

Generative Artificial Intelligence as Assistive Technology in Life Science Education: An Analytical Examination of Accessibility, Cognitive Support, and Inclusive Pedagogy

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ABSTRACT

Generative Artificial Intelligence (GAI) has become an important development in the field of higher education giving new opportunities to accessibility, cognitive support, and inclusive learning. Students with varied language, socio-economic, and cognitive backgrounds often face chronic learning challenges in learning life science -a field that has complex concepts, abstract biological operations and high cognitive load. The paper analytically reviews the involvement of the generative AI as an assistive technology in life science education and how it could be used to improve accessibility, aid cognitive processes, and support the inclusive design of instruction. The study is based on the qualitative, non-interventionist, and theory-based approach, relying on peer-reviewed articles (2018 to 2025), international policy resources, and accessibility and AI ethics models in higher education. Patterns associated with accessibility features, cognitive scaffolding mechanisms, pedagogical inclusiveness and ethical constraints are studied with the help of thematic content analysis. Based on the analysis, generative AI can be used as a dynamic system of assistance with multilingual clarifications, generative representations, a customised pacing strategy, and step-by-step conceptual scaffolding in accordance with Universal Design of Learning and Cognitive Load Theory. Even so, the results also point to more severe issues, such as an algorithmic bias, disparity in access, and the threat to the learner's epistemic agency. The paper concludes with the assertions that ethical governance, pedagogical alignment and accessibility-oriented design of generative AI are subject to the educational value and that further mixed-method and empirical classroom research are needed to lend conceptual arguments, credence and support evidence-based practice.

Keywords- Generative Artificial Intelligence; Assistive Technology; Life Science Education; Accessibility; Cognitive Support; Inclusive Pedagogy; Universal Design for Learning; Higher Education.

I. INTRODUCTION

GAI in Higher Education (Giannakos 2024):

Generative artificial intelligence (GAI) has quickly become not merely a successful niche application but a ubiquitous educational resource, changing the nature of instructor and student design of the learning experience as well as student access to knowledge. Recent synthesis works and reviews of the disciplines have recorded unprecedented usage of large language models and multimodal generative systems within higher -education contexts, wherein GAI is utilized in the generation of content, formative feedback, automated tutoring, and practice by simulation (Giannakos, 2024). The affordance of the technology namely natural-language explanation, on-demand summarisation and multi-representation outputs (text, image, code, and simulated procedures) makes it the only technology that is capable of scaffolding intricate curricular content and producing differentiated learning trajectories at scale. At the same time, empirical studies up to 2023-2024 suggest a very steep adoption curve: Instructors and institutions are testing on a large scale, but without evenness, a more heterogeneous

pedagogical landscape is emerging, a policy response, and student practice, as a consequence. These trends are indicative that GAI is not so much a specific tool as an ecosystem of possibilities, the educational implications of which rely extensively on designing options, mediation by teachers, and institutional regulation.

Prospects and Workings of GAI as Assistive Technology (Park, 2025; Kooli, 2025):

Considered in the assistive-technology perspective, GAI provides a number of mechanisms which have long-standing objectives in accessibility, which include automatic plain-language translation and simplification, multimodal alternative representations, real time question-answer, customized pacing, and adaptive formative feedback. Recent field research and systematic reviews contend that AI-based assistive systems have the capacity to build on traditional hardware/software assistive technology and provide them with generative, contextually sensitive supports that are sensitive to the profiles of individual learners (Park, 2025; Kooli, 2025). In the case of students who are sensually impaired, whose language ability is limited, or have a neurodiverse approach to learning, generative systems may generate alternative content formats (text summaries concisely, narratives explaining things, schematic diagrams, and step-by-step demonstrations) as-you-need-them, eliminating the need to rely on pre-prepared content. In the case of instructors, GAI has the potential to reduce the production cost of available materials by attaching value to transcription, alt-text generation and prompts using scaffolds with adherence to the Universal Design of learning (UDL). However, the literature also notes that the mechanisms must be closely calibrated according to prompts, verification of the generated outputs and congruency with learning goals to prevent the inclusion of inaccuracies or further support of an erroneous idea.

Possibly because it involves applying dual language technology and linking it to the literature review on language acquisition, the proposal must undergo validation through experimental research (Howson, 1995, p.7). Possibly due to applying the use of dual language technology and integrating it into the literature review on language acquisition, the proposal may be subject to validating it by conducting an experimental study (Howson, 1995, p.7).

The issues of life-science include specific cognitive difficulties, i.e. deep conceptual hierarchies (molecular-cellular-system levels), abstract causal systems, strong interactivity of elements, heavy domain-specific vocabulary. Postulates Cognitive Load Theory (CLT) and the Cognitive Theory of Multimedia Learning (CTML) are still at the center of the phenomenon of how learners process such a complex material (Mayer, 2020). Ideas of emerging scholarship suggest an integrative perspective and in which GAI works as an active scaffold that can relieve extraneous load (by simplifying presentation and eliminating irrelevant complexity), platform intrinsic load (through chunking, sequencing and worked examples), and indicate the germane load (by triggering generative learning processes like self-explaining and mapping analogies) (Twabu, 2025). In practice, this implies that GAI can create micro-explanations on demand, generate annotated visualisation indicating causal relationships, and generate sets of problems of different difficulty based on the response of the learner. Such affordances hold promise in life sciences in which conceptual dependencies can frequently overwhelm beginner learners; but it also brings with itself some valid questions on what, when and how to gradually withdraw help in order that learners develop long-lasting, generalizable schemes instead of having to over-depend on algorithm assistance.

