

Assessment Strategies for Learning Outcomes in Light of the Fourth Sustainable Development Goal (SDG 4): A Descriptive Study of AI Opportunities and Challenges

Osayd Sulayman Fatayer 1*, Zahera A. Baniamer 2

Type: Full Article. Received: 31 January 2025, Accepted: 23 January 2026

Accepted Manuscript, First Online

Abstract: Objective: In response to the need for pedagogical innovation, this descriptive study explores the role of artificial intelligence (AI) in enhancing assessment strategies that capture foundational competencies and complex cognitive processes. It examines the connection between technological capabilities and educational equity in light of the Fourth Sustainable Development Goal (SDG 4). **Methodology:** Based on a descriptive-analytical approach, a comprehensive review of leading peer-reviewed international studies and policy documents was conducted. Dominant AI-augmented evaluation systems were analyzed against a framework focusing on fairness and accessibility. **Key Findings:** AI-enhanced adaptive testing improves assessment accuracy and enables targeted interventions. Predictive analytics can forecast learning trajectories, and computerized feedback systems provide personalized instruction. However, three main obstacles remain: algorithmic bias from flawed training data, inadequate institutional capacity to implement AI systems, and a lack of unified regulations to protect data confidentiality. **Conclusions:** Integrating AI into educational assessments presents transformative opportunities. Yet, realizing this potential requires overcoming critical ethical, technical, and institutional barriers to ensure equitable education for all. **Recommendations:** The study proposes an inclusive multi-modal assessment model that seamlessly incorporates AI tools into conventional assessments. Key recommendations include devising detailed governance procedures for data privacy and algorithmic transparency, investing in infrastructure and personnel training, and fostering collaborative feedback systems. **Keywords:** Artificial Intelligence, SDG 4, Educational Testing, Algorithmic Bias, Inclusivity, Data Confidentiality.

استراتيجيات تقييم مخرجات التعلم في ضوء الهدف الرابع من أهداف التنمية المستدامة (SDG 4): دراسة وصفية

لفرص وتحديات الذكاء الاصطناعي

أسيد سليمان فطائر 1*، زاهرة بني عامر 2

تاريخ التسليم: 2025/01/31 تاريخ القبول: 2026/01/23

الملخص: الهدف: استجابة لضرورة الابتكار التربوي، تستكشف هذه الدراسة الوصفية دور الذكاء الاصطناعي (AI) في تعزيز استراتيجيات التقييم التي تقيس الكفاءات الأساسية والعمليات المعرفية المعقدة، وتبحث العلاقة بين التقنيات الحديثة والإنصاف التعليمي في ضوء الهدف الرابع من أهداف التنمية المستدامة (SDG 4). **المنهجية:** بالرجوع إلى المنهج الوصفي التحليلي، أجريت مراجعة شاملة لأبرز الدراسات ووثائق السياسات الدولية المحكمة. وتم تحليل أنظمة التقييم البارزة المعززة بالذكاء الاصطناعي بناءً على إطار يركز على العدالة وإمكانية الوصول. **أهم النتائج:** تعمل منصات الاختبار التكيفية المعززة بالذكاء الاصطناعي على تحسين دقة التقييم وتمكين التدخلات الموجهة. ويمكن للتحليلات التنبؤية توقع مسارات التعلم، بينما توفر أنظمة التغذية الراجعة المحوسبة تعليمات مخصصة. ومع ذلك، تبرز ثلاث عقبات رئيسية: التحيز الخوارزمي الناتج عن بيانات تدريب معيبة، وضعف القدرة المؤسسية لتنفيذ الأنظمة، وغياب اللوائح الموحدة لحماية سرية البيانات. **الاستنتاجات:** يوفر الذكاء الاصطناعي إمكانات تحويلية للتقييم التربوي. إلا أن تحقيق فوائده للتعليم الشامل يتطلب معالجة التحديات المتعلقة بالعدالة الخوارزمية والجاهزية المؤسسية والأخلاقية. **التوصيات:** تقترح الدراسة نموذج تقييم شامل متعدد الوسائط يدمج الذكاء الاصطناعي بسلاسة في التقييم التقليدي. وتوصي بوضع إجراءات حوكمة تفصيلية لخصوصية البيانات وشفافية الخوارزميات، والاستثمار في البنية التحتية وتدريب الكوادر. **الكلمات المفتاحية:** الذكاء الاصطناعي، الهدف الرابع للتنمية المستدامة، التقييم التربوي، التحيز الخوارزمي، الشمولية، سرية البيانات.

