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Research Article:

GenAI-Supported Approach to Lesson Planning for Inclusive Science Classrooms

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ABSTRACT

The emergence of generative Artificial Intelligence (GenAI) presents transformative opportunities in education, yet its role in preparing future educators for inclusive instruction remains underexplored within international teacher education scholarship. This article addresses the critical need for pedagogical reform by investigating how AI-supported instructional design can enhance inclusive learning in science classrooms. Specifically, it explores the impact of an AI-integrated lesson planning framework, grounded in Universal Design for Learning (UDL), Constructivist, and Sociocultural perspectives, on the instructional design competencies of pre-service science teachers. This study employed a pre- and post-intervention mixed-methods design, engaging 25 pre-service science teachers from the University of Delhi, India, in a targeted training module. Before the intervention, a questionnaire assessed their knowledge, attitudes, and preparedness regarding inclusive science education and AI integration. The intervention module provided practical training on leveraging GenAI tools, such as ChatGPT and Gemini, to design inclusive science lessons, emphasising strategies for differentiation, accessibility, and diverse learning needs. Post-intervention, data were collected to evaluate the training's impact on their lesson planning skills and confidence, analysed through descriptive statistics (including effect sizes) and qualitative thematic analysis to ensure methodological rigour. The study found that the GenAI-supported training improved pre-service science teachers' perceived ability to design lesson plans tailored for inclusive classrooms. This training module also increased their confidence in utilising GenAI tools and enhanced their capacity to design inclusive science lessons. While the findings provide valuable insights into the practical application of GenAI, the results are framed within the context of self-reported data and the specific scale of the study. This exploration demonstrates GenAI's potential to strategically empower future science educators to create more inclusive and responsive learning experiences, contributing to the evolving field of AI-assisted pedagogy.

Keywords: Generative AI, GenAI, lesson planning, inclusive instruction, science education, teacher education

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INTRODUCTION

Global education is constantly changing due to the growing demands of equity and technological advancement. Pursuing truly inclusive education has only been more intense as classrooms accommodate pupils from a broader range of language, cultural, socioeconomic, and ability backgrounds (Ainscow, 2020). In science education, which lays the groundwork for civic engagement and workforce participation in a world that is changing quickly, this problem is greater than anywhere else (Bybee, 2010; Strat et al., 2023). Both national educational policies, like India's National Education Policy (NEP) 2020, and the Sustainable Development Goal 4 (SDG 4) of the United Nations call for revolutionary measures to guarantee that all students have access to inclusive, high-quality, and relevant science education (UNESCO, 2015; Ministry of Education India, 2020). Despite robust policy frameworks, practical implementation often falls short due to significant systemic and pedagogical barriers. Science classrooms remain constrained by rigid curricula, limited resources, and insufficient teacher preparation for differentiated and inclusive instruction (Kotte, 2021). Teachers who are crucial agents for translating the vision of inclusivity into reality report persistent gaps in both theoretical knowledge and hands-on strategies to address the complexities of learner variability, especially concerning disabilities, language diversity, and sociocultural marginalisation (Ainscow, 2020; Sahin-Taskin, 2017).

For this study, an "inclusive science classroom" is operationally defined as a learning environment that proactively anticipates and removes barriers to learning arising from disability, linguistic diversity, socioeconomic background, gender, and cultural context. This definition is grounded in UNESCO's (2008) conceptualisation of inclusion as a process of addressing the diversity of needs of all learners, and the Universal Design for Learning (UDL) framework (Rose & Meyer, 2002), which mandates multiple means of engagement, representation, and action to accommodate this variability. Beyond UDL, this study aligns with social constructivist and sociocultural theories (Vygotsky, 1978), recognising that inclusive science instruction must be mediated by tools that bridge the gap between a student's current ability and their potential for scientific inquiry. By adopting this multidimensional definition, the study moves beyond a narrow focus on special educational needs to encompass an intersectional approach, where science instruction is designed to be culturally relevant, linguistically accessible, and cognitively adaptable for every student.

Against this backdrop, technological advancements in artificial intelligence (AI), particularly in generative AI (GenAI), offer unprecedented opportunities to personalise instruction and support diverse learning needs. GenAI refers to AI-driven tools capable of creating original content, including text, images, simulations, assessments, and even adaptive feedback, thereby empowering teachers to reconceptualise lesson planning as a responsive, data-informed, and student-centred process (Dwivedi et al., 2023). This shift sparks a vital conceptual debate in international scholarship: whether GenAI should be used merely as a tool for administrative efficiency or as a catalyst for "pedagogical augmentation" that fundamentally redefines inclusive design (Moundridou et al., 2024). Influential GenAI platforms such as ChatGPT and Gemini provide science educators access to resources and scaffolds that were previously time-consuming or unattainable, such as multilingual lesson materials, alternative representations of core concepts, or dynamic simulations tailored for students with disabilities (Karpouzis et al., 2024; Moundridou et al., 2024). Traditional hurdles to science engagement are reduced by GenAI platforms, which seamlessly create tailored material and provide various pathways for students to acquire and demonstrate learning (Chiu, 2024). For example, an AI-powered lesson built around the 5E model (Engage, Explore, Explain, Elaborate, Evaluate) can instantly modify assessments, materials, and activities to accommodate students who need sensory accommodations, are neurodiverse, or have limited language proficiency (Powell & Courchesne, 2024).

Nevertheless, the practical realities of leveraging GenAI for inclusive lesson planning are not free from challenges. Teachers often lack targeted exposure and confidence in using such tools. Concerns persist regarding digital equity, ethical safeguards (e.g., data privacy, bias), and the alignment of AI-generated content with both curricular standards and students lived experiences (Dwivedi et al., 2023; Picasso et al., 2024). Pre-service teachers, in particular, report insufficient opportunities within teacher education programs to experiment with GenAI for differentiating instruction, limiting their preparedness for the demands of modern, technology-infused science classrooms (Krepf & König, 2022).

A critical knowledge gap thus emerges: while the potential of GenAI for inclusive education is often declared in conceptual terms, there is scant empirical research exploring how structured, scaffolded training in GenAI-supported lesson planning influences the actual competencies, mindsets, and confidence of pre-service science teachers within the broader landscape of international AI-assisted teacher training (Karpouzis et al., 2024). Most prior studies have either examined general teacher attitudes toward digital technology or focused on the technical capabilities of AI tools without situating them within the nuanced realities of inclusive pedagogy (Chiu, 2024; Martinez & Porter, 2018). The need for practical, evidence-based models to guide teacher preparation for GenAI-driven instruction remains pressing.

