per se*, but rather the presence of barriers such as inadequate initial teacher education, lack of resources, and unsupportive structures that impede teachers from effectively implementing ISE. Therefore, it is crucial to break this cycle and provide PTs with the necessary education and support to teach ISE. To address these issues, initial teacher education programs should prioritize knowledge of effective strategies of inclusive teaching and provide practical experience in inclusive classrooms (Delorey et al., 2020; Mintz et al., 2020; Dignath et al., 2022; Nel et al., 2023). It is beneficial for PTs to have a more comprehensive understanding of students by observing them in different environments and reflecting on practical experiences in theoretical coursework (Sharma et al., 2008; Essex et al., 2019). Additionally, teachers need support, resources, and personal support to have more positive perceptions of inclusion.

4. How to boost initial teacher education for inclusive science education

It has become apparent that fundamental changes are needed in initial teacher education to adequately prepare PTs for ISE in school. Three approaches shall be discussed in the following part. This requires firstly more coherent and effective university education to ensure that PSTs feel confident and equipped to meet the needs of all students in an inclusive classroom environment (as will be discussed in Section 4.1). To overcome the specialist knowledge problem, promoting interdisciplinary collaboration could be one solution (see Section 4.2). Another strategy for teacher education would be to share projects and resources in science teacher education for inclusion (see Section 4.3).

4.1. Fundamentals and evidence-based approaches

As a basis for a common ground, Florian (2021) presents a so-called *value-based approach* for IE in initial teacher education that is founded on three fundamental principles. Firstly, teachers should consider diversity among students as a natural aspect of human development. By acknowledging that students have different backgrounds, experiences, and abilities, teachers can better comprehend varying needs and customize their teaching methods accordingly. Secondly, teachers should perceive difficulties in learning as challenges in teaching, not issues with the student. This means that teachers should reflect on their pedagogical approaches and find ways to support the student's learning rather than attributing it to their lack of effort or ability. Finally, teachers should actively seek support to cater to individual needs without isolating students or limiting their access to opportunities available to others. By collaborating with other professionals and colleagues, teachers can provide quality education to all students. This approach necessitates teachers to be reflective and collaborative while respecting and valuing diversity among their students. The value-based approach constitutes a foundational component of IE in initial teacher education, as it imparts a fundamental mindset that may inspire and inform action intention and behaviors (Ajzen, 1991). Consequently, it is imperative to incorporate these fundamental principles in teacher education programs.

However, to effectively influence the behavioral level, PTs must also acquire practical skills (see Chapter 3.3). They must be equipped with knowledge about diverse strategies and methodological-didactic approaches that are available to facilitate inclusive teaching in their respective subjects. By providing practical skills for planning IE, all students would benefit. Research has shown that "what is good for pupils with special education needs is good for all pupils" (European Agency for Development in Special Needs Education, 2003, p. 4). To bolster this claim, Florian (2021) underscores how certain practices intended to benefit a particular group can yield unforeseen advantages for other groups as well. As a result, by implementing those strategies and practices in initial teacher education, PTs may experience an increased sense of preparedness and competence in delivering IE (see Section 3.3). Additionally, PTs would recognize that implementing inclusive practices does not represent an additional burden, but rather a modification of their planning and teaching approach. This could contribute to increased acceptance and thus probability of implementation. The evidence-based nature of these strategies would also ensure a high-quality education (Bain et al., 2009). Hence, we now present selected evidence-based practices that have demonstrated their efficacy in the domain of ISE which may be included in initial science teacher education.

Table 1 presents selected evidence-based approaches for promoting ISE in class. A comprehensive overview of the research reveals a vast knowledge base in this field, and many effective approaches that can be seamlessly integrated into school teaching without relying on add-on strategies. Some of these approaches, such as mnemonic strategies and scaffolds for inquiry-based learning, have undergone extensive research, particularly in the context of students with learning difficulties. However, all students can benefit from these approaches. Other approaches, such as UDL or KinU, prioritize the needs of all students, and teaching is planned accordingly.