1. Assistant Professor, Dept. Of Islamic Banking, Faculty of Sharia, An-Najah National University, Nablus, Palestine. Email: osayd.f@najah.edu, ORCID: <https://orcid.org/0009-0001-6396-2237>

2. Teacher, Ministry of Education, Jordan/Irbid, Email: Zahera.bnmr@gmail.com, ORCID: <https://orcid.org/0009-0008-1775-2109>

* Corresponding author

1- أستاذ مساعد، قسم المصارف الإسلامية، كلية الشريعة، جامعة النجاح الوطنية، نابلس، فلسطين.

2- معلم، وزارة التعليم، إربد، الأردن
*الباحث المراسل

First: Introduction

Artificial intelligence use in education is no longer a possible idea in the future but a growing field that can have huge implications in terms of economic and pedagogical sustainability. The global AI in education market, valued at USD 3.43 billion in 2023, is projected to grow at a compound annual growth rate (CAGR) of 35.96% to reach USD 54.5 billion by 2032 ([Knowledge Sourcing Intelligence LLP, 2025](#)). This technological surge places a new imperative on educational systems to evolve, and educational assessment, in particular, must adapt to address the demands of the fourth industrial revolution, ensuring that learning environments promote inclusive, equitable, and quality education in line with SDG 4 ([Palomares et al., 2021](#); [Zawacki-Richter et al., 2019](#)). Traditional summative approaches, which often provide only a snapshot of learner performance, are ill-suited to capture the complex, multifaceted competencies required in today's digital era ([Zawacki-Richter et al., 2019](#)). As digital technologies permeate every domain of society and the economy, assessment strategies must transition from static, one-off tests toward dynamic, continuous evaluation models that can adapt to diverse learner profiles and emerging educational needs ([Palomares et al., 2021](#)).

Innovations in the field of artificial intelligence provide unequalled opportunities to reinvent the assessment practices. AI-driven platforms can deliver real-time, personalized feedback, monitor socio-emotional engagement, and scaffold higher-order thinking skills, thereby transforming how educators measure and support student learning ([Shafiee Rad et al., 2023](#); [Swiecki et al., 2022](#)). For example, natural language processing tools analyze student writing for conceptual growth, while learning analytics detect patterns in interaction data to predict learning trajectories and recommend tailored interventions ([Shafiee Rad et al., 2024](#)).

Nonetheless, deploying AI in assessment raises ethical concerns—such as algorithmic bias, data privacy, and transparency—that must be addressed to preserve fairness and trust ([Swiecki et al., 2022](#)).

Research Gap

Despite the proliferation of AI-enabled assessment studies, existing research often examines adaptive testing, predictive analytics, or automated scoring in isolation, without integrating these components into a cohesive evaluative framework ([Zickafoose et al., 2024](#)). Moreover, most investigations lack longitudinal designs that track the sustained impact of AI-driven assessments on learning outcomes, especially across culturally and socio-economically diverse contexts ([Zickafoose et al., 2024](#)). Scholarship on the governance measures that would reduce the influence of algorithms on bias but, at the same time, be accessible to everyone is lacking as well. This paper fills these gaps by suggesting a multi-modal assessment model that integrates adaptive testing, formative analytics, and ethical governance and empirically tests its capacity to support the achievement of goals SDG 4.

1.1 Background of the Study and Its Importance

Education has experienced significant upheaval over the last few decades, with technology creating new chances for digital tools to pervade instructional processes across all learning domains. Artificial intelligence (AI) is one of the key parts of the fourth Industrial Revolution that will alter educational assessment. Students receive customized instruction and real-time performance assessments via AI technology, which benefits both learners and teachers.

International education systems are seeking to improve their effectiveness and quality, and AI has the ability to achieve both equity and inclusion. "Artificial intelligence can help fulfill Sustainable Development Goal 4 more effectively since it offers customized

assessment methods for a variety of learner groups ([Palomares et al., 2021](#))".