While international scholarship on Generative AI in teacher education has expanded rapidly, much of the current discourse remains centred on general functional literacy, academic integrity, or administrative efficiency (Wen & Wen, 2024). There is a conspicuous lack of empirical research originating from diverse educational contexts, such as India, that specifically examines how GenAI can be harnessed to operationalise inclusive frameworks like UDL within specialised disciplines like science. To address this conspicuous global research gap, this study shifts the focus from viewing AI merely as a tool for productivity to utilising it as a catalyst for inclusive pedagogical reform. Rather than stopping at generic AI literacy, the research introduces and evaluates a domain-specific pedagogical workflow tailored to the unique challenges of the science classroom, where abstract concepts frequently create barriers for diverse learners. Specifically, this study investigates how GenAI-supported instructional design enhances the competencies of pre-service science teachers in inclusive lesson planning. It examines changes in their knowledge, attitudes, and preparedness following their participation in a targeted training module. Unlike standard adoption studies, this module utilises a novel "Learner-First" method focused on creating exhaustive learner profiles. By conditioning GenAI outputs on specific sociocultural and contextual data before lesson generation, the approach actively prioritises contextual equity and needs-based learning over simple administrative efficiency. Ultimately, this research contributes a localised yet globally relevant perspective on the role of GenAI in fostering equitable teacher preparation.

This study addresses the following research questions:

1. How does participation in a GenAI-supported instructional design module affect pre-service science teachers' perceived competencies in inclusive lesson planning?
2. What changes occur in pre-service science teachers' attitudes toward the use of AI in creating inclusive learning environments following the intervention?
3. What facilitators and barriers do pre-service teachers encounter when using GenAI tools for inclusive lesson planning?

Adopting a pre- and post-intervention mixed-methods design, the research engaged pre-service science teachers from the Department of Education, University of Delhi in a comprehensive training experience. The module emphasised the co-construction of inclusive lesson plans using GenAI tools, leveraging the UDL framework (Rose & Meyer, 2002), sociocultural theory (Vygotsky, 1978) and the 5E inquiry model (Duran & Duran, 2004) as guiding pedagogies. Data from baseline questionnaires, post-intervention feedback, and reflective artefacts were systematically analysed to uncover the impact and challenges of GenAI-enhanced lesson planning.

LITERATURE REVIEW

The landscape of science education has undergone profound change in response to the demands for inclusivity, technological advancement, and evolving pedagogical paradigms (Bybee, 2010; Dwivedi et al., 2023). Science education has been recognised globally as critical for preparing learners to participate in an increasingly complex, technology-driven world, fostering knowledge acquisition and higher-order thinking, problem-solving, and scientific literacy (UNESCO, 2015; Strat et al., 2023). This aspiration has led global and national policies, such as SDG 4 and India's NEP 2020, to position science as a key discipline for driving inclusive and quality education (Ministry of Education India, 2020).

Theoretical Underpinning

Historically, science education has moved from teacher-centred transmission models focused on rote memorisation towards constructivist, student-centred approaches

(DeBoer, 1991; Piaget, 1970). Pioneers like Dewey (1938) emphasised the value of experiential, inquiry-based learning, which has since become a central pillar of science pedagogy (Strat et al., 2023). Constructivism positions learners as active agents who construct understanding through hands-on engagement. At the same time, Vygotsky's (1978) sociocultural theory situates learning in collaborative, socially mediated contexts where peer interaction and scaffolding are vital (Johnson & Johnson, 1989). Within the international research on AI-assisted teacher education, a critical conceptual debate has emerged regarding the "scaffolding" role of technology. While early Computer-Assisted Instruction (CAI) followed a behaviourist model, recent scholarship argues that GenAI should be viewed through a Social Constructivist lens, serving as a "More Knowledgeable Other" (MKO) that provides adaptive scaffolding within a student's Zone of Proximal Development (Vygotsky, 1978).

This theoretical shift suggests that GenAI's value lies not in replacing the teacher, but in mediating the complex social interactions required for inclusive inquiry (Chiu, 2024). These theories underpin modern inclusive educational practices, advocating for teaching strategies that accommodate diverse learner needs, enable differentiated learning paths, and emphasise the richness of classroom diversity as a resource rather than a challenge (Ainscow, 2020; Florian & Spratt, 2013). However, translating these theoretical ideals into routine practice is hampered by enduring barriers, rigid curricula, limited teacher preparation, and persistent stereotypes (Kotte, 2021).

Inclusive Pedagogy and Universal Design for Learning

As UNESCO (2008) articulated, inclusive education aims to transform schools so that all students, regardless of ability or background, participate fully in meaningful educational experiences. In science classrooms, this necessitates a deliberate focus on accessible, multimodal content, culturally relevant instruction, and environments where every learner can thrive (Martinez & Porter, 2018). The challenge is especially pronounced in inquiry-based science education (IBSE), where active participation and hands-on activities must be adapted for neurodiverse learners and those with physical or sensory differences (Rose & Meyer, 2002). The UDL framework has become a leading approach in operationalising inclusivity, advocating for multiple means of engagement, representation, and action/expression in teaching (Rose & Meyer, 2002; Rao et al., 2014).

Scholarly debates currently focus on the "synergy" between UDL and sociocultural perspectives. Critics of traditional UDL argue it can sometimes focus too heavily on individual cognitive barriers; however, integrating it with sociocultural theory ensures that "inclusive design" also addresses the social and cultural barriers inherent in science curricula (Ainscow, 2020). This study adopts this integrated view, positing that UDL provides the technical architecture for inclusion, while sociocultural theory provides the pedagogical soul. UDL aligns closely with constructivist and sociocultural tenets, emphasising student agency and flexible curriculum pathways (Kraayenoord, 2007). Empirical studies consistently link UDL practices with improved learning outcomes for diverse cohorts, but also note the challenges teachers face in applying UDL principles without adequate support or resources (Karpouzis et al., 2024).

Generative Artificial Intelligence (GenAI) in Science Education

Technological innovation is widely recognised as a catalyst for transforming access and personalisation in education (Chiu, 2024; Selwyn, 2019). Early digital tools provided novel, if sometimes superficial, enhancements to science teaching; more recently, artificial intelligence (AI), and generative AI (GenAI) in particular, herald the promise of adaptive, responsive learning environments (Dwivedi et al., 2023; Moundridou et al., 2024). GenAI platforms such as ChatGPT and Gemini can generate high-quality lesson content, formative assessments, visualisations, and even multilingual resources, offering teachers a means to design lessons that closely fit the UDL framework (Karpouzis et al., 2024). Despite this promise, international scholarship highlights a "Pedagogical Gap": while GenAI can generate content instantly, the "conceptual debate" centers on whether this content aligns with the inquiry-based nature of science education. There is a risk that AI-generated materials may revert to "content delivery" rather than fostering the "Explain" and "Explore" phases of the 5E model (Duran & Duran, 2004). This underscores the need for training that focuses on AI-pedagogy alignment rather than just technical proficiency (Moundridou et al., 2024). Despite this promise, evidence from systematic reviews demonstrates that teacher educators and pre-service teachers seldom receive in-depth, practice-based training in GenAI-supported lesson design (Krepf & König, 2022). Many studies focus narrowly on attitudes, self-efficacy with general digital tools, or conceptual alignment with UDL. However, robust, empirical research on competencies in inclusive, GenAI-powered lesson planning remains limited (Sahin-Taskin, 2017).