It is important to note that the evidence-based approaches presented in the table are not exhaustive, and other aspects, such as promoting engagement in science education, also deserve attention (Hadzigeorgiou and Schulz, 2019). Additionally, effective implementation of these approaches requires a skilled and reflective teacher who acknowledges the diversity of students, identifies barriers in the learning environment, and promotes participation for all students (Stinken-Rösner et al., 2020; Louis and King, 2022). When selecting approaches, teachers should consider individual lesson planning and design. Overall, the presented approaches are intended to provide inspiration and ideas for educators and teachers seeking to deepen their knowledge of ISE.

4.2. Collaboration

Collaboration has been identified as a crucial element within the realm of IE. The notion of collaboration being "the heart of inclusive education" has been posited by Florian (2017), referencing the work of Outi Kyrö-Ämmälä and Suvi Lakkala. Moreover, the significance of collaboration in initial teacher education has been emphasized within the European Agency *Profile of Inclusive Teachers* project. Working with others is regarded as one of the core values. Corresponding areas of competence underscore the importance of collaboration and teamwork, including working with parents and families and engaging with various educational professionals. As such, fostering collaboration skills during initial teacher education programs is essential in cultivating inclusive practices and beliefs in schools.

TABLE 1 Evidence-based approaches in inclusive science education (ISE).

Evidence-based approach	Description
Big ideas	Identification of major concepts that science teachers want students to understand by the end of a unit (Hand et al., 2009; Watt et al., 2013)
Formative Assessment	Method to gain insight into students' conceptions by planned or interactive assessment to improve their learning processes (Black and William, 1998; Cowie and Bell, 1999; Therrien et al., 2011)
Graphic Organizers	Adapted visual aids designed to assist students in organizing information based on the specific content (Ellis and Howard, 2007)
Inquiry-Based Learning	Inquiry-based learning at different levels of openness, supported by scaffolds, feedbacks, instructions, science writing heuristics, and structured procedures (Keys et al., 1999; Therrien et al., 2011; Villanueva and Hand, 2011; Villanueva et al., 2012; Watt et al., 2013; Kranz et al., 2022)
Framework for Inclusive Science Education (KinU)	Strategies for incorporating inclusive practices in established ways of thinking and working in science education, using categories as a scaffold for planning (Brauns and Abels, 2021)
Mnemonic Strategies	Techniques used to support memory by capitalizing on natural memory processes such as visual imagery, organization, and elaborative encoding, and include strategies ranging from simple acronyms to complex methods for remembering numbers (Putnam, 2015; Lubin and Polloway, 2016)
Multimodal Presentations	Use of multiple modes of representation, such as graphs, equations, models, tables, and diagrams, to assist students in comprehending and retaining significant scientific concepts (Scruggs et al., 2007; Taylor and Villanueva, 2014)
Peer-Assisted Learning	Promoting student interaction, collaboration, and support through implementing smaller group scenarios with opportunities for exchange (Jimenez et al., 2012)
Scientific Concepts and Language	Providing multiple means of representation for the foundational concepts and vocabulary and prioritizing language and vocabulary in the planning and implementation of lessons (Norris and Phillips, 2003; Jitendra et al., 2004; Buxton et al., 2019)
Universal Design for Learning (UDL)	Framework involving usage of multiple ways to represent information, flexible engagement options, and varied ways for students to demonstrate learning with the aim of increased motivation, participation and accessibility (CAST, 2011, Schreffler et al., 2019)
Use of Technology	Digital tools as additional or alternative approach to address typical ways of thinking and working in science education (Stinken-Rösner and Abels, 2021, Fränkel and Schroeder, 2023, Stinken-Rösner et al., 2023)

Collaborating between PSTs and prospective special education teachers to co-plan lessons can result in synergistic integration of their respective areas of expertise. According to a study by Kahn et al. (2018), PTs often prefer inclusive teaching methods, and working alongside prospective special education teachers can significantly enhance the comfort level of PSTs in co-planning and co-teaching (also Friend et al., 2010; Wang and Fitch, 2010). Moreover, this collaboration can also help prospective special education teachers to broaden their understanding and proficiency in the field of science education. PSTs are well-versed in, for example scientific concepts and inquiry-based teaching, whereas prospective special education teachers specialize in diagnostics and implementing effective interventions for individual students. By pooling their respective areas of expertise, they can collaboratively design a lesson that caters to the needs of all students in an accessible and inclusive manner (Schildknecht et al., 2022).