This study formulates a cohesive descriptive framework to examine AI-driven evaluations of learning outcomes, while assessing the principal benefits and challenges associated with the implementation of SDG4. This study contributes to theoretical examinations of digital educational evaluation by investigating how artificial intelligence might improve measurement accuracy while also providing immediate feedback capabilities. The study provides practical guidance for educational leaders and politicians in making AI technologies available securely and evenly across all parts of the population.

This research provides substantial value by effectively integrating smart technology into the ethical frameworks, educational standards, and societal advantages of educational institutions. Student assessment serves as both a pedagogical and ethical activity, preserving students' rights while also protecting their dignity and privacy, yet it is nevertheless plagued by potential algorithmic biases and personal information vulnerabilities. "AI assessment deployment necessitates fast practical application in order to give improved fairness and educational quality that benefits all students, particularly marginalized ones ([Shafiee Rad et al., 2024](#))".

1.2 Statement of the Problem and Research Questions

The major issue of this research can be described in the following overall question: The study of learning outcomes using artificial intelligence approaches has the potential to contribute to Sustainable Development Goal 4, while also addressing inclusiveness and fairness issues.

This main question leads to a series of sub-questions:

1. What key characteristics define the current AI applications that are utilized to analyze learning outcomes across international systems?

2. To what extent does the use of AI assessments align with the SDG4 framework for inclusive and equitable learning?
3. What are the main institutional, ethical, and technical obstacles preventing the best possible use of AI in assessment systems?
4. What are the practical planning recommendations for directing AI tool investment toward improved educational delivery across all demographics?

1.3 Objectives of the Study

1. Descriptive Objective: The diverse assessment landscape now prominently features advanced AI-based tools that are specifically designed with a focus on the authentication of multiple academic goals. These goals encompass various aspects, including the retention of educational content, the development of practical abilities, as well as a thorough understanding of theoretical concepts. This holistic approach ensures a more comprehensive evaluation of student learning outcomes and academic performance.
2. Analytical Objective: The paper investigates the implementation challenges of these technological solutions using SDG4 Equity Standards and ethical concerns as they interface with pedagogical standards.
3. Propositional Objective: Establish a workplace-ready system for evaluating student accomplishment results using AI applications that combine boosted assessment efficiency with educational equity. ([Halagatti et al. 2023](#); [Khlaif et al., 2025](#)).

1.4 Definitions of Key Terms

1. Artificial Intelligence (AI): Systems and software demonstrate human intelligence to accomplish tasks which need thinking abilities alongside learning features and decision-making "intelligence." Machine learning tops the list within this diverse

cluster which contains neural networks and related subfields.

2. **Learning Outcomes:** Educational outcomes consist of knowledge while also including skills and values when learners finish their course or educational program. These outcomes cover a wide range of cognitive and practical abilities. ([Koivisto & Grassini, 2023](#)).
3. **SDG4 (Fourth Sustainable Development Goal):** This education objective works to deliver quality education equally to all while both supporting learning throughout life and welcoming students from any background. The realization of this goal requires assessment tools that function as both equitable and powerful learning measurement methods.
4. **Educational Assessment:** The system uses processes combined with practices to both evaluate outcome success from reaching curricular targets and determine learner success in mastering defined competencies.
5. **Data Privacy:** Student data requires protection through this principle which ensures both security against exploitation and unauthorized public disclosure.
6. **AI-based adaptive assessment** can model learners' knowledge states and item difficulty over time, enabling assessment content to be adjusted in response to learners' prior performance ([Murtaza et al., 2022](#)).
7. **Predictive Analytics:** Advanced mathematical systems combined with artificial intelligence algorithms perform the task of student behavior and academic achievement prediction.
8. **21st-Century Skills:** Students must possess advanced communication abilities together with collaborative skills and problem-solving expertise while also demonstrating critical thinking expertise and creative aptitude and proficiency with modern technology.

9. **Intelligent Feedback:** Artificial Intelligence technology processes student responses to generate specific guidance which enhances their academic achievements and helps them develop individually ([Khan et al., 2021](#)).

