Barriers to Effective Science Education: A Standpoint from Educational Policies

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Abstract: Promoting scientific literacy and critical thinking among students through effective science education is essential. However, various barriers, including systemic issues in educational policies, inadequate educational resources, insufficient teacher professional training and lack of student-centred engagement in class activities, impede the effectiveness of science teaching and learning. This paper explores various approaches to address these challenges, emphasizing on addressing the systemic issues in educational policies, enhancing availability of educational resources, improving teacher professional development and increasing student-centred engagement in classroom activities. By adopting these strategies, educators can enhance the standards of science education by equipping students to tackle the demands of the 21st century.

Keywords: *Barriers; Classroom; Inclusive Education; Professional Development; Prospective Science Teachers; Science Education; Special Education; Student-Centred.*

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I. INTRODUCTION

Effective science teaching and learning are important for developing cognitive thinking, inquiry-based learning and collaborative skills among students. However, numerous barriers impede the effectiveness of science education. These barriers include systemic issues in educational policies, inadequate educational resources, insufficient teacher professional training and lack of student-centred engagement in class activities (Soysal & Radmard, 2022). Addressing these barriers requires multifaceted approach that includes curriculum reform, teacher support and innovative pedagogical strategies.

II. BARRIERS TO EFFECTIVE SCIENCE TEACHING AND LEARNING

A. Systemic Issues in Educational Policies

Systemic issues in educational policies refer to deep-rooted, widespread problems that affect the entire education system.

- *Gaps in Early Science Teacher Training for Inclusive Education*

Early science teacher education programs face numerous challenges, such as the prevalence of Add-on methodology, Isolated teacher training pathways, and Inadequate preparedness of science teachers collectively contribute to a decline in self-efficacy regarding inclusive education (Fränkel et al., 2023). Science education encompasses more than merely acquiring knowledge of science; it necessitates a distinct mode of cognition and operation, which imposes significant challenges on educators and learners (Fränkel et al., 2023). Prospective Science Teachers (PSTs) encounter the difficulty of harmonizing divergent and opposing views on inclusion, student diversity, and academic performance. This underscores the necessity for a coherent and high-standard science teacher training that offers explicit direction and support for inclusive education (IE) (Fränkel et al., 2023). In the absence of adequate professional development, teachers may unintentionally reinforce existing inequalities and restrict students' chances for success (Jordan et al., 2010; Jordan & Stanovich, 2003). The beliefs and practices of teachers either hinder or support students in achieving targeted academic goals (Fränkel et al., 2023). According to Forlin et al. (2009) and Sosu et al. (2010), early teacher education programs can

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facilitate the development of attitudes necessary for inclusive education.

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).

According to Stinken-Rösner et al. (2020), attaining inclusion in science education (ISE) necessitates the integration of inclusion pedagogies in science teacher trainings. This would demand on PSTs to acquire the essential knowledge and hands-on skills to merge pedagogies of inclusion with science-specific content (Fränkel et al., 2023).

- *Add-On Method and Mastering of Specific-Subject*

Early teacher education programs at the tertiary institutions need to prepare prospective teachers (PTs) with the knowledge to modify their specific subject teaching methods to cater for diverse student groups (Fränkel et al., 2023). The add-on method for IE involves integrating aid for students who need special care within general classrooms settings. This method includes supplementing existing teaching practices with special services tailored to the needs of individual students, without significantly altering the core teaching methods.

The add-on method not only conflicts with the comprehensive concept of inclusion but also poses challenges for subject teachers. These teachers, who often have limited teaching hours across multiple classes, may not have the necessary resources to evaluate individual student learning needs in order to adjust their content and methods accordingly (Fränkel et al., 2023). Therefore, inclusive subject education should emphasize teaching and learning subject-specific concepts and practices in a manner that is accessible and meaningful to all students, rather than concentrating solely on individual students with special needs (Florian, 2021 as cited in Fränkel et al., 2023). Fränkel et al. (2023) noted that PSTs encounter difficulties in applying inclusive education strategies to their specific subjects. This is because most existing approaches are derived from special education and do not sufficiently address the unique requirements of specific subjects.