Therefore, the *autonomy-interdependence principle* (Morgenroth, 2015) is considered superior to the *autonomy-parity pattern* (Lortie, 1975) as it values cooperation and interaction while simultaneously promoting the autonomy of individual professional groups. This principle is especially relevant in the inclusive school context where various professionals, including subject teachers, special education teachers, and social workers, work together to address the diverse needs of students. Successful implementation of the *autonomy-interdependence principle* promotes optimal support for students in class, whereas the *autonomy-parity pattern* can result in isolated work and insufficient support. Thus, adopting the *autonomy-interdependence principle* can lead to a collaborative and effective approach to IE, which can benefit all students.

Delorey et al. (2020) found that practicum and collaboration experiences were the most important factors in developing inclusive beliefs in PTs, followed by work and personal experience, and then education. The findings suggest that both professional and personal experiences are critical to the development of teachers' beliefs, and that teacher education programs play an essential role in this process.

However, the potential of collaboration in teacher education and practice is presently underutilized, as a vast corpus of research on prospective and in-service teacher cooperation practices indicates. For example, a metasynthesis of qualitative research conducted by Scruggs et al. (2007) demonstrate that the most common co-teaching approach observed was "one teach, one assist," in which one teacher designs the lesson and the other provides individual support. The special education teacher was frequently viewed as playing a secondary role, and the recommended strategies, such as peer mediation, strategy instruction, mnemonics, and training in study skills, self-advocacy skills, and self-monitoring, were seldom observed. Swanson and Bianchini (2015) conducted a qualitative study on the co-planning process of high school science and special education teachers collaborating to create inquiry-based science units. The study finds a lack of parity among the teachers in discussing science and special education topics, and differences in resource-sharing and group roles may contribute to this differential discussion. In conclusion, by promoting collaborative practices between special education PSTs and regular teachers, we can reduce the risk of children with special needs being taught separately and increase their inclusion in mainstream classrooms, creating a more equitable learning environment (Pancsofar and Petroff, 2016).

With regards to PT education, it is imperative to find ways to integrate such courses in university curricula since collaboration is hardly part of initial teacher education (Allday et al., 2013). When collaboration is integrated, the focus is often on the collaboration between subject and special education PTs (Fränkel et al., 2020; Link et al., 2022), without addressing the specific knowledge and expertise of PSTs. There are only a few initial projects that promote collaboration between prospective science and special education teachers in initial teacher education (for an overview, see Section 4.3).

Fränkel et al. (2020) developed a university course for primary science and special education PTs, in which the two groups worked together to plan and teach lessons in an inclusive school during a one-semester internship, having been prepared in advance in a joint course. The lecturers of the course were also from the two different professions and co-taught the course. The project evaluation found that PTs had a positive attitude toward collaboration, and that the joint practice phase expanded their professional vision (Lammerding et al., in press). They also found the co-planning and co-teaching of lessons to be conducive to the PTs as well as the lecturers' professional development due to co-constructive practices. However, challenges of the pilot project included the inability to embed a double staffing model within university structures. As an implication, universities should seek ways to integrate collaborative courses into the existing university structure or develop curricula further toward inclusion by breaking down the discipline structure (Pugach and Blanton, 2009). Promoting collaboration within the same discipline can also be beneficial for PTs' professional and personal development. For instance, during practical phases like internships or teaching placements, PTs can work collaboratively toward shared goals, provide constructive feedback and support to each other, and learn from their peers in a supportive environment.