Second: Theoretical Framework and Previous Studies

Research on assessment strategies that are specifically intended to successfully implement Sustainable Development Goal 4 (SDG 4) focuses extensively on the various and diverse ways in which artificial intelligence (AI) and digital technologies engage dynamically with the ongoing and transformative reforms within higher education systems across the globe. Scientific evidence documenting this intricate and highly significant area of study reveals inconsistent patterns that are largely attributable to weak theoretical frameworks, as well as a notable lack of robust methodological approaches employed in the numerous studies that have been conducted. This apparent discrepancy highlights the critical need for more rigorous, comprehensive, and in-depth research efforts to better comprehend the complex connections and dynamics between technology and educational reform attempts. A detailed and nuanced knowledge of these relationships is vital to guarantee that the solutions created are not only effective in reaching their desired results but also resilient over time in varied learning environments... ([Pigola et al., 2021](#)).

2.1 AI and Digital Technologies in SDG 4 Implementation

The theoretical foundation of this study rests on four main pillars:

1. **SDG4:** The SDG4 ensures an education system which provides “inclusive” and “equitable” and “quality” learning opportunities to all students throughout their whole life through “lifelong learning opportunities.” Realizing this goal needs consistent support between governments educational establishments and civil

society to utilize digital technologies particularly AI as promising accelerators to achieve comprehensive development throughout the educational journey.

2. **Assessing Learning Outcomes:** Educational assessment serves as an essential tool to enhance teaching and learning quality through specific measurements, which assess both curricular objective attainment and students' acquisition of conceptual and technical abilities. Instead of traditional theoretical information retention, current educational concerns focus evaluating student creativity, critical thinking ability, and problem-solving skills ([Zickafoose et al., 2024](#)).
3. **AI in Educational Assessment:** AI technology has the unrivaled ability to change the way we measure educational attainment results. Standardized answer grading is already available through automated systems, and educational tests dynamically change their difficulty levels based on student engagement. Educational systems use predictive analytics to identify student learning difficulties before complications arise, allowing teachers to provide customized assistance.
4. **Opportunities and Challenges:** Despite its valuable advantages of precise measurements combined with personalized feedback delivered immediately and broader inclusion chances, AI generates serious concerns because of algorithmic bias alongside privacy problems and a shortage of appropriately trained staff. Resolving these problems demands both solid ethical standards and proper laws. ([Lambert & Stevens, 2024](#)).

2.1.1 Main Dimensions of AI-Driven Assessment: From Pedagogical Constructs to Technical Components

To clarify how AI integrates with educational objectives and fairness

considerations (SDG4), we can focus on four key dimensions:

1. Pedagogical and Philosophical Dimension

- **Self-Directed and Active Learning:** Opportunities for students to consistently engage in and follow their personal development journeys help them to build meaningful and significant learning achievements through ongoing progress oversight and reflection on their experiences. By taking charge of their own learning, students can better navigate challenges and harness their potential for growth.
- **Inclusivity and Equity:** Because AI tools are designed to respond to a wide range of learning situations and adapt to diverse contexts, they will provide equal benefits and support to all students, including those who are disabled or suffer economic issues. "This guarantees that all students have access to the resources needed for academic and social success" ([Fitria, 2021](#)).

2. Technical Dimension of Algorithms

- **Machine Learning:** The system develops advanced forecasting algorithms designed to detect intricate patterns in educational performance, while also reviewing subjective assessments, thus enabling a more comprehensive understanding of learning outcomes.
- **Neural Networks:** Writing and expressive skill assessments have become increasingly sophisticated over time, yet they still require extensive and diverse datasets to effectively prevent biases while simultaneously enhancing testing precision and accuracy in evaluations.
- **Adaptive Assessment:** Real-time performance adjustment is a critical process that occurs through sophisticated algorithms designed

specifically for educational environments. These algorithms identify and select questions by carefully matching the individual mastery levels of students, ensuring that each learner receives personalized and targeted questions that align with their current knowledge and skills. This approach enhances the learning experience and promotes effective mastery of the material ([Wu et al., 2024](#)).