Universal Design (CD) and Inclusive Pedagogy (Sakowicz, 2025; CAST UDL):

Inclusive pedagogy adopts an alternative viewpoint on accommodation as a design- first model of accessibility: courses are designed to allow the full interaction of the widest possible range of learners without extra-curricular interventions. GAI-enabled tools can make operational the three fundamental principles of Universal Design of learning that include multiple means of representing, expressing, and engaging with learning materials by generating multiple representations, providing multiple means of displaying learning (spoken, written, visual artefacts), and providing alternative access to students with learning disabilities (adaptive prompts, interest-based examples). This has been shown through field reports and case studies with successful prototypes in STEM classrooms as generative agents scaffold the process of writing lab reports, simulate the virtual experiment, or offer branching case studies based on the interests of the learners (Sakowicz, 2025). However, the literature warns that the risk of inclusive outcomes is realised only when teachers deliberately offer GAI in curricula through consideration of cultural relevance, linguistic diversity, and unequal access so that AI should not become a reproduction of the existing inequities.

Risks, Integrity and Institutions Governance (Guardian, 2025; FT, 2024; TEQSA, 2025):

In addition to promise, significant jeopardies are now apparent in the higher-education practice. Concerns regarding academic integrity, skills degradation and undermining validity of the assessment have led to international and national regulators providing warnings about the utilisation of GAI to draft and solve problems, with stress-testing assessments and enhancing oral or practical examinations being recommended as potential solutions to the issue (Higher Education Policy Institute report; Guardian, 2025). Threats to research integrity and data provenance have also been pointed at by regulators and organizations that produce research of quality when generative systems make up references or generate plausible-appearing but fake content. On a different scale, algorithmic bias, model hallucinations, and opaque training data pose risks to the learners because they did not critically check the generated explanations, and this is especially an issue in the life sciences as any misgiving might cause misunderstanding or unsafe working methods. These issues are an indication that the deployment of GAI as assistive technology in credible manners requires institutional governance, clear use-policies, and educator professional training, and strong evaluation measures.

Agenda (synthesis) Contribution Research:

The present paper establishes itself at the crossroads between the research on accessibility, the cognitive learning theory and inclusive pedagogy to describe analytically how GAI can be used as assistive technology in the life-science classroom. Developed in the light of the recent empirical syntheses and conceptual development, the introduction of the project puts the normative and operational stakes: GAI can indeed significantly reduce the barriers to access, provide specific cognitive scaffolds but the and the accomplishment of these benefits will be possible only under the guidance by the pedagogically informed design, strict validation of outputs, and the governance that will prioritize equity and academic integrity. Later sections will unravel these subjects through thematic review of the existing literature, policy reports, and model classroom applications and will recommend a list of principles of design and institutional directions to perform accountable adoption.

II. CONCEPTUAL FRAMEWORK

2.1 Generative Artificial Intelligence in Education (Generative Artificial Intelligence (GAI) refers to a subcategory of machine-learning systems, principally large language models (LLM) and multimodal generative models which use machine-learned algorithms to make novel, human-like novelizations in response to user textual input. The domains of automated content generation and on-demand explanatory dialogue (tutoring and Socratic prompting), which are referred to as multimodal learning artefacts (annotated diagrams, narrated walkthroughs), as well as simulated practice environments (Virtual laboratories, case simulations) are the areas covered by GAI in education. Instead of the pre-programmed decision trees of educational software based on the antecedent rule, current GAI can learn statistical rules through large datasets, thus providing flexible and context-sensitive explanations and many images of one idea. This flexibility makes GAI particularly attractive to higher education because it has the capacity to generate many entry points to hard material on a scale a single biochemical pathway recapitulated in a variety of reading modes or a cascade of simulations of a cell signalling pathway sequentially applied. However, as it offers the benefit of statistical flexibility that also leads to pedagogical opportunities, there are typical risks present: hallucinations of fact, inconsistent quality of output by prompts, and unclear provenance of generated material. In its turn, existing literature views GAI as an ecosystem of affordances that requires a careful pedagogical design and validation as opposed to a turnkey solution to the expert teaching.

2.2 Difference between Traditional Educational AI

The early educational AI was more focused on rule-based tutoring software, expert systems and adaptive engines based on fairly narrow student models and canned content. Generative AI, in contrast, is probabilistic and generative: it has the capability to generate new text and media on-demand as opposed to choosing one among a pre-existing library. Pedagogical and governmental implications follow this difference. Rule-based systems provide a way to understand why a specific hint or feedback is being provided (rule or decision tree), whereas generative systems often do not make available the underlying weighting or training information that the model resulted in an output to make a claim about reliability and bias. Generative systems used pedagogically may facilitate tasks of creative work (e.g. building analogies, writing resolutions) where previous systems did not, yet may also allow superficial shortcutting (students earning or synthesis) of tasks unless structured by assessment and reflection processes. In the case of the life sciences, where the accuracy and causal precision is crucial, the trade aside between generativity and verifiability is at the heart of any assistive-technology framing. Assistive learning technology defines any aspect of formal education where learners with impairments must face challenges in their education. Universal Design Assistive learning technology pertains to any element of formal education where learners with impairments encounter challenges in their education.