While current empirical work establishes a consensus that GenAI enhances pre-service teachers' capacity to differentiate instruction (Karpouzis et al., 2024; Moundridou et al., 2024), there is a conceptual divergence over how this capacity is framed within teacher education. For instance, whereas Krepf and König (2022) frame these gains primarily as improvements in general technology integration, Karpouzis et al. (2024) elevate the discourse by explicitly linking GenAI proficiency to equitable, UDL-aligned lesson planning. Powell and Courchesne (2024) complicate this narrative further by applying it specifically to inquiry-based science (the 5E model), demonstrating that AI can scaffold complex, project-based activities. However, a critical synthesis of this literature reveals a distinct contextual limitation: these predominantly Western studies assume a baseline of digital infrastructure and pedagogical autonomy that is not universally applicable. As Picasso et al. (2024) argue, the seamless adaptation of GenAI reported in these studies is frequently disrupted by systemic implementation barriers. This tension is particularly acute in the Global South; frameworks like UDL and AI-driven 5E adaptations often lack contextualisation for local pedagogies, exacerbating the digital divide rather than bridging it (Ministry of Education India, 2020). Consequently, evaluating the efficacy of GenAI requires shifting the lens from general technical capability to context-specific, equitable integration. Furthermore, much research to date adopts qualitative or survey-based methods; there is a need for more mixed-methods and longitudinal studies that assess changes in pre-service teachers' competencies before and after explicit GenAI-based interventions.

Ethical Considerations and Challenges

The integration of GenAI in science education is fraught with ethical and practical controversies that directly impact teacher adoption. While macro-level critiques highlight systemic risks such as algorithmic bias, data privacy, and the reproduction of curricular inequities (Dwivedi et al., 2023; Picasso et al., 2024), these issues are not merely abstract; they manifest acutely in resource-constrained contexts. Building upon these concerns, Selwyn (2019) introduces the critical concept of "algorithmic coloniality", the danger that dominant global AI models lack the sociocultural and linguistic nuances necessary for the Global South. Crucially, this misalignment between global AI outputs and local realities directly fuels the mixed attitudes observed among educators. As Krepf and König (2022) note, teacher apprehension is frequently rooted in perceived threats to professional autonomy and the reliability of these tools when tasked with culturally relevant pedagogy. Therefore, the contemporary debate extends beyond whether AI can generate lessons, focusing instead on whether teachers possess the critical digital pedagogy required to actively interrogate and "contextualise" these outputs in light of inherent biases and local curricular needs.

Emergent Conceptual Debates

Recent international scholarship on Generative AI in teacher education has shifted from initial exploration of tool utility to more nuanced conceptual debates. One primary debate centre on the tension between "AI-driven automation" and "pedagogical agency". Scholars such as Selwyn (2019) and Dwivedi et al. (2023) express concern that over-reliance on AI may lead to the de-skilling of educators, where teachers become passive consumers of AI-generated content rather than active designers. Conversely, others argue that AI serves as a "co-designer" that liberates teachers from administrative burdens, allowing them to focus on high-order relational and inclusive tasks (Karpouzis et al., 2024; Wen & Wen, 2024).

A second conceptual debate involves the "Contextual Intelligence" of AI. While GenAI tools demonstrate high linguistic proficiency, critics argue they often lack the localized, sociocultural nuance required for truly inclusive education in diverse settings like the Global South (Ainscow, 2020). There is a documented gap in current literature regarding how pre-service teachers can be trained not just to use AI, but to "interrogate" it for cultural and disability-related biases.

Furthermore, while the application of UDL is well-established in traditional settings, its operationalisation through GenAI in specialised disciplines like Science remains an emerging frontier. Most current studies focus on general lesson planning; however, the specific intersection of Science-specific pedagogical content knowledge (PCK), inclusive frameworks, and GenAI-mediated scaffolding represent a significant gap that this study aims to fill.

Identification of Research Gaps

Despite conceptual and policy momentum, persistent research gaps remain. The most pressing of these are (Rao et al., 2014):

1. Insufficient empirical investigation of how GenAI-supported instructional design training affects pre-service science teachers' real-world competencies in inclusive lesson planning.

2. Limited evaluation of sustained changes to attitudes or skills over time.

3. Lack of comparative data between global and local contexts, especially in the Global South.

Consequently, this study seeks to address these gaps by providing robust, context-specific evidence on the impact of a structured, GenAI-integrated training module for pre-service science teachers. By grounding the intervention in UDL and inquiry-based science education, and employing a mixed-methods, pre-post design, the research aims to move beyond mere attitudes or self-reports, offering actionable insights for teacher education policy and practice in a rapidly digitising era.

METHODOLOGY

This study empirically investigated how a GenAI-supported instructional design framework could enhance pre-service science teachers' competencies in inclusive lesson planning. The central research question explored the effect of participation in a targeted GenAI-integrated training module on pre-service science teachers' perceived knowledge, attitudes, and preparedness for inclusive science education. Subsidiary objectives included assessing changes in self-reported knowledge, skills, and confidence regarding inclusive lesson planning and GenAI integration, analysing the effectiveness of a practical training module in scaffolding differentiation, accessibility, and diverse learning needs using GenAI, and documenting participant feedback to identify facilitators and barriers to GenAI adoption in lesson planning.

A pre- and post-intervention mixed-methods design was employed to capture both quantitative and qualitative dimensions of teacher learning, aligning with the principles outlined by Creswell and Plano Clark (2017). The methodology comprised three phases: (i) baseline assessment, (ii) intervention, and (iii) post-intervention data collection. The baseline phase assessed participants' existing knowledge, attitudes, and practices concerning inclusive science instruction and AI use. This was followed by the intervention, which delivered a GenAI-integrated training module emphasising inclusive lesson design, aligned explicitly with UDL (Rao & Meo, 2016) and the 5E science education model (Duran & Duran, 2004). Crucially, this intervention was also grounded in Social Constructivist and Sociocultural theories (Vygotsky, 1978), where GenAI acted as a tool for cognitive scaffolding and social mediation within the teacher-training context. Finally, the post-intervention phase collected quantitative and qualitative data to evaluate competencies, perceptions, and attitude changes.

The study engaged a purposive sample of 25 pre-service science teachers enrolled at the Department of Education, University of Delhi, during the 2024–2025 academic year. While the sample size is modest ($N = 25$), it reflects a focused pilot implementation within a specific teacher education program, allowing for deep, context-specific inquiry (Cohen et al., 2018) Inclusion criteria for participation required enrolment in a Bachelor of Education program with a science specialisation and voluntary informed consent. Sampling aimed to include individuals with at least foundational digital literacy but varying degrees of exposure to inclusive education and technology integration, as supported by Etikan et al. (2016). Efforts were also made to ensure diversity across gender, language, and socioeconomic backgrounds among the participants.

