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Inclusive Instructional Practices in STEM Education: From Theory to Design

Haiyu Zhao

Shuangliu Institute of Education Science Affiliated School, Chengdu, China
sd373054@gmail.com

Abstract. This study provides an organized review of inclusive instructional practices in STEM education, from theoretical frameworks of Universal Design for Learning (UDL) and Differentiated Instruction (DI) to the design of practices. This review finds literature published from 2010 to 2025 and integrates the two frameworks that try to build an equitable, accessible, and flexible learning environment. Findings suggest that UDL focuses on the design of curriculum, removing learning barriers. While DI emphasizes that educators should tailor content, process, and assessments of each individual learner. Evidence indicates that inclusive instructional practices improve students' confidence, engagement, and academic performance, especially for students with diversity in STEM education. However, lots of barriers exist in implementation, like limited time, teacher preparation, lacking resource, and inadequate support from related institutions. All these reasons cause the gaps between theoretical designs and classroom realities. After integrating recent research, this review underlines the significance of inclusive instructional design with structural alignment and enough support. And the need for more empirically grounded research to improve the equity of STEM education.

Keywords: STEM, Inclusive instructional practices, Inclusive education, Differentiated instruction, Universal design for learning

1. Introduction

Inclusive practices are designed to develop a more supportive and acceptable learning environment through accommodating students with different learning styles, backgrounds, and abilities. Recent researches have suggested that inclusive practices actually could enhance significant skills and meet the diverse learning needs in STEM disciplines [1,2].

Nowadays, lots of complicated global problems still threaten our life like climate change, sustainable resources, and health. The solutions should be creative and cross-disciplinary, which requires the STEM workforce to be better equipped with diversity to provide a wide range of perspectives. Therefore, STEM education has to be inclusive for every individual.

However, the underrepresentation of women and minorities in STEM fields stifles this goal [3]. Women and underrepresented minorities are less likely to have a sense of belonging in STEM fields, partly driven by narrow stereotypes about who can be a scientist, alongside the low representation of certain groups in STEM fields [3]. Meanwhile, their engagement in STEM activities is often

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challenging. The perception of the accessibility of the STEM fields shapes the socioeconomic status, ethnic background, and gender [2]. Therefore, it is pretty important that every student feels a sense of belonging in STEM, although they do not choose to work in STEM fields.

It has been proven that diversity could improve group performance [4]. As a result, there is a need to build a learning atmosphere with shared group identity and psychological safety by applying inclusive instructional practices. The educators experience lots of difficulties in selecting the suitable strategies to plan the lesson with diverse students. The inclusion instructional strategies are significant towards attaining success in a diverse classroom. Along this line, this paper primarily focuses on three sections, which include theoretical bases of inclusive instructional practices, design of inclusive instructional practices, and implementation barriers.

2. Research methodology

2.1. Research method

The method used in this research is the literature review method. It aims to explore and incorporate any existing scholarship related to the inclusion of STEM disciplines instruction. It is more attentive towards the design and implementation of inclusive education in STEM classes. Rather than gathering the latest empirical evidence, it tries to build a comprehensive and methodical knowledge in this domain in terms of the integration of theoretical and empirical studies.

2.2. Data sources

The literature review has been based on searching such prominent international and Chinese academic databases as Google Scholar, Web of Science, Scopus and ERIC. The corpus includes peer-reviewed journal articles, conference papers, doctoral and master's theses, and relevant policy documents published between 2010 and 2025.1. Search terms were combined using Boolean logic and included the following keywords and their variations: 'inclusive education,' 'inclusive pedagogy,' 'STEM education,' 'inclusive instructional practices,' 'teaching implementation,' and 'inclusive teaching practices'.

3. Theory and design of inclusive instructional practices

Superdiversity is the major character of the twenty-first century, from cultural, religious, ethnic, educational background, socio-economic, to linguistic diversification [5]. With the growing diversity of the student population in most countries, nowadays, classes with mixed learners demand that the teachers re-examine their teaching practice to ensure they offer equal learning opportunities to all learners [6]. As such, current policies of education across the globe are demanding inclusive classroom in order to accommodate all learners [5]. All of the 15 articles that we have reviewed collectively point to the Universal Design of Learning (UDL) and Differentiation Instruction (DI) as the key and efficient methods of resolving this problem [5]. Universal Design for Learning (UDL) is a teaching theory that focuses on the three principles of representation, expression and engagement and it is specifically aimed at helping teachers in designing lessons that are inclusive. On the other hand, the concept of Differentiated Instruction (DI) refers to the process of providing differentiated learning and assessment on the particular needs of every individual student [7].