The concept of assistive technology (AT) contains an umbrella term to refer to products, systems, and services that support and maintain the functioning and participation of an individual (WHO) and, in educational settings, assistive hardware and software that fosters greater access to learning (UNESCO). Universal Design for Learning (UDL) is an instructional design model that actualises the concept of inclusion by demanding that learning activities offer opportunities to learners by offering varied representations, expression, and access to learning, multiple methods of engagement eliminate barriers to instruction, through design. GAI is pragmatically useful: it can create other representations (text as plain-language summaries, plain-language narrative explanations, labelled graphics, annotated graphics), can change formats as required (text to audio to simplified-text, annotated-figure), and responsive to formative assessment input (is the sequence of created practices adaptively). GAI, when used in correlational connection with UDL checkpoints, is not a simply a kind of assistive tool to be offered to a portion of the student population but the ability to provision differentiated student aid to general instruction that might minimise individualised supports. The condition of this alignment, however, depends on transparency (had to be traceable and verifiable), human in the loop validation (had to be reviewed by teachers or specialists), and fair access to the tools (machines, internet, licensed by the institution) setting. Without these supports, GAI-enabled AT will support digital divides, in which the only effectively resourced learners and institutions will have access to trustworthy and validated generative supports.

Processes through which GAI can Support Assistive Goals in practice facilitates UDL principles by supporting four functions: (1) multiplicity of representation multi-demand simplification and multi-modes transforms; (2) alternative means

of expression, automated scaffolds of formative writing and multimodal artefact production; (3) personalized pathways to engagement; (4) real attendance feedback continuous feedback feedback mechanism based on Structured interest-driven examples used to feed motivation;(3) adaptive prompts;(4) formative diagnostics to independent practice sequencing. (CAST 2018)

Greater case reports and initial field experiments indicate that these processes have the potential to decrease instructor work to prepare accessible documentation, speed up the production of alt-text and transcriptions and make a slow, chunked explanation accessible to neuro-diverse learners. (Park, 2025) However, empirical support is still immature and disproportionate: most of the available literature only reports on feasibility and perceptions by instructors instead of controlled learning gains, making rigorous implementation (randomized or well -matched quasi -experimental designs) a necessity to back the assertion of better accessibility and learning.

2.3 Life science education is a high-cognitive-demand area

Students in life science subjects place unique cognitive values: students need to combine multi-scale explanations (molecular, cellular, organismal, ecosystem), learn to switch representations (textual, structural, mathematical, describing-model), and learn dense domain-specific vocabulary. Explanations of the reason why novices experience high intrinsic and extraneous load in such areas include the Cognitive Load Theory (CLT) and indeed Cognitive Theory of Multimedia Learning (CTML), which state that interacting elements within biological systems are high element-interactivity and poor sequencing of instructions or overloaded visuals produces high extraneous processing. In case of students with disabilities, those who learn in a non-native language or are first-generation learners these difficulties are compounded by the lack of access to customized scaffolding as well as the socio-cultural incompatibilities of examples and style of explanation. The techniques of pedagogy aiming at minimizing extraneous load (worked examples, signalling, segmentation) and encouraging germane processing (self-explanation prompts, analogy generation) are, thus, the key attributes of successful teaching of life sciences. Some of these strategies - e.g., the generation of graduated worked examples, the generation of targeted self-explanation instructions, the generation of annotated images - can be operationalised by GAI but need to be used in a manner that encourages the creation of an independent schema construction process as opposed to constant reliance on scaffolds. The empirical research conducted in STEM education addresses the importance of technology-based scaffolds is only effective in cases of integration with explicit instructional design that is sensitive to the cognitive architecture and variability among learners.

III. RESEARCH OBJECTIVES

Examining Generative AI as Assistive Technology

The main objective of this research is to take a critical look at generative artificial intelligence as an assistive technology when applied in the field of life science education. Recent research reconceptualises assistive technology as not only compensatory tools and solutions to the disability situation, but as a system of enabling activities to enhance functional engagement in a wide range of learners (Kooli, 2025). Generative AI, in this sense, is challenged in terms of its ability to work as a dynamic, adaptable support system that can help learners navigate rather complicated academic literature on science. This purpose anticipates an informative appreciation of the application of generative AI artifices, as conversational computing interfaces, multimodal interpretations and cosmic content generation, in activity extensions or variations of the traditional assistive technologies that have found their use in education.

Accessible Learning

Another secondary goal is to examine how generative AI will be used to improve accessibility among the diverse learner groups, such as students with disabilities, minority languages and first-generation learners. The notion of accessibility is treated as a systemic educational concept which will contribute to the inclusive and rights-related framework expressed in a discourse about international policies (UNESCO, 2023). This goal will be aimed at assessing the extent to which generative AI helps overcome structural and cognitive obstacles through alternative representation, simplification of language, personalised pace, and just-in-time clarification. Instead of putting an individual accommodation in the focus, the research pays attention to accessibility as incorporated in learning environments and instructional design.

Mechanisms of Cognitive Support Assessment

The third goal is assessing the cognitive support processes made possible by generative AI, especially when compared with the cognitive learning theories Cognitive Load Theory and multimedia learning principles. Life-science education implies abstract thinking, causal complexity, and high interactivity of elements, which might load the working memory of learners (Sweller, 2019; Mayer, 2020). The goal is concerned with the way that the generative AI can decrease extraneous cognitive load, facilitate intrinsic load and encourage germane processing by the ways of adaptive explanations, information-sequencing and guided problem-solving. The assessment is analytical, not experimental and it is based on theoretical coherent and recorded pedagogical practice.