A semi-structured questionnaire was administered for the pre-intervention assessment. This instrument evaluated participants' knowledge of inclusive pedagogy and science lesson planning, familiarity and confidence with GenAI tools and UDL principles, and attitudes toward technology integration and inclusive practices. The instrument comprised 25 items divided into five distinct constructs that directly corresponded to the study's key variables:

1. Familiarity with UDL Principles.
2. Confidence Adapting Science Lessons.
3. Proficiency with GenAI Tools.
4. Preparedness for Accessibility and Inclusion.
5. Perception of Importance of Inclusive Science Education.

Responses were recorded on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). It also included 10 open-ended questions based on the above same themes to capture nuanced perspectives of the participants. Post-intervention data collection involved a follow-up questionnaire. To ensure comparability, the post-intervention questionnaire was designed to mirror the baseline instrument. The reliability of the scale was assessed using Cronbach's alpha coefficient for both administration phases. As shown in Table 1, the instrument demonstrated high internal consistency, with an overall Cronbach's alpha of 0.84 for the pre-test and 0.88 for the post-test, exceeding the recommended threshold of 0.70.

The core intervention was a training module, collaboratively developed with science teacher educators and AI experts. This module provided an overview of inclusive science education and UDL, guided participants through hands-on lesson planning tasks using GenAI tools (e.g., ChatGPT, Gemini, etc.), and included focused sessions on differentiation, accessibility, and adaptation for diverse learning needs. The 5E lesson planning model (Duran & Duran, 2004) was used to structure AI-supported, inclusive lesson sequences, and collaborative peer review and feedback cycles were integrated. The module emphasised practical engagement, iterative design, and critical reflection on the ethical and contextual challenges of using GenAI in lesson planning.

Table 1. Reliability statistics for data collection tool

Domain/Constructs	Number of items	Cronbach's alpha (pre)	Cronbach's alpha (post)
Familiarity with UDL principles	5	0.81	0.83
Confidence adapting GenAI tols	5	0.82	0.86
Profciency with GenAI tools	5	0.85	0.89
Preparedness for accessiblity and inclusion	5	0.79	0.84
Perception of inclusive science education's importance	5	0.76	0.80
Total	25	0.84	0.88

To ensure analytical rigour, quantitative data from the baseline and post-intervention questionnaires were analysed using descriptive statistics and paired-sample *t*-tests. To move beyond simple significance testing, Cohen's *d* effect sizes were calculated to evaluate the magnitude of change, providing an interpretation of the practical significance of the instructional module. Qualitative data from open-ended responses underwent thematic analysis following Braun and Clarke's (2006) six-phase framework, utilising a hybrid approach of inductive coding and deductive alignment with UDL principles. To ensure methodological transparency, the analysis involved two independent coders. The process moved from initial data familiarisation to the generation of open codes, followed by a collaborative reconciliation phase where discrepancies were resolved through iterative discussion to achieve 100% inter-coder consensus. Themes were iteratively refined and explicitly mapped back to Constructivist, Sociocultural, and UDL frameworks to ensure theoretical integration.

While the mixed-methods approach provided multidimensional insights, several limitations are acknowledged. The study relied on perception-based, self-reported data, which may be subject to social desirability bias. Furthermore, the absence of objective performance measures, such as independent assessments of the final lesson plans or classroom observations, is noted. While the purposive sampling of 25 participants at a single institution constrains broad generalisability, the focus on in-depth context-specific analysis offers valuable transferable insights for inclusive teacher education (Cohen et al., 2018).

The GenAI-Supported Training Module

Gen AI-based training program is intended to give pre-service science teachers the skills they need to create inclusive lectures. This module is organised around the well-known 5E instructional paradigm (Duran & Duran, 2004) and based on Differentiated Instruction (DI) and UDL pedagogical frameworks (Rose & Meyer, 2002; Tomlinson, 2014). It incorporates three fundamental elements: learner profile, inclusive lesson planning, and assessment. Every aspect has been carefully planned to promote the strategic use of generative AI tools, develop a thoughtful approach to moral and responsive teaching methods, and stimulate context-sensitive educational thinking.

Developing a thorough Learner's Profile is the module's fundamental component. Teachers start this process by conducting a rigorous setting analysis, in which they methodically collect and enter data about each student and the larger classroom setting. At this stage, generative AI technologies enable effective data collection and pattern recognition. The curriculum inherently presents opportunities and challenges to the educators to consider various aspects, such as sociocultural elements including linguistic diversity, cultural and religious backgrounds, and gender issues like representation, equity, and sensitivity in interactions and materials. Economic factors are also looked at, including household surroundings, material limitations, and resource availability. Specific attention is given to the challenges faced by Children with Special Needs (CWSN) or Learners with Disabilities (LWD), identifying accessibility requirements and necessary accommodations. Furthermore, the analysis extends to geographical distinctions, such as rural-urban divides, the local relevance of science content, and other contextual nuances like English Language Learner (ELL) status, prior learning experiences, and digital literacy levels. Complementing this, GenAI tools are pre-programmed to reference relevant curricular frameworks (e.g., NCERT, CBSE, State boards) and school/system policies, ensuring the learning outcomes and materials are valid and institutionally recognised.

The module progresses to Inclusive Lesson Planning, a process enhanced by generative AI across four distinct stages to promote comprehensive inclusion. The first stage focuses on Learning Outcomes, where GenAI is crucial in generating differentiated and personalised learning outcomes. This is achieved by referencing individual and group learner profiles, established curriculum standards, and specific school or institutional expectations. This capability empowers teachers to develop realistic, yet ambitious and measurable, learning goals for all students, encompassing those with disabilities, linguistic diversity, and varying levels of prior attainment.

The subsequent stage, Resource Selection, leverages GenAI to suggest and create diverse soft resources. These digital and multimodal materials include text, visualisations, simulations, and sound files, all meticulously tailored to align with specific learner profiles and lesson objectives. Teachers are guided in selecting or adapting these resources based on UDL principles (emphasising multiple means of engagement and representation) and DI strategies (such as tiered tasks and content presented at varying complexities). The module also supports identifying activities appropriate for specific learning needs, encouraging experiential, project-based, and cooperative methodologies.

In the Developmental Steps & Procedures stage, GenAI assists teachers through prompt engineering to generate engaging lesson hooks and introductions designed to captivate learners in diverse classroom settings. Examples include science demonstrations with sensory adaptations, discussion prompts incorporating students' home languages, real-world local scenarios, and visually-rich or hands-on alternatives. Moreover, based on the intended class context, GenAI proposes various alternative lesson structures, including whole-class, small-group, or individualised paths, allowing teachers the flexibility to select or combine these options. The system naturally encourages scaffolding and flexibility by enabling teachers to repeat steps and modify course structures in response to real-time student input and growing requirements.