3. Digital Infrastructure

- **Databases:** Because of their proven effectiveness, AI-based assessment systems require extensive and comprehensive databases to gather valuable statistics on student performance, as well as important information regarding their demographic backgrounds and records of academic advancement.
- **Technical Readiness:** To effectively assess students, all educational institutions must guarantee reliable and trusted technology platforms, alongside efficient software, by providing continuous online service coverage. This commitment extends to ensuring accessibility to every education site, regardless of how isolated or remote the locations may be. Providing such robust support is essential to foster learning environments that are equitable and inclusive for all students, thus enabling them to thrive academically.
- **Cybersecurity:** The system requires a robust and secure infrastructure in order to effectively protect personal data against various breaches and also to prevent any forms of improper use that could compromise sensitive information ([Murtaza et al., 2022](#)).

4. Ethical and Legislative Dimension

1. **Privacy Protection:** Student data usage requires careful oversight and

management to ensure that it remains compliant with the established guidelines outlined in the European General Data Protection Regulation, as well as other similar data protection requirements that may vary across different jurisdictions. It is crucial to implement necessary measures to safeguard personal information effectively.

2. **Algorithmic Transparency:** System users need educational information regarding algorithm working principles along with an understanding of how systems handle different learner attributes. Openness within systems helps discover biases that hide behind opaque seals.
3. **Accountability:** A comprehensive and effective legal system must create clear and enforceable responsibilities, especially when faulty assessment results significantly affect student acquisition of knowledge or influence educational direction and choices. This responsibility is crucial to ensure that all students receive the quality education they deserve and that their academic journeys are not hindered by inaccuracies in assessments.

The essential continuation of fair treatment remains central to all education assessment efforts. AI integration for educational assessments requires an integrated system of technical elements alongside pedagogical social and ethical aspects which embody SDG4 standards. The International Journal of Educational Technology in Higher Education published [Zawacki-Richter et al. \(2019\)](#) which shows that AI creates enhanced personalization for teaching and assessment, with pedagogical, social, and ethical dimensions that reflect the spirit of SDG4 ([Laak & Aru, 2024](#)).

2.2 Literature Review

The body of literature concerning the implementation of Sustainable Development Goal 4 (SDG 4) and the role of Artificial Intelligence (AI) reveals a complex landscape of pedagogical challenges, institutional barriers, and technological opportunities. Thematic synthesis of more recent entries indicates a number of important areas of overlap and non-overlap.

2.2.1 Pedagogical and Institutional Barriers to the SDG 4 Implementation

Another substantial theme of the literature is the wide array of selection of systemic barriers that inhibit successful integration of SDG 4 in various settings of education. It has also been revealed that lack of obvious governance and resource imbalance acts as the major hindrance to progress. For instance, a study in South Africa by [Nyika \(2024\)](#) revealed that while universities have adopted sustainability principles, they suffer from a lack of definitive governmental guidelines and persistent issues in teacher training and funding distribution. Similarly, research in China by [Lin \(2024\)](#) identified significant mismatches between academic course design and practical, hands-on learning experiences, coupled with ineffective teaching methods that limit student engagement with SDG 4.7 concepts.

These institutional problems are multiplied by pedagogical problems. Frequently, traditional models of assessment are ill-suited to gauge the complex competencies that SDG 4 advocates, such as critical thinking and collaboration. [Chamba and Chikusvura \(2024\)](#) argue that the education system in Zimbabwe requires a fundamental reimagining of assessment practices, moving beyond traditional knowledge tests to integrated frameworks that can evaluate a wider range of mental skills and communication abilities. This has shown that there is a relative agreement that SDG 4 needs more than a policy alteration, but a paradigm shift in the way of teaching and assessment.

2.2.2 AI and Data Analytics Potential in the Assessment

Responding to such pedagogical issues, scientists are discussing the use of AI and data analytics as revolutionizing tools. The technologies provide a potential to design more detailed and real-time evaluations of student progress. A study by [Jokhan et al. \(2022\)](#), for example, successfully used a Random Forest classification prediction model to determine student success in an IT literacy course with 97.03% accuracy, highlighting AI's powerful capacity to enable revolutionary early intervention approaches. But the same research points out that this potential comes with major ethical considerations on the security of data and data algorithm discrimination that needs to be looked into deeply. While some research, such as a study in Nigeria by [Adamu \(2022\)](#), shows positive short-term outcomes for students taught by teachers trained in SDG 4 programs, the lack of a longitudinal component makes it difficult to assess the long-term sustainability of these gains.