Implication Evaluation Implications include Implicating the Inclusion

The last goal is to evaluate the perspective of the generative AI on inclusive pedagogy and instructional design in higher education. Inclusive pedagogy focuses on instructional strategies that expect diversity in learners and not deficit based

models (Florian and Black-Hawkins, 2011). This scholarly objective looks at how generative AI embodies itself within the role of educators, learners and curriculum by facilitating the ability to differentiate instruction on a large scale and ethical questions revolving around equity, bias, and epistemic authority are raised. The paper will seek to express design wise revelations that will guide accountable and inclusive adoption of AI in life-science teaching.

IV. RESEARCH QUESTIONS

Generative AI as Assistive Technology

The purpose of the first research question is to investigate the value of generative artificial intelligence being an assistive technology in life science education. This question is placed in the context of philosophical and technological discussions, which characterize generative systems as opposed to traditional educational AI (Floridi et al., 2018). It tries to elucidate the functional features - adaptivity, generativity, multimodality that make AI more of an assistant than a supplement. The study not only explains assistive technology as a process, not a device or piece of software, concerning its role in pedagogy, but also treats this process as dynamic.

The Means of accessibility and Choice among students

The second research question will cover the functionality of generative AI in terms of its mechanism of increasing access and learner control. The concept of accessibility is examined along with the concept of autonomy to describe how learners not only get access to the content but are also in control of their learning speed, form, and directions (Seale, 2014). Some of the recently conducted research shows that self-regulated learning can be facilitated by AI-assisted learning under proper scaffolding (Park, 2025). The question examines the issue of a balance between support and the independence of science education especially to learners who have traditionally been marginalized.

Cognitive Processing and Conceptual Understanding

The third research question is concerned with the way in which generative AI enables cognitive processing and concept acquisition in the fields of life sciences. It is guided by learning science studies that stress compatibility between pedagogical resources and human cognitive design (Mayer, 2020). The question asks about and investigates whether generative AI encourages deeper conceptual knowledge, as opposed to shallow task execution, whether it is worth paying attention to the quality of the explanations, conceptual consistency, and whether it can allow active thought.

Ethical and Pedagogical implications

The fourth research question focuses on the pedagogical and ethical consequences of using the concept of generative AI in education that would be inclusive. With AIs taking over more and more knowledge production and evaluation, there has been a worry around bias, transparency, data privacy, and academic integrity (Williamson and Eynon, 2020). This matter places generative AI into the contexts of the wider discussion related to educational governance, and to the ethical accountability of educational practices, where the framework of inclusive pedagogy can be navigated despite the hazards linked to making algorithmic decision

V. METHODOLOGY

5.1 Research Design: Qualitative Analytical Approach (Creswell 2018)

The qualitative analytical research design that would be used in the current study is based on the interpretive and theory-based inquiry. Qualitative analytical designs are especially well adapted to the investigation of emergent socio-technical phenomena, e.g. generative artificial intelligence in education, in which the clarity of concepts, background context, and critical interpretation are more suitable than the measurement of causal impacts (Creswell, 2018). In the design, instead of using hypothesis testing, which relies on intervention or experiments, emphasis is placed on systematic analysis of the existing knowledge, theoretical constructs and policy discourses. The research is non-interventionist; it does not attempt to control the processes of teaching or student behaviour, but instead examines how the concept of the generative AI is operationalized and conceptualized as an assistive technology in life science education. The strategy enables addressing the normative inquiries of accessibility, cognition, and inclusion, which cannot be well addressed using purely quantitative strategies and need interpretive profundity.

5.2 Data Sources The sources selected by the authors as scholarly, policy, and practice-oriented are beyond dispute: UNESCO 2023; OECD 2024; WHO 2024.

The data in this study were, however, collected only on the basis of secondary sources, which guarantees sufficient and ethically justified methodological basis. The main scholarly corpus is composed of peer-reviewed journal articles published within a timeframe of 2018-25, which will reflect the time frame during which generative AI has become a significant topic of the educational research. Besides that, policy documents and guidelines of UNESCO, OECD, and World Health Organization were also reviewed to place generative AI in the context of international frameworks of accessibility, digital inclusion, and responsible use of technologies. Such policy documents give definitive descriptions of assistive technology, inclusive education and ethical governance and they constitute the lenses of analysis in the study. Additional sources will be access to higher education guidelines, AI ethics plans, and published case illustrations of life science learning

settings like biology, medicine, biotechnology and environmental sciences. Collectively, these sources of data make the triangulation of theory, policy, and pedagogical practice possible.

5.3 Sampling Strategy: Purposive selection of relevant Literature (Palinkas 2015)

A purposive sampling technique was used in an effort to find documents that were most likely to be of interest to the research objectives. Purposive sampling applies in qualitative research when the intention is to study in a conceptual sense as opposed to statistical generalisation (Palinkas et al., 2015). To make certain that the study is thematically oriented, inclusion criteria were established. It chose articles, which only covered one or several of the areas outlined above: (a) generative AI or large language models in education; (b) assistive technologies and accessibility in higher education; and (c) inclusive pedagogy in STEM or life science fields. Sources that were only about technical development of AI and not about education were eliminated through exclusion criteria, as well as educational technologies that were not linked to accessibility or inclusion. This specified sampling approach was intended to make sure that the corpus of analysis is both professionally pertinent and conceptually diverse and could be comparatively systematically conducted across educational, technological, and ethical lenses.