GenAI plays a significant role in supporting assessment, the module's last essential component, which guarantees fairness and accuracy in assessing student learning. GenAI makes it easier to create differentiated assessment tools by producing several formative and summative assessment versions and formats. Incorporating suitable adjustments and modifications for CWSN/LWD and language learners can include digital formats and oral, written, and practical examinations. Furthermore, the AI suggests personalised feedback, providing tailored prompts, rubrics, and feedback statements that directly reference each learner's progress and personal goals. Crucially, the training heavily emphasises inclusive and ethical evaluation, reaffirming that although GenAI is a potent tool, educators are ultimately in charge of competent teacher judgement, contextualisation, and fairness. Pre-service teachers submit their GenAI-enabled, UDL/DI-aligned lesson plans (Rose & Meyer, 2002; Tomlinson, 2014) and assessment samples for thorough peer and instructor review during the practical training module. This cooperative review process offers insightful criticism and chances for improvement. The module concludes with structured collaborative reflection, encouraging participants to discuss successes, analyse challenges, address ethical dilemmas encountered, and formulate strategies for their continual professional improvement in inclusive science education.

DATA ANALYSIS AND RESULTS

A total of 25 pre-service science teachers participated in the pre- and post-intervention. The sample included 68% female (n = 17) and 32% male (n = 8) participants, aged between 21 and 27 years. All were enrolled in the B.Ed. Programme with science pedagogy at the Department of Education (CIE), University of Delhi. While all participants had at least intermediate digital literacy, only 24% reported prior hands-on experience with AI tools in an educational context. In the pre-intervention questionnaire, respondents expressed moderate familiarity with inclusive education and UDL principles (Mean = 3.2, SD = 0.8), and only limited confidence in adapting science lessons for diverse needs (Mean = 3.1, SD = 0.9). Awareness and prior use of AI tools in lesson planning were also relatively low (Mean

= 2.8, SD = 0.9). Although most participants agreed that inclusive science education is essential (Median = 4), fewer felt ready to implement differentiated instructional strategies.

Matched pre–post questionnaire data collected using a five-point Likert scale revealed statistically significant improvements across all core competencies measured (Table 2). Items assessed familiarity with inclusive science pedagogy, UDL principles, lesson adaptation for diverse learners, and AI/GenAI integration. The reliability of the questionnaire was verified using Cronbach's alpha, which indicated high internal consistency for both the pre-intervention ($\alpha = 0.84$) and post-intervention ($\alpha = 0.88$) scales.

Substantial improvements were observed across almost all core questionnaire items after completing the GenAI-supported training module. Participants' familiarity with inclusive science education and UDL principles increased, with the mean score rising to 4.1 (SD = 0.7). Their confidence in adapting lessons rose, reaching a mean of 4.2 (SD = 0.6). Participants' reported their proficiency with AI/GenAI tools had a mean score of 4.0 (SD = 0.7), and their preparedness to use GenAI for diversity and accessibility also improved. Strongest improvements were observed in preparedness for accessibility (+1.28 mean gain) and confidence in lesson adaptation (+1.16). Intermediate gains occurred in familiarity with UDL and proficiency with GenAI tools (+0.92 and +1.16), which suggests the module not only introduced concepts but also embedded them in practical contexts. The smallest gain, though still statistically significant, was in the value attached to inclusive science education (+0.64). This was already relatively high pre-intervention, indicating pre-existing positive attitudes. The low post-intervention standard deviations (all < 0.70) imply convergence of responses, suggesting that the intervention not only elevated mean scores but also reduced variability, leading to more uniformly high competency and confidence.

Beyond the mean improvements, the analysis of Standard Deviation (SD) reveals a convergence in participant skills. Pre-intervention SD values indicated high variability in participant competence (e.g., Proficiency with GenAI tools, SD = 0.90). Following the intervention, standard deviations across all items decreased to below 0.70. This reduction in variability suggests that the intervention was beneficial across the cohort, appearing to narrow the self-reported skill gap and elevate participants with lower initial confidence to a higher standard of perceived competence. Paired t-test analyses showed significant positive shifts in self-reported competencies ($p < 0.01$) for all matched items. The most significant gains are related to the ability and willingness to use GenAI tools for differentiated instructional design and assessment.

To evaluate the practical significance of the intervention, Cohen's d effect sizes were calculated for all key items. Following Cohen's (1988) guidelines, where 0.2 represents a small effect, 0.5 represents a medium effect, and 0.8 represents a large effect. All results in this study demonstrated a large effect size ($d > 1.10$). The most notable gain was observed in participants' Preparedness for accessibility and inclusion ($d = 1.83$), followed by Confidence in adapting science lessons ($d = 1.52$). While these high values indicate a significant perceived improvement in pre-service teachers' competencies, these findings must be interpreted cautiously, given the study's reliance on self-reported measures, its small sample size, and the absence of a control group. Nevertheless, the effect sizes suggest that the intervention holds considerable promise as a pedagogical tool for inclusive teacher education.

Table 2. Comparative statistics and effect sizes (Pre vs. Post, $N = 25$)

Items	Pre-mean	Post-mean	Difference between mean	Pre-median	Post-median
Familiarity with UDL principle	3.20	4.12	+0.92	3	4
Confidence adapting science lessons	3.08	4.24	+1.16	3	4
Proficiency with GenAI tools	2.84	4.00	+1.16	3	4
Preparedness for accessibility and inclusion	3.00	4.28	+1.28	3	4
Perception of inclusive science education's importance	3.84	4.48	+0.64	4	5

(Continued to next line)

Table 2 (*Continued*)

Items	Pre-SD	Post-SD	t-value	p-value	Cohen's d	Effect size
Familiarity with UDL principle	0.81	0.70	−4.82	< 0.001	1.21	Large
Confidence adapting science lessons	0.88	0.62	−5.14	< 0.001	1.52	Large
Proficiency with GenAI tools	0.90	0.69	−5.02	< 0.001	1.44	Large
Preparedness for accessibility and inclusion	0.76	0.63	−5.91	< 0.001	1.83	Large
Perception of inclusive science education's importance	0.61	0.50	−3.98	< 0.01	1.14	Large

Thematic analysis of open-ended survey responses revealed three dominant themes regarding the facilitators and barriers to GenAI adoption, namely, a shift in pedagogical agency, contextualisation and resource generation, and ethical concerns. Pre-intervention open-ended responses commonly mentioned resource constraints, lack of strategies for differentiation, and uncertainty about using technology for inclusion. Post-intervention, teachers cited GenAI as a time-saver and valuable support. Respondents credited GenAI for providing alternative lesson hooks, personalised analogies, and multimodal aids. However, several requested further guidance on ethical use, prompt engineering, and managing erroneous outputs. Most participants successfully used GenAI to generate content alternatives, structure lessons with diverse hooks, and address UDL/DI principles. Assessment artefacts included differentiated assignments, alternative feedback formats, and rubrics tailored to CWSN/LWD and ELL learners. Teachers described GenAI as "a tool for making inclusive science accessible." Peer feedback stressed the value of the collaborative module format and practical engagement.