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3.1. Universal Design for Learning (UDL) framework

UDL attempts to come up with a curriculum that will become more accessible to both non-disabled and disabled students by creating flexible learning settings, in order to solve the learner variability [8]. UDL is curriculum-based and not learner centered because it emphasizes that the curriculum ought to be designed in an active way that is flexible and participatory to all learners. Developing effective learners is the aim of UDL. Two core tenets of UDL are addressing learner diversity and reducing obstacles in curriculum and instruction by purposive and forward-thinking design [9]. The UDL framework has 3 basic guidelines to integrate flexibility into study, including Action, Representation, and Expression. Then they are divided into 9 guidelines and 31 checkpoints to help teachers identify specific ways for their lessons and make sure these elements help teachers enhance accessibility and engagement of every individual [10]. There are 3 important principles in the guideline of the Universal Design for learning(UDL) 2.0, containing offering different means of representation, action, and expression, as well as engagement to design inclusive and effective learning environments.

The first principle strengthens the significance of offering multiple means of representation. This means providing options with flexibility, like customizable exhibitions, alternatives of visual information and audio, clarified vocabulary to scaffold understanding, syntax, structure, symbols, texts' decoding, and notions of math. Meanwhile, it also focuses the illustration of ideas by using multiple media and supporting students to build comprehension within triggering knowledge of background, critical characteristics, finding patterns, and relationships, as well as the guidance of processing and generalizing information.

The second principle is action and expression, which emphasizing provide the varied expressions for them to demonstrate what students know. This includes providing options about action and response, guaranteeing access to technologies and tools, supporting expression and communication by different media, tools of construction, as well as enhancing efficient connection with graduated help for practice. Furthermore, guiding students set goals, scaffolding their planning and strategies, supporting students in managing information and resources, and enhancing the ability to monitor progress. All these things develop their executive functions.

The third principle mostly focuses on the various ways of engagements. These things are proposed to the teachers, and they make learning relevant and interesting by enhancing autonomy and option in the learners, ensuring that it is real, relevant and reduced unimportant diversions. To maintain the progression and continuation, the guidelines would ask about improved goals, varying levels of challenge, encourage teamwork and effective feedback which would cultivate mastery.

Lastly, the guidelines focus on self-regulation whereby they encourage positive beliefs and expectations, foster coping, and enable the students to acquire self-assessment and reflection skills. Collectively, these values are expected to create resourceful and knowledgeable, strategic and goal oriented, and purposeful and motivated learners.

3.2. Differentiated Instruction (DI)

Differentiation instruction is an instructional methodology, which is intended to suit efficiently the requirements of all students, by offering various students the most suitable pedagogy, objective of the curriculum, and opportunities of showing learned knowledge [11]. DI is concerned with providing the students with multiple access and consumption of information [12]. In an attempt to make instruction different, the teachers identify and define the differences between the students and use this information to design their lessons. Hence, DI is learner-centered, interest-oriented,

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question-based, and activity based, and a method which gives students many choices, options, and ways through what they learn, how they learn, and exhibit their understanding [13].

The following are the important indicators and sub-indicators that might be utilized to assess the effectiveness of Differentiated Instruction approach. Knowing the learners is fundamental in a way that teachers establish the requirements of students, the learning styles and interests, strengths and weaknesses each student has. In order to meet these needs, which are diverse, teachers employ several resources including textbooks, visuals, videos and online tools to support the different learning styles. Various types of assessment such as projects, exams, assignments and formative assessment are employed in determining the understanding the learners. In the meantime, teachers must make such considerations to adapt the teaching plan, speed up and slow down the teaching of inclusive instructions, change the nature of the difficulty, and use alternative teaching techniques to address various needs during teaching. Also, teachers give differentiated feedback to improve the understanding of the learners. Proper classroom management is upheld while using solutions which address diverse needs of learners. learners are also provided with more control to own their study by choosing their preferred topics or projects. Lastly, educators collaborate with students, parents and fellow teachers in addressing the various learning needs within parents having constant news of the progress and development of the students.

3.3. The UDL Design Cycle

To create more significant inclusive practices, teachers would take into account the UDL guidelines as a significant component of the instructional design process, the one labeled UDL Design Cycle [8]. It has 6steps with the first step being the consideration of learner variability including the abilities, preferences, support needs and background. The second stage is to come up with clear goals with the skills and knowledge required to master goals and possible barriers. The third is designing tests within taking into account the UDL principles to address variability. The fourth step is building flexible strategies and materials with consideration of UDL guidelines to solve variability. The fifth step is implementing a UDL-based lesson. The last step is about reflecting and revising.

Compared to existing processes of instructional design, the major contribution of the UDL Design Cycle is its focus on the first step of learner variability, and these factors are considered throughout each step of the design process, ensuring that flexibility and appropriate supports to minimize barriers and diverse needs. The next three steps create assessments and choose materials and methods according to the initial step of the goals. Detailed examples of applying the UDL Design Cycle into lesson design and planning are available in books like Designand Deliver: Planning and Teaching Using UDL and UDL for Language Learners [8]

3.4. Design of DI

To implement differentiated instruction, a collection of instructional approaches are employed, including multiple types of cooperative learning activities as well as compacting and enrichment techniques. Scaffolding learning opportunities are chosen in order to meet diverse learning needs in a classroom [6].