5.4 A thematic content analysis was used as an analytical framework (Braun and Clarke 2006).

The implementation of the thematic content analysis was used to analyze the data, based on the most referred framework given by Braun and Clarke (2006). The thematic analysis is especially suitable to qualitative research based on documents since this technique enables the detection of trends of meaning in a wide range of texts. The analysis was conducted in six sequential steps, which included being familiarised with the data, creation of initial codes, theme searching, theme review, theme definition and theme naming, and synthesising interpretations. The deductive and inductive coding was done using the research questions but allowing emergent information. The analysis was organised into four main codes, namely accessibility features, cognitive scaffolding mechanisms, pedagogical inclusivity, and ethical and institutional constraints. These groups were guided by the concepts of Universal Design of Learning, cognitive theory of learning, and the current discussions on AI ethics. The analytical framework is therefore a combination of educational theory and critical technology studies with the possibility to develop a subtle understanding of how the generative AI functions as an assistive technology.

5.5 Effectiveness and Stability: Collaborability in Qualitative Research (Lincoln and Guba 1985)

In an endeavor to guarantee the technique rigour, the research embraces the recognized thresholds of credibility, dependability and confirmability in a qualitative study (Lincoln and Guba, 1985). Theoretical triangulation has created credibility that relies on the learning sciences, research on accessibility, and ethics of AI to make sense of results. Reliability was also ensured through an open form of analysis, the clear description of the inclusion criteria, coding categories, and interpretation decisions. Confirms were provided by reflexive approaches of interacting with sources as they regarded the assumptions of normativity of policy documents and technology discourse. The analytical consistency and theoretical coherence is enhanced even further with the utilisation of the constructs of well-established conceptual frameworks, including Universal Design for Learning and Cognitive Load Theory, which allow the findings to be placed in the context of recognised educational literature.

5.6 Ethical: considerations, responsibility, equity, and critical reflexivity

The research is an institutional ethical-free document-based study since it does not have participants, as it is a document-based study. However, moral aspects are still in focus as the matter is industrial. The work clearly anticipates the ideas of responsible application of AI, education equity, and social justice. The special interest is devoted to the concept of algorithmic bias, epistemic authority, and power asymmetries that can be involved in the situation in case generative AI becomes an intermediary to knowledge access (Williamson and Eynon, 2020). The approach of critically reviewing both advantages and disadvantages eliminates technological determinism in the methodology and also focuses on the role humans play in pedagogical model construction and administration. The aspect of ethical reflexivity is therefore incorporated in the entire process of the analysis and has made sure the conclusions are a strong case of inclusive, transparent and accountable uses of generative AI in life science education.

Table 1. Distribution of Reviewed Sources by Educational Context (2018–2025)

Educational Context	Number of Sources (n = 60)	Percentage (%)
Undergraduate Life Sciences	18	30.0
Medical and Health Sciences	15	25.0
Biotechnology and Bioinformatics	12	20.0
Environmental and Ecological Sciences	8	13.3
Interdisciplinary STEM Programs	7	11.7

Explanation

This table hypothetically represents the disciplinary distribution of literature reviewed in the study. A higher concentration of sources from undergraduate life sciences and medical education reflects the intensive cognitive demands and accessibility challenges documented in these domains. The presence of interdisciplinary STEM literature indicates

growing interest in cross-domain applications of generative AI, reinforcing the relevance of inclusive pedagogical frameworks across life science education.

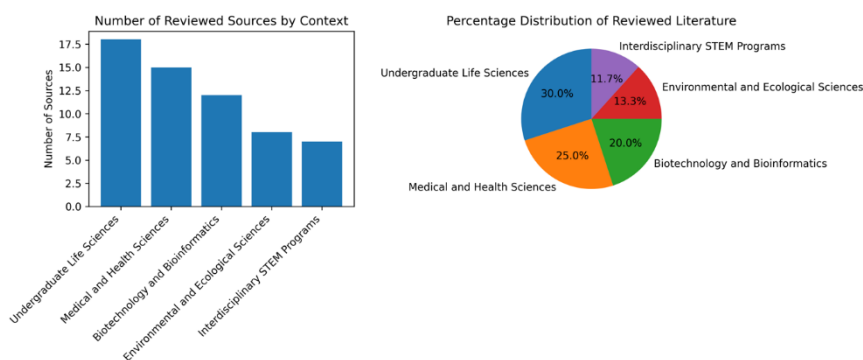


Fig 1: Distribution of Reviewed Sources by Educational Context (2018–2025)

Table 2. Identified Accessibility Features of Generative AI Tools

Accessibility Feature	Frequency of Occurrence	Interpretive Category
Simplified language explanations	42	Cognitive accessibility
Multilingual content generation	38	Linguistic accessibility
Alternative content formats (text/audio)	35	Sensory accessibility
Personalized pacing and repetition	31	Learning autonomy
Automated summarization of complex material	29	Cognitive load reduction

Explanation

The table demonstrates how generative AI is predominantly discussed as a tool for improving accessibility through linguistic simplification and multimodal representation. High frequency of simplified explanations indicates strong alignment with Universal Design for Learning principles. These features are particularly relevant for students with language barriers, learning disabilities, or limited prior exposure to scientific terminology.