This review shows that although AI has valuable implications on assessment, its effective and fair application is subject to resolving the underlying challenges in policies, the formation of pedagogy, and uniform evaluation, because numerous inconsistency and disparity noted in studies suggests applied AI reflects the governance or delivery channel.

2.2.3 Policy Framework and Assessment Standard Loopholes

The third overwhelming theme is the continued absence of standard mechanisms of institutionalizing and assessing SDG 4 among the institutions and countries. [Ferrer-Estévez and Chalmeta \(2021\)](#) conducted a methodical investigation into techniques for integrating SDGs into curricula and confirmed that the absence of standardized evaluation criteria remained a persistent issue. Although their research identified a very useful framework, it failed to establish concrete guidelines on how this framework could be applied by other

school systems in other regions in the globe. On a macro level, research by [Huan et al. \(2021\)](#) developed a composite index for tracking SDG implementation across 15 nations, providing an evidence-based method for assessing policy outcomes. However, this macro-level strategy is not tenable at the individual institutional level research level implying that micro-level studies should be carried out to substantiate the research proposal.

2.3 Theoretical and Empirical Gaps

Despite the growing body of research on SDG 4 implementation, key inconsistencies persist:

- Variability in AI adoption: Some studies show that AI evaluation methodologies provide accurate insights, while others produce contradictory results (e.g., [Jokhan et al., 2022](#)). Critical investigations demonstrate both the hazards of adjustment bias and system accessibility issues.
- Policy and institutional disparities: Research from China ([Lin, 2024](#)), South Africa ([Nyika, 2024](#)), and Nigeria ([Adamu, 2022](#)) SDG 4 implementation experiences unequal integration because districts face financial obstacles alongside governance problems in their journey to progress.
- Lack of long-term impact studies: Most research examines SDG 4 using cross-sectional analysis that does not track how programs will endure over time and scale beyond current capacities.

Numerous findings emerge throughout the variety of examined studies concerning assessments of Sustainable Development Goal 4 (SDG 4), which reveal significant limitations in the connections observed between artificial intelligence analyses and the available digital resources, alongside existing educational regulations. In order to advance this field, future research must prioritize the establishment of standardized assessment

methods, ensuring they are consistent across various contexts. Furthermore, it is imperative to extend the data collection processes over time. This should be done while conducting comprehensive cross-country analyses. Such efforts will be essential in fostering a policy-focused understanding of the implementation processes related to SDG 4, ultimately contributing to more effective strategies in educational development on a global scale.

Third: Study Methodology and Procedures

3.1 Research Design and Methodological Framework:

This research adopts a structured **descriptive-analytical approach**, utilizing an **Integrative Literature Review** design. Given the complex nature of the Fourth Sustainable Development Goal (SDG 4) and its intersection with rapidly evolving Artificial Intelligence (AI) technologies, a qualitative descriptive design was selected as the most appropriate framework. As defined by Snyder (2019), the integrative review method is sophisticated enough to combine diverse streams of data—including theoretical papers, empirical studies, and international policy reports—to create a holistic conceptual model. Unlike systematic reviews that focus strictly on statistical meta-analysis of primary data, this descriptive approach allows for a broader evaluation of how AI assessment strategies align with the ethical and pedagogical mandates of equity and inclusion. The study aims to describe the "state of the art" in AI assessment, deconstruct its mechanisms, and critically analyze its potential to achieve learning outcomes without conducting a field experiment or census.

3.2 Data Collection Strategies To ensure the scientific rigor of this descriptive study, a systematic data collection protocol was implemented based on strict inclusion and exclusion criteria. The researchers focused on secondary data sources that provide high-level evidence regarding AI implementation in education.

3.2.1 Information Sources The study drew from three primary pools of knowledge to ensure a comprehensive perspective:

1. **Academic Databases:** A comprehensive search was conducted in high-impact databases, specifically **Scopus, Web of Science, and ERIC**, to locate peer-reviewed articles addressing technical and pedagogical aspects of AI.
2. **International Reports:** To cover the policy dimension of SDG 4, the study included official publications from **UNESCO, the OECD, and the World Bank**. These documents are essential for understanding the global governance frameworks and the "Education 2030" agenda.
3. **Grey Literature:** Technical white papers and reputable educational technology reports were reviewed to understand the latest capabilities of adaptive learning systems and algorithmic fairness.