- *Isolated Education Pathways of Prospective Teachers for Science Education and Special Education*

In teacher education programs, there are often specialized courses designed for those aiming to advance their study in special fields like special education (Fränkel et al., 2023). According to Winn and Blanton (2017), this method supports the idea that distinct teacher training courses are required for various student categories, leading to a fragmented approach to diversity. According to Florian and Rouse (2009), fragmented teacher education approaches can result in subject teachers believing they were not trained to handle students with special needs, while teachers for special education feel in charge for educating students with special educational. This division can leave teachers feeling ill-equipped to handle a diverse student body (Young, 2008). The report of UNESCO International Conference on Education titled Inclusive Education: The Way of the Future (2009) as cited in Fränkel et al. (2023) endorses the view that isolated teacher training courses for subject teachers and special education teachers are ineffective.

Stayton and McCollum (2002) identified three models for inclusion-oriented teacher training programs. The Infusion Model; incorporates inclusion-linked topics to specific subject teacher training programs (e.g., science) without altering the fundamental separation between training for the specific subject and special education. The Collaborative Model; provides combined training on inclusion for PTs for specific subjects with limited content of interest in special education. The Unification Model; removes the distinction between programs for specific subject and special education, integrating inclusion-related content as a core part of a unified curriculum for all prospective teachers (Fränkel et al., 2023). Many researchers contend that effective preparation for IE in schools can only be accomplished through interdisciplinary and well-developed curricula, as exemplified by the Collaborative Training Model and the Unification Model (Pugach et al., 2020).

- *Inadequate Preparedness of Teachers for Inclusion*

Fränkel et al. (2023) cited that the insufficient quality of education in ISE has a significant impact for PSTs, who are tasked with teaching in inclusive classrooms without proper preparation. As a result, due to their inadequate training, they feel unprepared for ISE (Cretu & Morandau, 2020). Science educators acknowledge the importance of natural sciences in fostering students' literacy (Villanueva & Hand, 2011). Nevertheless, research indicates that many science teachers struggle with insufficient support and guidance in selecting effective pedagogical approaches, methodologies, and technological tools to effectively cater for their students' diversity (Mutch-Jones et al., 2012; Spektor-Levy & Yifrach, 2019). Consequently, they face difficulties in designing inclusive lessons (Egger & Abels, 2022). Additionally, making mental concepts comprehensible to all learners (Buxton et al., 2019) and maintaining their interest in science remain

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significant challenges (Potvin & Hasni, 2014 as cited in Fränkel et al., 2023).

B. Inadequate Educational Resources

A significant challenge in executing a more student-centred pedagogy is lack of adequate educational resources. This obstacle encompasses infrastructural shortcomings such as limited classroom space for hands-on experiments, insufficient science laboratories, and a shortage of technological devices and instructional materials and software (Soysal & Radmard, 2022). Additionally, the scarcity of educational resources forces educators to exert greater effort and time to implement student-centred teaching. From the viewpoint of expectancy-value theory, the inadequacy of resources necessitates that educators weigh the decision of whether to pursue more learner-centred activities or not (Soysal & Radmard, 2022). Many schools lack the necessary resources, such as laboratory equipment and up-to-date textbooks, to effectively teach science (Hayes, 2017). Insufficient laboratory equipment and teaching and learning materials hinder practical learning experience, which is central for understanding scientific concepts (Hurd, 2000).