Beyond the evident statistical improvements and fundamental artefact changes, a deeper examination of participant experiences reveals how the GenAI-supported training module fostered genuine transformation in teacher agency, classroom creativity, and nuanced understanding of inclusion. As participants progressed, their reflections and peer interactions pointed to a shifting definition of "inclusive planning", from a compliance task to an intentional, adaptive and student-centred process shaped by technology and local context.

Initially, participants described feeling "boxed in" by curriculum constraints and fixed notions of lesson design. Post-module, a recurrent theme was a perceived sense of pedagogical liberation. While participants interpreted this as empowering them to be active instructional designers rather than passive consumers of rigid curricula, this sudden ease of planning also raises important questions about the underlying cognitive processes. A participant reported, "Suddenly, I have options. Before, I tried to imagine four or five different activities for students with different needs. Now I am asking GenAI for help and getting ten. Nevertheless, I still choose. The choice is mine, and it feels powerful." Another explained, "With GenAI, differentiation is no longer about extra work for me; it is more doors opening for students." While this shift reflects an essential tenet of inclusion, centring learner needs by expanding the repertoire of instructional strategies, it also requires critical interrogation. Does this perceived ease and abundance of options reflect a genuine, internalised understanding of how to design for diverse needs, or does it risk a form of tool dependency where the AI assumes the cognitive load of pedagogical reasoning? Even as participants felt they retained the power of "choice", the parameters of that choice were heavily mediated by the algorithm.

Participants repeatedly utilised GenAI's ability to generate context-specific resources, asking for stories, analogies, and examples rooted in local languages, festivals, and familiar phenomena. One lesson plan, for instance, connected electricity concepts to Diwali celebrations; another used regional food preservation practices as a springboard for teaching scientific methods. For students from under-resourced backgrounds or linguistic minorities, GenAI-supported lesson hooks and alternative materials offered accessibility without compromising curricular rigour. Such adaptability was especially critical for students with disabilities. Teachers described using GenAI to create large-font printouts, tactile diagrams, or simple science summaries translated into home languages for CWSN/LWD.

The training module emphasised not just individual work but collaborative peer feedback. Teachers shared GenAI-generated drafts, iterated based on peer suggestions, and reflected on the possibilities and pitfalls of rapid digital adaptation. This process built digital and pedagogical confidence as reported by the teachers. The design, review, and revision cycle fostered a professional learning community, where GenAI replaced isolation with connected, context-aware creativity.

Assessment practices changed substantially post-intervention. Participants noted that GenAI could rapidly generate differentiated assignments, formative quizzes, and multimodal response prompts, supporting genuine evidence of learning for all students. However, they acknowledged challenges: GenAI sometimes produced assessments not aligned with local standards or overlooked subtle accessibility needs unless carefully prompted. The more skilled practitioners learned to vet critically and, if necessary, adjust AI outputs, a key step in balancing automation and teacher judgement.

Ethical use of GenAI was a recurring concern as mentioned by many participants. Teachers debated questions about bias, representation, and privacy, as one remarked, "I learned to check if GenAI suggestions were truly inclusive; sometimes they missed a cultural or disability perspective." Others sought clear institutional guidelines, suggesting that sustained integration of GenAI into education will require robust policy and ongoing professional development. Although the study's short time frame limited analysis of long-term change, many participants expressed intentions to integrate GenAI into their future teaching practice. Requests for a "prompt bank," periodic refresher workshops, and collaborative planning spaces illustrate teachers' desire for ongoing support. Some also raised critical points: "Will my school let me use AI like this? How do I keep students' data safe? What happens if we lose access to these tools?" Such questions highlight that successful adoption of GenAI for inclusion will require systemic infrastructure, leadership, and professional culture to evolve alongside teacher skill development.

DISCUSSION

These findings align with previous research (e.g., Sotiropoulos & Kalogiannakis, 2025; Karpouzis et al., 2024). GenAI substantially supports teachers in creating differentiated lesson materials, adapting content for diverse contexts, and enhancing accessibility for CWSN/LWD. Participants learned to engineer prompts and select resources aligned with the curriculum framework and school context. The three-component module, learner profile, inclusive planning, and differentiated assessment, effectively operationalised inclusive pedagogy through technology.

However, this study extends these findings by both demonstrating and quantifying the specific value of this three-component workflow. While Karpouzis et al. (2024) identified the potential of GenAI, our results, specifically the significant rise in preparedness for accessibility (Table 2), demonstrate that these gains are most pronounced when a specific pedagogical framework, such as UDL, directs the AI. The reduction in standard deviation further suggests that this structured approach may act as an equaliser, helping to raise the perceived competency of less tech-savvy teachers to more closely align with their peers.

While previous research has highlighted GenAI as a content repository (Chiu, 2024), our results indicate that the "Learner Profile" component is the critical differentiator. By forcing the AI to process detailed learner data (socioeconomic, linguistic, and ability-based, etc.) before generating content, the module acts as a contextualisation engine rather than just a productivity tool. This distinguishes the present model from general AI integration by embedding the Universal Design for Learning (UDL) framework directly into the prompt engineering structure. Thus, the intervention did not merely "support inclusion" in an abstract sense; it provided a practical mechanism to satisfy the UDL and UNESCO frameworks across the full spectrum of learner diversity. By utilising the "Learner-First" prompt structure, this approach offers a direct solution to the barriers identified by Kotte (2021), who noted that rigid curricula often hamper inclusive efforts. Unlike the generic "AI literacy" often criticised in teacher education, this workflow ensures that efficiency does not come at the cost of personalisation.

Teachers demonstrated improved ability to apply UDL across lesson planning through personalised learning outcomes based on extensive context data (sociocultural, gender, linguistic, economic, geographic). GenAI's ability to suggest multimodal soft resources and inclusive activities reinforced teachers' confidence in reaching varied learners. This mirrors the results that Wen and Wen (2024) reported. It also helps in developmental steps such as generating alternative lesson hooks and adaptable lesson structures, enhanced engagement, and personalisation.

Consistent with Sotiropoulos and Kalogiannakis (2025), teachers welcomed GenAI's support but raised concerns regarding ethical safeguards, data privacy, and the authenticity of AI-generated ideas. There remained a moderate ambivalence about the degree of disruption AI might cause to traditional educational processes. This aligns with Dwivedi et al. (2023), who warn of the risks of algorithmic bias. However, the teachers' response, checking if suggestions were truly inclusive, indicates the development of "critical AI literacy". Teacher education curricula must therefore include explicit modules on ethical AI use and digital rights, ensuring that future educators are equipped to vet AI outputs for cultural bias and accuracy.