The studies demonstrate that collaboration is a crucial aspect of teachers' professional development that should be incorporated into initial science teacher education programs. By learning co-teaching practices, exploring roles and responsibilities, and addressing unequal power dynamics, PTs can better prepare for inclusive classroom settings. One way to achieve this is by creating opportunities for PTs to collaborate across disciplines, such as through structured school internships, which provide a platform for co-planning and co-teaching. Moreover, teacher education programs should emphasize the importance of equal partnership and mutual respect between subject and special education PTs. By doing this, teacher education programs can help address hierarchies between professions by encouraging collaboration and shared responsibility.

The promotion of collaboration for inclusion on a more global level requires the overcoming of individualistic ideals. This includes the facilitation of working together at all levels, including PTs and lecturers, through sharing resources, generating innovative ideas, and undertaking inclusive initiatives collectively (e.g. through networks). Additionally, it is imperative that lecturers collaborate interdisciplinary and establish opportunities for PTs to acquire cooperative skills (Chitiyo, 2017). Universities must take responsibility for promoting collaboration at all levels, as opposed to solely expecting it from PTs. Lastly, this includes collaborative behaviors among lecturers as a catalyst for change.

4.3. Good-practice projects and knowledge transfer

As demonstrated in previous chapters, there exists a wealth of knowledge that can contribute to successful initial teacher education in the field of ISE. However, despite the availability of such resources, the transfer of existing knowledge into university courses remains a challenge (Egger et al., 2020). The transfer of knowledge in teacher education is hindered by various factors such as university lecturers' insufficient knowledge of IE, a missing practical orientation and the need for future-oriented curricula (refer to Section 3.2).

Rather than relying solely on general coursework, specific seminars provide a more comprehensive approach to exploring and reflecting on the content, ideally allowing for practical application as well (Entress, 2022). A structured and recursive approach to teacher education, alternating between coursework and field experiences, is necessary to promote practice-oriented learning opportunities that facilitate practical experience and reflective processes. By incorporating such opportunities, we can work toward a successful transfer of theories that are more closely aligned with classroom practice (Nilholm, 2020). While science teacher education programs may currently not follow systematic and consecutive concepts that encompass all these practices, Table 2 presents singular courses that address or implement effective practices to prepare PST for IE. These courses serve as good practices that could be used as a starting point toward broader implementation.

The presented projects and courses display various opportunities of how to implement practices for inclusion-orientated science education into science teacher education. At this point, it should be noted that many of the presented projects refer to Germany, as the authors are based in this country and in general, university course concepts are probably often published nationally rather than internationally. Therefore, it can be assumed that there are many more projects that have not been published internationally or at all. The presented projects are concerned with a lot of different topics including NOS, UDL, collaboration, subject-specific language, easily-accessible experiments or enabling cross-sectional, recurring learning opportunities over some years. The aim is to continue and to embed them into a coherent teacher education, where an appreciative attitude toward heterogeneity and non-separated understandings of inclusive and subject-related issues are crucial.

A potential strategy for further improving the quality of teacher education would be to implement evaluations that continuously monitor the development of PTs and use the results to revise and optimize university courses (Symeonidou, 2017). Currently, evaluations are primarily focused on isolated time points and are not used formatively to inform ongoing course improvements. Therefore, the practice of design-based research could be a valuable approach for conceptualizing and developing effective teacher education concepts, whereby iterative cycles of design and re-design are employed to optimize targeted courses (Mackey et al., 2023). Additionally, Salend's (2010) nine aspects of evaluating IE courses could serve as a theoretical framework for evaluating and improving ISE courses.

One effective approach to bridging the dissemination gap in science teacher education and integrating aspects of inclusive pedagogy is through the use of open educational resources (OER). OER refers to "learning, teaching and research materials in any format and medium (…) that permit no-cost access, re-use, re-purpose,

TABLE 2 Selected prospective science teacher education projects for inclusive science education (ISE).