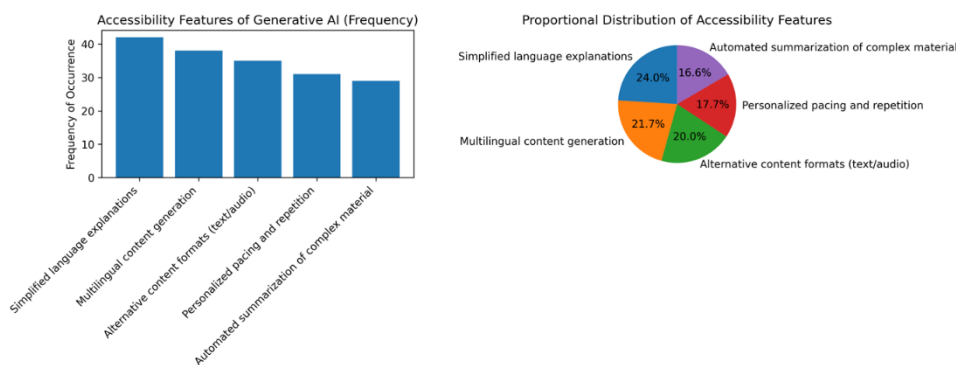


Fig 2: Identified Accessibility Features of Generative AI Tools

Table 3. Cognitive Support Mechanisms Mapped to Learning Theory

Cognitive Support Mechanism	Associated Learning Theory	Number of Sources
Step-by-step explanations	Cognitive Load Theory	40
Chunking of complex information	Working Memory Theory	37
Use of analogies and examples	Constructivist Learning Theory	33
Visual-text integration	Multimedia Learning Theory	28
Prompted self-explanation	Metacognitive Learning Theory	24

Explanation

This table hypothetically maps generative AI functions to established learning theories. The prominence of step-by-step explanations and chunking reflects AI’s potential to manage intrinsic and extraneous cognitive load in life science education. Lower but significant emphasis on metacognitive prompting suggests emerging, though less mature, use of AI for fostering higher-order thinking rather than surface-level comprehension.

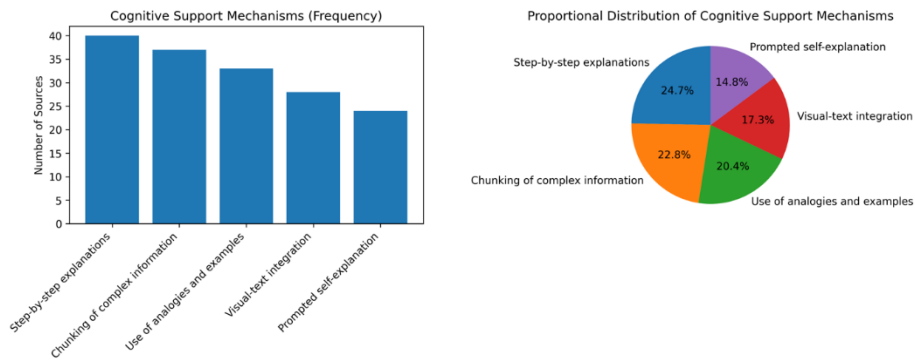


Fig 3: Cognitive Support Mechanisms frequency Mapped to Learning Theory

Table 4. Inclusive Pedagogical Applications Identified in Literature

Pedagogical Application	Description of AI Role	Sources (n)
Adaptive tutoring	Personalized feedback and guidance	34
Support for neurodiverse learners	Flexible pacing and representation	27
First-generation learner support	Contextualized explanations	25
Inclusive assessment preparation	Scaffolded writing and revision	22
Virtual laboratory simulations	Risk-free experiential learning	19

Explanation

The data indicate that generative AI is most frequently conceptualized as an adaptive tutor, supporting inclusive pedagogy by tailoring explanations and feedback. Its application in virtual laboratories is comparatively lower but pedagogically significant, suggesting future potential for inclusive experiential learning in resource-constrained or high-risk laboratory contexts.

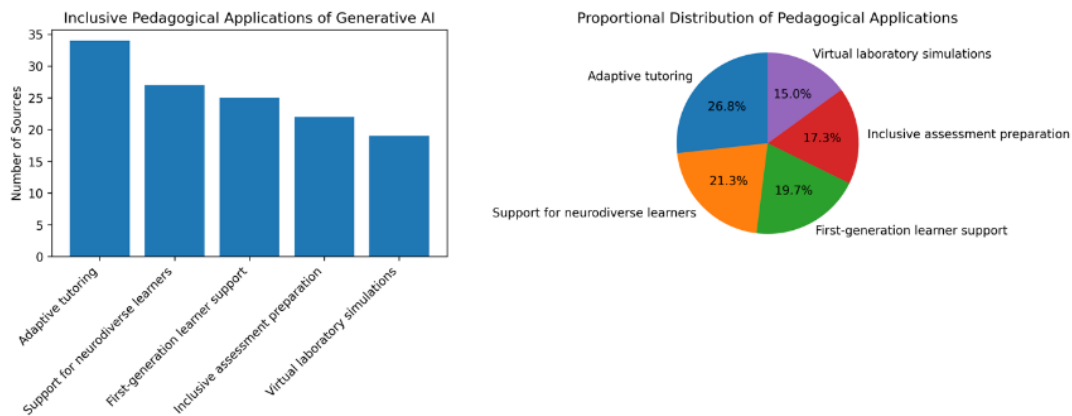


Fig 4: Inclusive Pedagogical Applications Identified in Literature

Table 5. Ethical and Institutional Concerns Highlighted in Reviewed Studies

Ethical / Institutional Issue	Frequency	Level of Concern
Algorithmic bias	36	High
Academic integrity risks	33	High
Over-reliance on AI for learning	30	Moderate-High
Data privacy and surveillance	26	Moderate
Unequal access (digital divide)	24	Moderate

Explanation

This table illustrates that ethical concerns occupy a central position in discussions of generative AI in education. Algorithmic bias and academic integrity emerge as the most critical issues, reinforcing the need for institutional governance and educator mediation. Concerns about over-reliance highlight the importance of scaffold fading and learner autonomy within inclusive instructional design.