3.2.2 Search Protocol and Keywords The search strategy utilized Boolean operators to combine key constructs effectively. The primary search strings included: ("Artificial Intelligence" OR "AI-driven Assessment" OR "Adaptive Testing" OR "Predictive Analytics") AND ("Learning Outcomes" OR "Competencies" OR "21st Century Skills") AND ("SDG 4" OR "Inclusion" OR "Equity" OR "Fairness").

3.2.3 Time Frame In response to the rapid pace of technological change, **the time frame for the literature review was strictly set from January 2015 to December 2024**. This period was deliberately selected to align with the inception of the Sustainable Development Goals (SDGs) in 2015 and to capture the most recent literature on Generative AI and Large Language Models (LLMs) that have emerged in the post-2022 era.

3.3 Data Analysis: Inductive Qualitative Content Analysis To process the collected

information, the study employed **Inductive Qualitative Content Analysis**. This method goes beyond simple summarization to interpret the underlying meaning of the text (Elo & Kyngäs, 2008). The analysis proceeded through three rigorous phases:

1. **Preparation Phase (Open Coding):** The researcher read the selected documents extensively to obtain a sense of the whole. Key segments of text related to "opportunities" (e.g., personalized feedback, early intervention) and "challenges" (e.g., algorithmic bias, data privacy, digital divide) were highlighted and assigned initial codes.
2. **Organization Phase (Categorization):** These codes were grouped into higher-order categories based on semantic similarities. For instance, codes related to *internet access*, *device availability*, and *teacher training* were synthesized under the category of **"Institutional and Infrastructural Barriers"**. Similarly, codes related to *measuring critical thinking* were grouped under **"Pedagogical Enhancements"**.
3. **Abstraction Phase (Synthesis):** Finally, the emerging categories were mapped against the specific targets of SDG 4. This process allowed the researchers to move from specific technical descriptions to general theoretical conclusions about the role of AI in promoting quality education.

3.4 Study Limitations As a descriptive review, this study acknowledges certain limitations. The analysis relies on secondary data and does not involve primary fieldwork or statistical testing of student performance. Furthermore, the findings are limited by the availability of literature, which is predominantly centered on developed contexts, potentially affecting the generalizability to low-income regions targeted by SDG 4.

Fourth: Discussion and Analysis

Improving outcomes for children, as clearly outlined in the Fourth Sustainable Development Goal, emphasizes the crucial importance of accountability, assessment, and measurement within our education systems to ensure that we are making tangible progress. The overarching aim of SDG 4.1 is for all girls and boys to achieve equitable, quality primary and secondary education by the year 2030, with a particularly strong focus on enhancing global learning outcomes across diverse contexts and communities. In the past decade, the introduction of standardized high-stakes testing has led to an impressive figure, with approximately half a billion children worldwide preparing diligently for these assessments each year. This substantial trend of reaching high-stakes testing is rooted on substantive issues, which show that the inputs provided by traditional education processes were no longer achieving the desired outcomes in terms of learning. As a result, testing and accountability have become increasingly important tenets of educational governance reforms at the global, regional, and national levels, aligning closely with the widely recognized "Education for ALL" initiative, which seeks to ensure quality education for all children, regardless of background. ([Bhatia et al., 2024](#)). New technologies based on AI are revolutionizing the evaluation process by using automated grading and adaptive, real-time personalized feedback. This innovative process not only boosts efficiency but also demands the integration of ethical safeguards to block biases, thereby providing an equitable educational setting that supports the ideals of SDG4 ([Swiecki et al., 2022](#)).