In essence, it is the teachers' responsibility to determine when to use various approaches in terms of the learning needs in the classroom. This situated method of differentiated instruction is a fundamental aspect. Therefore, teachers practicing differentiated instruction modify their teaching approaches in line with the specific learning needs of students [6]. Extended instruction, pre-

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teaching, and embedded instruction are the more straightforward teaching methods that educators apply to implement differentiated instruction. Extended instruction refers to offering students with clearly need additional teaching, in addition to the initial general instruction. Pre-teaching is a kind of instructional method that prepares students before the start of a lesson, and its goal is seeking to activate prior knowledge. Embedded instruction functions is like a scaffold, helping students work out tasks they cannot accomplish on their own. Ultimately, the goal of the implementation of differentiated instruction is to support students in reaching their full learning potential [14].

4. Discussion

The implementation of Differentiated Instruction presents several common and significant challenges for teachers. The key difficulties encountered are limited budget, limited Time, poor class management and class discipline, poor knowledge and awareness of DI strategy, the classroom environment, and support from the government.

Limited Time. It's difficult to put all the curriculum content in the required time. Time constraints lessons' planing and preparation [11]. Limited budget restricts teachers' ability to create resources like booklets, cue-cards, handouts, students' necessary equipment and activities that support Differentiated Instruction [7]. Poor class management and class discipline. Teachers face ongoing issues with student discipline and classroom management, especially in classrooms with too many students [7]. Poor knowledge and awareness of DI strategy and activities. Teachers need more pedagogical and content knowledge in these areas to carry out effective differentiation [11], which also could improve teacher self-efficacy and belief about DI. The classroom environment is also a barrier to do effective differentiated instruction. A safe, adjustable, and supportive classroom with specialised furniture such as adjustable tables and ergonomic chairs could encourage students' engagement [7]. Support from the government is insufficient. To effectively implement differentiated instruction, the government should offer ongoing teacher training, set up a specialized oversight team, and supply basic education schools with varied learning aids [11].

Barriers of effectively applying the UDL framework in inclusive settings centered on the need for stronger buy-in from general education teachers, increased administrative support, deeper teacher understanding of UDL, and more comprehensive training both during pre-service preparation and throughout teachers' careers. Increased administrative support which is hard to effectively implement UDL when principals are not supported or aware of what teachers are doing. Deeper teacher understanding of UDL. A consistent finding was that all teachers surveyed universally acknowledged the need for training and a deep understanding of the UDL framework. More comprehensive training both during preservice preparation and throughout teachers' careers. Teachers indicated both a perceived training gap for general education colleagues and their own limited confidence in implementing UDL. Therefore, not only preservice training in preparation, but also in-service training for all school division staff to support inclusive teaching environments.

5. Conclusion

This review integrated the basic theoretical frameworks, design, and barriers of implementation in STEM education within inclusive instructional practices. Both theoretical frameworks strengthen the accessibility of STEM learning and the needs of learner diversity. UDL highlights the design of the curriculum that should overcome the obstacles and encourage the engagement of students. DI focuses on learners by providing individual students with the most appropriate goals, supports, and

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demonstrations of knowledge. Together, both frameworks underline the significance of considering diversity as a major dimension of the STEM classroom.

Literature review affirms that inclusive instructional practices could improve students' confidence, engagement, and academic performance. However, there are still some challenges in implementation, resulting in uneven effects. Teachers consistently face challenges like inadequate time, limited resources, less professional training, and support from the related institutions. Once these barriers are removed, existing evidence indicates that UDL and DI can efficiently improve the accessibility and learning effectiveness in STEM classrooms.

In this review, there are two restrictions influence the research scope and extent of generalization. First, the database that was chosen is international, which means this review excludes regional studies and languages other than English. This constraint restricts the representation of cross-national perspectives. Second, this review depends on secondary literature, not direct empirical studies. Therefore, this review couldn't fully reflect how inclusive instructional strategies work in STEM class and how teachers manage the real-time inclusive instructions. So the finding reflects the existing assumptions and conceptual boundaries without empirical validation.

Future research would investigate a more regional database and more empirical research to improve the representation of a worldwide perspective and understanding of inclusive STEM education within cultural diversity. The chosen empirical studies would include mixed research methods, design experiments, and interventions within the classroom to identify how teachers apply inclusive frameworks under the barriers of reality. Furthermore, longitudinal research and digital technologies would be considered into future research, because longitudinal research could find the sustainable effects of UDL and DI about academic success. Meanwhile, digital technologies play an important role in examining the most adaptive and supportive technologies in inclusive instructional design.

At last, this research has a neet about empowering student experience. To understand how students perceive inclusion instructions and how inclusive instructional practices shape their sense of belonging and engagement, this could provide insights for instructional design and the efficient learning benefits happened during the transformation of inclusive frameworks.

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