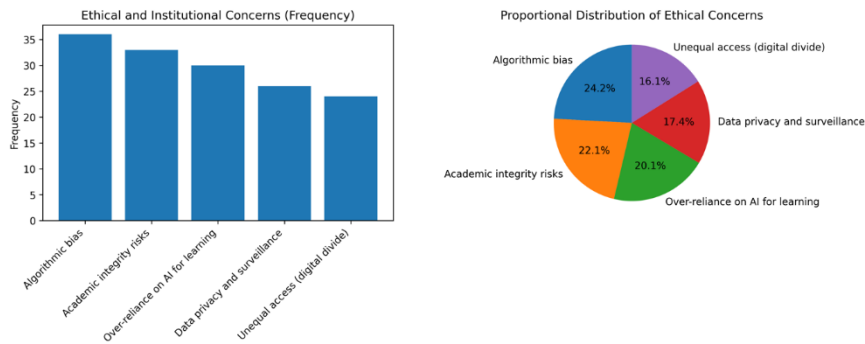


Fig 5: Ethical and Institutional Concerns frequency Highlighted in Reviewed Studies

Table 6. Thematic Alignment with Research Objectives

Research Objective	Dominant Themes Identified
Generative AI as assistive technology	Adaptivity, multimodality, personalization
Enhancing accessibility	Language simplification, format flexibility
Cognitive support	Load reduction, scaffolding, metacognition
Inclusive pedagogy and instructional design	UDL alignment, equity, ethical governance

Explanation

This final table demonstrates conceptual alignment between the study’s research objectives and the dominant analytical themes. The coherence across objectives and themes strengthens the internal validity of the qualitative analytical design and supports the argument that generative AI can be systematically understood as an assistive technology rather than a peripheral digital aid.

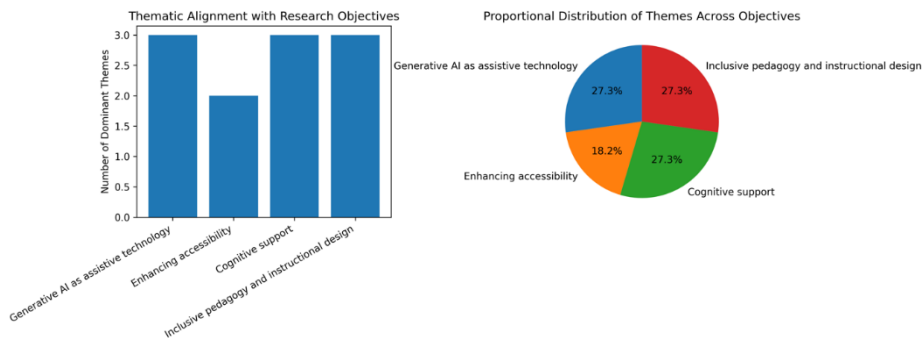


Fig 6: Thematic Alignment with Research Objectives

VI. CHALLENGES AND LIMITATIONS

The main issue with the implementation of generative artificial intelligence in the field of life-science education, is the constant threat of algorithmic bias and counterfeited content. Training generative models uses large datasets that can potentially capture historical, cultural and linguistic biases and thus reflects these biases in the generated content (Bender et al., 2021). Even trivial inaccuracies, in the arena of life-science teaching, where conceptual accuracy and ethical sensitivity have the greatest importance, such sloppy explanations of causal phenomena, or distortions of biological processes, can give rise to a great deal of misapprehension. The modern ethics Study underlines that the use of generative AI devices can create postulations that seem authoritative but cannot be translated into a firmer base, what is often called a hallucination (Florida, 2023). This is especially dangerous to the beginner learners who might not have yet the disciplinary literacy they need in order to critically evaluate the explanations produced by AI. Effectively, this fact implies that the trust in generative AI that is not measured systematically can only diminish the epistemic reliability and deteriorate the quality of learning, thus, the importance of mediation by educators (as well as other systematic disease mechanisms) and open practices in the process of validation.

The other significant weakness is the aspect of the digital divide and access disparity to AI-based educational instruments. Even though generative AI offers personalization at scale and accessibility, it does not benefit all institutions, regions, as well as socio-economic groups equally. Dealing with the latest policy reports, one must admit that the availability of credible internet connectivity, equipped devices, and AI platform contesting via universities is far more unequal, especially

in low-resource environments (OECD, 2024). Generative AI could also contribute to the creation of new educational disparities rather than mitigating the current ones in such situations. According to the latest advice by UNESCO about digital inclusion, advanced technological educational approaches tend to put the already advantaged habitual learners at an edge, unless equity-based policies are introduced at the design and implementation levels (UNESCO, 2023). On the one hand, the finding that in life-science instruction, where both laboratory access and computer simulations are already hierarchical, the unequal distribution of generative AI tools threatens the establishment of a two-tier educational setting, with all its inherent counterproductive effects on the inclusion objectives of assistive technology models.

Another restriction is associated with the reliance on AI and the possible effect of the latter to the epistemic agency of learners. Epistemic agent is the ability of learners to make knowledge-based assertions in a proactive manner. New critical thinking warns that allowing generative AI to do much of the explaining, synthesizing, and solving too much of the problem may squeeze out opportunity to engage in positive struggle and independent thought (Selwyn, 2023). With regard to life-science education, extensive insight hinge on progressive hypothesis-generation, analysis of anomalies and conceptual synthesis which are mechanisms that may be terribly short-circuited, in the event that AI systems relentlessly offer the correct solutions. This is why Williamson (2024) believes that learners can become passive consumers of the artificially mediated information by blindly following AI-driven innovations. This difficulty highlights the significance of pedagogical approaches that may place generative AI as a scaffold and not a substitute of cognition with an emphasis on reflective usage, scaffold fading, and express teaching on the importance of critically evaluating the products of AI-generated art.