Project/Country/Authors	Concept/Approach	Evaluation	Transfer
Chemie all-inclusive, Germany (Schwedler et al., 2022)	Course Concept: Collaboration/IBL	Qual/Quant	Weirauch and Schenk (2022)
Family science nights, USA (Dani and Harrison, 2021)	Informal Learning Environment: Cultural Competencies	Qual	n/a
GeLernt, Germany (Schildknecht et al., 2022)	Course Concept: Collaboration & UDL	Qual/Quant	OERs
Nawi-In, Germany (Abels et al., 2022)	Course Concept: IBL	Qual	OERs (Abels et al., n.d.)
NinU, Germany (Stinken-Rösner et al., 2020, Fühner et al., 2022)	Framework: Planning inclusive science lessons	Qual	OERs
n. a., Australia, Ollerhead (2020)	Course Concept: Multilingual science learning	Qual	n/a
n. a., Republic of Korea (Da Kang and Martin, 2018)	Informal Learning Environment: IBL	Qual	n/a
n. a., USA (Kahn et al., 2018)	Informal Learning Environment: Collaboration & UDL	Qual	n/a
n. a., USA, Librea-Carden et al. (2021)	Course Concept: NOS for SPED teachers	Qual	n/a

IBL, Inquiry Based Learning; UDL, Universal Design for Learning; OER, Open Education Resources; Qual, qualitative; Quan, quantitative; NOS, Nature of Science; SPED, Special Education Prospective Teacher.

adaptation and redistribution by others" (UNESCO, 2019). To promote a culture of sharing among educators and researchers in the field of ISE and facilitate the transfer of knowledge into course practices, barriers in OER infrastructures need to be reduced (Baas and Schuwer, 2020). Sharing, evaluating, and adapting learning resources among educators globally can even support lecturers who lack specific knowledge in ISE practices. Some examples of OER are already available (Hawkins and Tualaulelei, 2020; also see *transfer* in Table 2).

5. Discussion

Currently, we are still far from having a conceptually grounded and successful initial science teacher education toward inclusion. PSTs often feel lost and receive impractical recommendations that contradicts a broad understanding of inclusion. We argued that an adequate approach to initial science teacher education must be based on inclusive values that have to be conveyed as a basis (Norwich, 2022), and we drew on the *value-based approach* of Florian (2021) here. We identified barriers and boosters toward inclusion in initial science teacher education. Our review has identified the following significant barriers that hinder its implementation:

1. In initial science teacher education, the *add-on approach* dominates, which can lead to unfavorable attitudes and is only partially meaningful in light of a broad understanding of inclusion.
2. Separate teacher education tracks for science and special education PTs hinder the fusion of subject-specific content with inclusive content.
3. The previous barriers lead to PTs, but also university lecturers, not feeling adequately prepared for the topic and its school or scholarly integration.

Drawing on our analysis of the current state of initial science teacher education and the significant barriers we have identified, we strongly advocate for the integration of the following "boosters" into science teacher education programs at universities. These critical elements have the potential not only to overcome the identified barriers but also to equip PSTs with necessary skills and knowledge to confidently deliver effective ISE:

1. Impart evidence-based approaches for successful ISE that strengthen PTs self-efficacy.
2. Collaboration between science and special education PTs and educators.
3. Knowledge transfer of good, evaluated practice projects.