The findings of this study provide empirical support for the integration of Sociocultural and Constructivist theories in the AI era. The participants' journey from GenAI literacy to confident lesson design illustrates Vygotsky's (1978) Zone of Proximal Development, where the AI served as a cognitive scaffold, allowing teachers to reach higher-order design complexities (such as UDL-aligned differentiation) that they struggled to achieve independently. Furthermore, the results validate the UDL framework, as the GenAI tools enabled the pre-service teachers to rapidly generate "multiple means of representation" for complex science concepts, effectively reducing barriers for diverse learners.

Globally, there is a valid concern that over-reliance on AI might de-skill teachers or create tool dependency (Selwyn, 2019). While participant self-reports in this study largely counter that narrative, suggesting that GenAI increases teacher agency and makes differentiation "manageable and inspiring", this perceived efficiency warrants a more critical examination. It is imperative to question whether the rapid generation of differentiated materials reflects a genuine deepening of pre-service teachers' conceptual understanding of inclusive design, or whether it signals an emerging dependency. For instance, the ability to instantly generate multiple alternative activities might inadvertently bypass the productive struggle that novice educators need to internalise UDL principles independently. If GenAI absorbs too much of the cognitive load of instructional design, there is a distinct risk that pre-service teachers may become highly adept at prompt engineering while their foundational planning skills atrophy. Therefore, the "agency" reported by participants must be carefully delineated. Is it the critical agency to orchestrate and evaluate outputs, or merely the efficiency of delegating complex pedagogical decisions to an algorithm? Our data suggest that when anchored in strong frameworks such as the 5E model, AI can function as a "partner in pedagogical design" (Wen & Wen, 2024), provided teachers actively engage in evaluating and refining outputs. Ultimately, acknowledging this tension is essential, as the long-term effectiveness of AI-integrated teacher education depends on ensuring that these tools scaffold human expertise rather than inadvertently replace it.

Despite the positive outcomes observed, the present study has limitations. The research was conducted at a single institution (University of Delhi) with a purposive, small sample size, which restricts the generalisability of findings to other contexts and populations. Moreover, the study's short duration and reliance on self-reported measures limit the ability to assess sustained changes in teacher competencies or classroom practices over time. There is also a possibility of response bias due to participants' awareness of the intervention focus and the absence of direct observation or classroom artefacts beyond self-reports and lesson plans. Participants requested ongoing professional development, robust ethical training, and greater institutional support for GenAI use.

The training module offers a replicable structure for other teacher preparation programs, showing clear advances in teacher confidence, knowledge, and skill for technology-enabled inclusive science instruction. Its approach of combining contextual profiling, differentiated planning, resource generation, and inclusive assessment corresponds with best-practice recommendations for GenAI integration in science education.

Implications for Teacher Education

As demonstrated in this study, integrating generative artificial intelligence (GenAI) into science lesson planning carries significant implications for pre-service and in-service teacher education in the 21st century. As education systems globally shift towards more inclusive and technology-enhanced pedagogies, teacher preparation programs must evolve to support teachers using digital tools and designing, implementing, and critically evaluating lessons that address diverse student needs (Ainscow, 2020; UNESCO, 2015).

Teacher education programs have traditionally focused on foundational pedagogies and subject content, with technology and inclusion often treated as separate strands (Kotte, 2021). This siloed approach is increasingly inadequate as digital tools such as GenAI become ubiquitous in schools. The findings from this study underscore the necessity for integrated digital inclusion curricula where GenAI literacy is embedded at the core of teaching practice rather than as an add-on (Krepf & König, 2022; Dwivedi et al., 2023). Teacher educators should champion GenAI as a technical tool enabler of differentiated, personalised learning (Karpouzis et al., 2024).

Lesson planning anchored in UDL principles (multiple means of engagement, representation, and expression) proved more effective when coupled with GenAI technologies, according to participant feedback and lesson artefact analysis (Rose & Meyer, 2002; Rao et al., 2014). Teacher education must foreground UDL frameworks, encouraging pre-service and in-service teachers to use GenAI's capacities (e.g., multimodal resources, alternative formats) to scaffold instruction for learners with disabilities, language barriers, socioeconomic disadvantage, and other diversity (Chiu, 2024; Martinez & Porter, 2018).

Effective GenAI use for inclusion requires more than technical familiarity; it demands critical digital pedagogy skills, including prompt engineering, digital content evaluation, and reflective practice (Picasso et al., 2024; Selwyn, 2019). Pre-service teacher programs should systematically build GenAI literacy through collaborative modules that blend practical experimentation with ethical problem-solving and peer review (Dwivedi et al., 2023). As participants in this study discovered, teacher agency, defined by the ability to select, adapt, and critically assess AI-generated material, must remain central (Martinez & Porter, 2018).

Participants noted that GenAI tools allowed for rapid generation of context-sensitive materials, tailored to sociocultural, linguistic, gender, economic, and geographic diversity. For Indian teacher education, this means leveraging GenAI to bridge gaps highlighted by the National Education Policy (Ministry of Education India, 2020), such as support for local languages and rural/urban divides. Teacher educators should help trainees use GenAI's "contextual intelligence" to honour community values, incorporate indigenous knowledge, and create lessons relevant to students' lived realities (Ainscow, 2020).

In the specific context of Indian teacher education, the findings offer a practical roadmap for implementing the National Education Policy (NEP) 2020. The NEP 2020 explicitly mandates a shift towards equitable, inclusive, and multilingual education; however, it often lacks implementation frameworks for resource-constrained classrooms. This study demonstrates that GenAI can serve as a critical bridge in three key areas aligned with NEP 2020. Firstly, the NEP 2020 emphasises instruction in mother tongues and local languages. Participants in this study successfully utilised GenAI to translate technical scientific concepts into their home languages and generate culturally rooted analogies. This confirms that GenAI can act as an immediate resource for the "contextualisation" of curriculum required by Indian policy standards. Secondly, by providing high-quality, diverse lesson resources through a smartphone or laptop, GenAI can democratise access to quality pedagogy for teachers in rural or under-resourced areas, addressing the equity gaps highlighted in the NEP 2020. Lastly, the study validates that GenAI significantly enhances teachers' preparedness for accessibility. This directly supports the rights of persons with disabilities as mandated in the NEP 2020, moving inclusion from a theoretical ideal to a manageable classroom practice.

While exploratory, these findings suggest potential pathways for global teacher education, particularly within the Global South and nations striving to meet Sustainable Development Goal 4 (SDG 4). For education systems in developing economies where specialised teaching aids and special educators are scarce, this study suggests that GenAI can function as a scalable, low-cost "virtual mentor." It enables pre-service teachers to design UDL-aligned lessons in settings with limited physical and human resources. This offers a model for international teacher preparation programs to integrate AI not just as a tool for efficiency, but as a partner in pedagogical design. The participants' concern regarding ethical bias and data privacy underscores a universal need. Teacher education curricula globally must prioritise "critical AI literacy", teaching educators to vet AI outputs for cultural bias and accuracy, to ensure that the technology supports rather than undermines educational equity.