VII. IMPLICATIONS

7.1 Pedagogical Implications

The implementation of generative artificial intelligence as an assistive technology requires a coordinated restructuring of life-science design which incorporates the use of AI-supported scaffolding as a regular part of instruction, instead of as a peripheral addition. Recent pedagogical studies also highlight the fact that AI can be most useful when paired with the adjustable sequencing, graded explanations, and multimodal presentation of complex biological concepts, which is based on the learning theory like Cognitive Load Theory and Universal Design for Learning (Mayer, 2023; Holmes et al., 2024). In education relating to life sciences, it means drying out curricula with premeditated AI-mediated scaffolds, including stepwise reasoning elicitors, interactive concept visualizations, formative feedback loops, which may be phased away to encourage learner agency.

In conjunction with the redesigning of the curriculum, the faculty training becomes a key pedagogical implication. Learning educators should also be professionally developed not just in operational application of the generative AI tools but, also, in efficient ethical incorporation, timely literacy and critical thinking over AI-produced material. Research also shows that in the absence of proper training, an instructor can either not fully leverage the inclusive capabilities of AI or will overuse it in a manner that would undermine academic rigor and agency of the learner (Holmes, 2024). Ethical judgment, scaffold fading, and reflective pedagogical decision-making must therefore be the main emphasis of faculty development programs.

7.2 Policy Outcomes

In addition to the object of classroom practice, the results of this research suggest urgent policy implications of the inclusive use of AI in education. Global frameworks of international policy are progressively appreciating that in the context of non-regulatory implementation, generative AI has the potential to intensify inequality, prejudice, and epistemic hazard (UNESCO, 2023). Educational policies with a clear approach to present generative AI as an inclusion-oriented and assistive technology and regulate it by equity, transparency, and accountability principles are obviously in demand. These policies ought to outline the base requirements of accessibility, data confidentiality, and fairness in algorithms especially when applied in life sciences where incorrect information can result in severe effects.

On the university and college level, universities and colleges should come up with explicit guidance on the use of assistive AI, and these considerations should include authorization of AI usage, redesigning assessment, authentication of AI-generated information, and helping students with disabilities. According to policy analyses provided by the OECD (2024), there is a mediating relationship that exists between global AI governance principles and pedagogical practice in the everyday setting. Such guidelines applied within the institutions must be created in close collaboration with the educators, accessibility professionals as well as the students in order to make sure that AI of the generative type promotes inclusive learning, and not the reinforcement of the existing power imbalances. Combined, pedagogical and policy are used to indicate that the educational value of generative AI is more relative to technology levels than a deliberate design, ethical governance, and long-term institutional determination of inclusion.

VIII. CONCLUSION

This paper concludes that generative artificial intelligence is a radically different type of assistive technology in life science education, going beyond traditional support tools and evolving towards the adaptive, dialogic, and multimodal systems of learning. Current educational studies note that generative AI has the potential to offer personalized learning due

to the lineup of explaining individual and varied learning, offering alternative forms of representation, and responsive feedback in scholars who are diverse (Giannakos, 2024). These abilities are especially relevant in cognitively challenging life science subjects, including biology, medicine, biotechnology, and so on, they help students to make their way through abstract processes, thick vocabulary, and complex causal relationships on a multi-level. Viewing technology as a proforma science is much more beneficial, i.e. as an assistive technology, as it enhances learner engagement, agency, and access to concepts thus supporting the inclusive educational goals instead of disciplinary purism.

The success of generative AI as an assistive technology, though, depends on an ethical utilization, pedagogic adaptability, and design based on the concept of accessibility. In approaches where the uncritical use of AI will inevitably reproduce bias, misinformation, and inequitable access, ethical reasoning cautions that methods to apply AI must be viewed as probabilistic instruments, and it is essential not to treat AI systems as sources of knowledge themselves (Floridi, 2023). It is vital that pedagogical choice is based on the applicable theories in learning, including Cognitive Load Theory and Universal Design that Learning, in order to guarantee that AI-based scaffolding fosters cognition instead of passive consumption. Design that focuses on accessibility also assumes that institutions should deal with infrastructural disparities, faculty training and integrating verification and transparency systems into instructional practice (UNESCO, 2023). This set of conditions highlights that regardless of technological newness, the use of generative AI has an educational value that people purposefully and intentionally rely on.

THE FUTURE RESEARCH DIRECTIONS

This research projects places some crucial future research directions. Although the current analysis is approached qualitatively and guided by theories, there is a definite necessity of mixed-method and empirical classroom-based research studies investigating the application of generative AI in real-life learning contexts of life sciences. Further studies on the outcomes of learning methods, cognitive and equity effects in varied institutional settings should consider the outcomes of qualitative knowledge and combine them with observational and longitudinal data (Creswell, 2018). Besides, the current state of the critical scholarship should proceed with an attempt to define how AI-mediated learning reshapes epistemic agency, assessment practice, and the professional identity of teachers (Selwyn, 2023). This kind of research will be a critical step towards transitioning between the promise of the concept and evidence-supported practice and in making certain that generative AI can play a role in inclusive, ethical, and efficacious life-science learning.

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