We acknowledge that providing a recipe for success is neither sensible nor possible. Evidence-based practices cannot fully address the unique needs of individual students. However, we argue that it is crucial to equip PSTs with evidence-based strategies to increase their sense of self-efficacy and enable them to take action (Bain et al., 2009; Savolainen et al., 2012; Yada et al., 2021; Woodcock et al., 2023). Initial science teacher education cannot prepare PSTs for every practical scenario, but it can provide a foundation that includes inclusive values and beliefs, reflective competence, and practical knowledge (Abels, 2011; Saylor and Johnson, 2014; Körkkö et al., 2016; Fränkel et al., 2022). Practical experiences during PST education cannot replace in-service science teacher practice, but they can offer opportunities for reflection on inclusive goals and requirements, paving the way for further professionalization (Øen et al., 2023). We must encourage PSTs to believe that ISE is achievable and not merely an add-on. They must be willing to advocate for inclusive values in their future schools and understand inclusive thinking and action as an ongoing process. It is essential to motivate PSTs to take the first steps and provide supportive practices without creating unrealistic expectations that may not be met due to suboptimal conditions in the school system (Forlin, 2010). Providing PSTs with clear, compelling, and convincing evidence of the benefits of IE is essential to reinforce these changes in beliefs (Posner and Strike, 1992; Gregoire, 2003).

In the coming years, there will be an increasing need to develop, evaluate, and disseminate ideas, courses, and resources that support initial science teacher education for inclusion. By building upon the foundational concepts of ISE and the proposed solutions presented in this paper, educators can design university courses that have a significant impact on PSTs. There is a substantial body of content that can be effectively taught in the context of science teacher education for inclusion, as our literature review has demonstrated. However, the identification of subject-specific foundational competencies and specific content that PTs should acquire remains an outstanding issue. Moreover, there is a dearth of information on how such competencies and content have been defined and differentiated subject-wise at various higher education institutions. Therefore, a scholarly discourse on this topic has the potential to yield valuable insights. Furthermore, as the field of education continues to evolve, it is essential to stay current with the changing needs of society, such as incorporating digital tools and AI into school practice (Walther et al., 2022). Creating effective courses that promote inclusive practices and values is crucial to ensuring that PTs have the necessary skills and knowledge to provide quality education to all students. We hereby should lead by example in demonstrating the teaching practices that we expect from our PTs, such as collaboration, active engagement, and scaffolding techniques. This aspect reaches the dimension of higher education didactics, which is often overlooked in studies or interventions and therefore deserves greater attention. Evaluating these courses will help determine their effectiveness and identify areas for improvement, allowing educators to reflect on their content and methods and make necessary changes to improve their impact. Furthermore, disseminating these courses to other universities will facilitate the widespread adoption of inclusive practices and contribute to creating a more inclusive educational system as a whole.

The urgent need to promote IE in science teaching demands action from academia, requiring lecturers to prioritize inclusion in their teaching agenda. It is not productive to merely scratch the surface and rebrand special education content as inclusive without addressing the underlying structural issues. We need individuals who are truly committed to tackling this issue and making a meaningful contribution as well as a more connected research community (Comarú et al., 2021). We also need to address the issue that PT educators have not received sufficient training to teach inclusion in subject didactics. A connected and committed community can contribute to disseminating the relevant knowledge and concepts. The vision of this paper is to inspire and motivate university educators to embark on this journey, and to work collaboratively to achieve improvement. We believe that it is only through collective efforts and shared resources that we can bring about the desired change. By adapting science teacher education for inclusion, we can equip teachers like Sarah with the necessary knowledge, skills, and confidence to create lessons that are accessible to all students. This will not only benefit students with additional needs but also enhance the learning experience for all. If we take steps toward an initial science teacher education for inclusion, Sarah's story could have an alternative ending:

> *The novel science teacher Sarah faces several challenges in her science class, but she is confident in her ability to handle the situation. Despite the different learning styles and needs of her students, Sarah is adept at creating lessons that are accessible to all students. For example, some students struggle with abstract concepts, while others need hands-on activities to grasp the content, but Sarah is able to adapt her teaching to cater to their needs. Sarah is aware that some of her students have additional needs, and she is well-equipped to support them through evidence-based practices. She also collaborates with the special education teacher and they share their expertise to create an accessible learning environment for all students. She provides the necessary adjustments and changes that enhance students learning, and she is constantly improving her knowledge and skills in IE. Sarah is not overwhelmed with the challenges of teaching, as she sees it as an opportunity to grow and develop as a teacher, since inclusion is a process.*

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