C. Insufficient Teacher Professional Training

A significant challenge for many teachers is subject matter knowledge, action system knowledge, skills in behaviour modification and classroom management. Furthermore, the incorporation of inclusive pedagogies in teaching and learning strategies, reflective practice, the development of teaching portfolios, and action research have been largely absent in the teaching profession. This absence has negatively impacted teachers' professional growth, leading to lower student achievement of educational goals. Continuous Professional Development (CPD) involves an ongoing enhancement of best practices in the management of professional knowledge, practice, and values. It also encompasses the transformation of both human and material resources within the school as an organization. Teachers often lack sufficient CPD opportunities to stay updated with current scientific knowledge and pedagogical techniques (Garet et al., 2001). The lack of adequate teacher training in inquiry-based and other modern pedagogical approaches such as Technology Integrated Learning especially in deprived rural areas is a challenge to comprehensive scientific literacy (Fitzgerald et al., 2019).

D. Lack of Student-Centred Engagement in Class Activities

Osborne et al. (2003) reported that science subjects are frequently viewed as challenging and unexciting, which results in reduced student motivation and involvement. Soysal and Radmard (2022) found that the main reason students did not actively participate in class activities was their preference for direct lecturing. The students viewed themselves as consumers of knowledge. Teachers in the study noted that students favoured rote learning, where teachers repeatedly convey knowledge to learners. This barrier can lead to classroom management issues when mutual respect is lacking. It relates to students' existing beliefs about learning. Prior to 21st-century reform initiatives, students were engaged in instructional processes where they passively received dictated knowledge. The reforms, however, required teachers to inspire students to take responsibility for their learning by active participation in classroom learning discussions, asking questions and evaluating ideas. These new roles demand more cognitive effort from students, but teachers reported that students were not fully prepared to act as active producers of knowledge (Soysal & Radmard, 2022).

III. POTENTIAL SOLUTIONS AND STRATEGIES

A. Addressing Systemic Issues in Educational Policies

Providing strategic solutions to the systemic problems have the potential of revamping the education system. Advocating for curriculum reforms that prioritize student-centred engagement in critical thinking and problemsolving over rote memorization can create a more conducive environment for science learning. The curriculum should prioritize the inclusion of learners' perspectives in classroom discussions (Soysal & Radmard, 2022). It is essential to consider students' existing knowledge and emotions (Soysal & Radmard, 2022).

➢ *Improving Early Science Teacher Training for Inclusive Education*

Fränkel et al. (2023) reported that it is evident that significant reforms are necessary in early teacher training to properly equip PTs for ISE. The following sections will explore three approaches to address this need. Firstly, it is essential to provide more cohesive and effective teacher education, ensuring PSTs are well-prepared to address the diverse needs of all students. One way to address the issue of specialist knowledge is by encouraging interdisciplinary collaboration. Additionally, sharing projects and resources focused on inclusive science teacher education could be another effective strategy for teacher training.

➢ *Basic Principles and Evidence-Driven Approaches*

To establish a basic foundation, Florian (2021) as cited in Fränkel et al. (2023) introduces an approach focused on core values and beliefs to IE in early teacher training, which is built upon three core principles. Firstly, educators should view student diversity as an inherent part of human development. Recognizing that students come from varied backgrounds, possess different experiences, and have unique abilities allows teachers to better understand their diverse needs and tailor their instructional strategies accordingly. Secondly, educators should view learning difficulties as challenges in their teaching methods rather than problems with the students themselves. This perspective encourages teachers to reflect on and adapt their instructional strategies to better support student education, instead of attributing the difficulties to lack of effort on the part of the students. Lastly, educators should

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proactively seek assistance to address the needs of individuals students without restricting their access to the same chances as their peers. Working together with other educational stakeholders can ensure teachers provide to all students a high standard of education. This method requires teachers to be reflective and collaborative. According to Ajzen (1991), this approach is essential as it inspire and guide actions and behaviours. Therefore, it is crucial to integrate these basic principles into early teacher education.

Prospective teachers must also develop practical skills. They need to be knowledgeable about various strategies and pedagogical approaches that can support inclusiveness within their subjects. Equipping them with these practical skills for planning inclusive education ensures equity for all students. Research findings indicates that what is beneficial for students with special needs is beneficial for all students (Fränkel et al., 2023).