GenAI-enhanced lesson planning opens new opportunities for collegial collaboration and co-construction of resources. This study's module structure mirrors best practices in professional learning communities, combining peer review, shared artefact creation, and problem-based reflection (Kotte, 2021; Florian & Spratt, 2013). Teacher preparation should embed collaborative GenAI-based design, enabling teachers to learn from each other's innovations and collectively address challenges in differentiation and accessibility. As highlighted by both participants and literature, GenAI presents new ethical challenges: algorithmic bias, data privacy risks, and the danger of uncritical adoption (Picasso et al., 2024; Dwivedi et al., 2023). Teacher education curricula must include explicit modules on ethical AI use, digital rights, and strategies for vetting and contextualising AI-generated content. Institutional policies should guide teachers on responsible use, safeguarding student data, and maintaining educational equity (Selwyn, 2019).

The module demonstrated that GenAI can help teachers design differentiated and alternative assessments, providing multiple pathways for students to demonstrate mastery (Powell & Courchesne, 2024; Sahin-Taskin, 2017). Teacher education should emphasise assessment for learning, equipping future educators to use GenAI for formative feedback, alternative rubrics, and accessible assessment tools, particularly for students with disabilities and language needs. Short interventions have an impact, but sustained professional development is crucial (Cohen et al., 2018). Teacher education must provide ongoing, research-informed professional learning in GenAI integration: refresher workshops, prompt banks, exemplars, and digital communities of practice. Partnerships between teacher education institutions, tech developers, and policy bodies can help scale and sustain these efforts.

Finally, evidence from this study suggests that GenAI-inclusive lesson planning should inform system-level policy development. Curriculum frameworks, teacher standards, and institutional strategies must recognise and support AI-enabled instructional design for inclusion (UNESCO, 2015; Ministry of Education, 2020). Policymakers should create enabling environments, regulations, funding, and infrastructure that allow ethical, contextual GenAI use and ongoing teacher upskilling (Selwyn, 2019). GenAI-supported lesson planning offers new routes to genuinely inclusive, responsive, and creative science teaching. The challenge and opportunity for teacher educators are to make GenAI literacy, blended with UDL, critical digital pedagogy, and ethical awareness, a cornerstone of 21st-century preparation programs. The evidence here reinforces that integrating GenAI must always begin and end with diverse learners' needs, voices, and rights, empowering teachers to create classrooms where every student can thrive.

CONCLUSION

This study investigated the key role that generative artificial intelligence (GenAI) can play in enabling pre-service science instructors to create and present lessons that are genuinely inclusive, differentiated, and sensitive to their students' diversity. The study suggests that GenAI has the potential to enhance how teachers are trained today by using a structured training module based on UDL and Differentiated Instruction (DI) and by carefully measuring how teachers' skills, attitudes, and lesson planning methods have changed.

Based on self-reported measures, the findings indicated substantial and statistically significant improvements in teachers' perceived knowledge of inclusive education, confidence in lesson adaptation, and competence with GenAI tools (Table 2). Pre-service teachers demonstrated increased preparedness to address learner variability, including accommodating disabilities, linguistic and cultural diversity, and socioeconomic disadvantage. These outcomes are in line with prior research, which underscores that technology, when coupled with pedagogical frameworks like UDL, enhances teachers' ability to design lessons that meet the needs of all students (Karpouzis et al., 2024; Rose & Meyer, 2002; Rao et al., 2014).

The module's three-component structure, starting with learners' profile construction, proceeding through inclusive lesson planning, and culminating in differentiated assessment, ensured teachers engaged deeply with context, curriculum, and the unique requirements of their learners. GenAI's capacity for generating multimodal resources, lesson variants, and assessment tools provided practical support and creative expansion, allowing teachers to implement genuinely personalised and accessible science instruction (Chiu, 2024; Powell & Courchesne, 2024). Many participants noted that differentiation, previously seen as burdensome, became manageable and inspiring with GenAI's assistance as they could explore multiple content representations, adjust complexity, and create alternative lesson hooks for their varied classrooms.

Qualitative data further illuminated shifts in teacher agency and pedagogical mindset. Teachers moved from passive use of digital tools to strategic and critical engagement, prompting, adapting, and vetting AI-generated materials in the light of ethical, cultural, and educational standards (Picasso et al., 2024). Collaborative peer design and reflection supported more accurate and relevant lesson planning and fostered a professional learning community attuned to the nuances of digital inclusion (Florian & Spratt, 2013).

Despite overwhelmingly positive impacts, several challenges were identified. Participants raised concerns about ethical safeguards, data privacy, occasional AI-generated inaccuracies, and a desire for explicit institutional guidelines for appropriate GenAI use. These concerns underscore the vital need for continuous teacher education in technical skills, critical digital pedagogy, and ethical literacy, consistent with findings in the larger literature (Selwyn, 2019; Dwivedi et al., 2023). To maintain inclusive digital innovation, schools and teacher education programs must invest in ongoing professional development, transparent policies, and cooperative structures.

The small, single-site sample and the brief length of the training intervention limit the study's generalisability. However, the thorough, practice-based approach provides an exploratory framework that other teacher preparation programs could adapt and test to promote inclusiveness through AI-supported instructional design. Given the research design's context-specific nature and brief intervention period, future research should adopt longitudinal approaches, tracking changes in teachers' competencies and instructional effectiveness over extended periods and across multiple institutions. Additionally, classroom-based observational studies and collaborations between diverse teacher education programs would provide richer insights into the sustained impact and scalability of GenAI-supported lesson planning. Exploring how these interventions affect actual student engagement, learning outcomes, and inclusive classroom practices is essential for building robust, evidence-based models in teacher education. The main goal should be determining how GenAI-enabled lesson planning leads to measurable improvements in student engagement, understanding, and achievement.

Critically, the study's approach of centring learners' profiles foregrounds the principle that effective use of technology for inclusion starts not with tools, but with a deep, holistic understanding of learners' backgrounds, needs, and aspirations (Ainscow, 2020). GenAI can and should be harnessed not to replace teacher creativity or judgement but to expand the repertoire of available strategies, making it possible for every student to access, participate in, and succeed in science education.

Ultimately, the specific contribution of this study to the literature lies in its operationalisation of inclusive theory. While existing research broadly advocates for AI literacy, this study provides empirical evidence that coupling GenAI with a "Learner-First" UDL framework specifically in science education shifts AI from a generic productivity tool to a catalyst for equitable pedagogical design. It offers a tested, context-sensitive workflow for teacher educators to move beyond theoretical discussions of inclusion into practical, technology-mediated implementation.

This research illustrates that GenAI may significantly enhance inclusive scientific instruction through careful design, substantial support, and ethical consideration. The implications for teacher educators, policymakers, and school leaders are obvious: incorporating GenAI into teacher preparation must be carefully designed, research-driven, and fiercely focused on equity and student input. Only then can GenAI fully contribute to the vision of inclusive, high-quality scientific education for all, transforming policy aspirations into classroom realities (UNESCO, 2015; Ministry of Education India, 2020).

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