- *Collaboration*

Fränkel et al. (2023) considered collaboration as a fundamental value. He explained that relevant competencies highlight the significance of teamwork and cooperation, including partnering with guardians and educational professionals. Therefore, developing collaborations during early teacher education trainings is crucial for promoting inclusiveness. Fränkel et al. (2023) continued that collaboration is recognized as a vital component of inclusive education. When prospective science and special education teachers work together to co-design lessons, they can effectively combine their expertise. Additionally, this partnership can enhance the knowledge of special education teachers in science education and vice versa. Thus, fostering collaboration can minimize the likelihood of special needy students being educated separately. According to Pancsofar and Petroff (2016), this approach promotes their integration into regular classrooms, fostering a more fair and inclusive learning environment.

- *Best Practices in Projects and Knowledge Sharing*

A well-organized and iterative approach towards teacher education, which alternates between academic work and practical field experiences is essential for fostering hands-on learning opportunities and encourage reflective practices. While hands-on experiences during PST education cannot substitute for the hands-on practice gained by in-service science teachers, they do provide valuable chances for reflecting on inclusiveness, thereby facilitating further professional development (Fränkel et al., 2023). A viable approach to enhancing the quality of teacher education involves implementing continuous evaluations to access the progress of PTs and utilizing the findings to study and improve courses in teacher education institutions (Symeonidou, 2017).

B. Enhancing Availability of Educational Resources

Government and Private Sector Investment: Increased funding from government and private sectors can ensure schools are equipped with necessary laboratory tools and materials (National Research Council, 2006).

Collaborations with local businesses and universities can provide additional resources and expertise (Hurd, 2000). Schools should seek partnerships with resourced business firms and community organizations to secure funding and resources for science education (Hayes, 2017).

C. Improving Teacher Professional Development Training

Regular, comprehensive professional development (PD) programs can help teachers stay current with scientific advancements and effective teaching strategies (Garet et al., 2001). Establishing mentorship programs and promoting Professional Learning Community (PLC) collaborations can enhance teachers' instructional skills and confidence (Darling-Hammond et al., 2017). Providing ongoing professional development opportunities focused on inquiry-based learning and other effective teaching strategies can empower teachers to improve their practice (Fitzgerald et al., 2019).

The purpose of CPD activities is to offer teachers guidance to continually enhance their competencies, thereby upholding the integrity of the teaching profession and elevating their professional status. Engaging in accredited CPD programs is expected to help sustain and improve the knowledge, skills, attitudes, and experiences acquired during initial training. It is crucial for teachers, as professionals, to maintain their professional integrity by regularly updating their knowledge and skills to stay current with contemporary issues and educational approaches.

D. Increasing Student-Centred Engagement in Class Activities

Implementing inquiry-based learning approaches can make science more interactive and engaging, fostering curiosity and deeper understanding (Hmelo-Silver et al., 2007). Integrating technology, such as simulations and virtual labs, can make science learning more dynamic and accessible (Hennessy et al., 2005). Soysal and Radmard (2022) suggested that the proposed teaching approach should emphasize dialogic instruction, where both educators and students are given opportunities and responsibilities to contribute intellectually to classroom discussions. This approach suggests that educational planning and design should highlight both the Piagetian cognitive psychology and Vygotskian sociocultural psychology (Koc et al., 2007 as cited in Soysal & Radmard, 2022). This aligns with a viewpoint that supports the participatory co-construction of information through learner-centred teaching methods, including inquiry-based learning, collaborative learning and project-based learning (Soysal & Radmard, 2022).

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IV. CONCLUSION

Overcoming barriers to effective science teaching and learning requires a multifaceted approach, involving addressing the systemic issues in educational policies, enhancing availability of educational resources, improving teacher professional development trainings and increasing student-centred engagement in class activities. By adopting these strategies, quality science education can be achieved, enabling students to fit well in the 21st century.

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