4.1 Alignment of AI Strategies with Learning Outcome Domains To address the study's core objective regarding "Learning Outcomes," it is imperative to analyze how AI tools impact specific domains of student performance. The synthesis of the literature

reveals that AI transforms assessment across three critical dimensions:

- **Cognitive Learning Outcomes:** Traditional assessments often focus on recall. However, AI-driven adaptive platforms utilize Natural Language Processing (NLP) to evaluate higher-order thinking skills. These tools can assess a student's ability to *analyze* and *create*, providing a valid measure of the deep learning required by SDG 4.1.
- **Skill-Based and Practical Outcomes:** For technical and vocational skills (SDG 4.4), AI simulations and virtual labs offer a dynamic assessment environment. In these scenarios, the algorithms analyze the *process* of problem-solving—tracking decision-making steps in real-time—rather than just grading the final result.
- **Affective and Social Outcomes:** A significant advancement is the use of AI to monitor socio-emotional learning. Through engagement tracking, systems can infer outcomes related to motivation and ethical reasoning, which are vital for the Global Citizenship Education component of SDG 4.7.

4.2 Evaluating AI-Based Strategies for Assessing Learning Outcomes in Light of SDG4

SDG4 emphasizes inclusive and equitable education. AI-based evaluation necessitates the creation of digital platforms that include learning solutions for students with disabilities, as well as dynamic assessments tailored to learners in small communities.

- **Digital Inclusion:** Public institutions and various levels of government are required to efficiently supply essential infrastructure, which includes a diverse range of devices, reliable internet access, and comprehensive technical support services, with a focus on underserved areas that currently lack these vital services.

- **Fairness in Assessment:** Computer-based exam systems require the integration of unbiased algorithm components, which are crucial for ensuring fairness and equity in assessments. Additionally, it is essential to include multiple linguistic and cultural choice options that cater to the diverse backgrounds and needs of learners. Such features not only enhance accessibility but also promote a more inclusive examination environment for all students ([Algahtani, 2024](#)). In addition, educational assessments intended for integration into SDG 4 evaluation should be reviewed for alignment with relevant learning standards, psychometric quality, representativeness, and transparency of procedures ([Pineda & Sandoval-Hernández, 2023](#)).

4.2.1 Learning-Outcome Dimensions

Assessment environments made possible by AI support the tracking of the learner through the entire range of digital Bloom with its foundational reflexes of recall and creative construction of knowledge. Adaptive item generation, supported by real-time analytics, elevates performance within the “evaluate” and “create” strata, thereby cultivating higher-order cognition ([Anderson & Krathwohl, 2001](#)). In parallel, the OECD Future-Ready Skills Framework emphasises metacognitive, socio-emotional and ethical competencies; empirical patterns in this study indicate that the examined platforms foster collaboration, resilience and responsible AI literacy—skills forecast to dominate 2030 labour markets ([OECD, 2026](#)). Consequently, AI-driven diagnostics articulate multidimensional growth trajectories that permit finely tuned, equitable intervention pathways for diverse learner profiles ([Khlaif et al., 2025](#)).

Besides the collation of skills it is also important to examine how the AI-driven assessment has a direct impact in learning

directly as the assessments help in building learning outcomes. The provision of immediate, personalized feedback, as highlighted in the study's findings, serves as the primary engine for this transformation. Such immediate feedback loop is not just providing error correction, but it creates the cycle of constant connection and self-regulation since students become engaged in thinking and constantly monitor their reactions and thinking pattern. Research indicates that immediate and valid AI-supported feedback can improve learning outcomes, motivation, engagement, self-regulation, and retention by encouraging learners to reflect on their own learning ([Hooda et al., 2022](#)). Consequently, the worth of AI measure goes beyond being efficient, but in the ability to redefine assessment as a summative value to a process that continuously contributes to learning.

4.3 Exploring Potential Opportunities of AI

1. **Personalization:** The evaluation technique achieves a substantially greater level of precision by customizing and adjusting task difficulty to the individual learners' existing accomplishment levels. This smart method successfully reduces student dissatisfaction while improving their overall learning experience. By taking into account each learner's specific needs, the approach creates a more engaging and supportive teaching environment.
2. **Immediate Feedback:** The outstanding processing capability of automated scoring systems dramatically increases student motivation. This is accomplished by providing rapid and timely feedback that assists students in more efficiently identifying and correcting errors, hence improving their learning experience and conceptual understanding.
3. **Big Data Analytics:** A comprehensive review of collective performance data

allows educational professionals to extensively search for and identify shared student shortcomings, resulting in well-targeted and successful educational responses and interventions.

4. Evaluating High Skills: Last generation AI assessment tools leverage the power of natural language processing combined with project-based assessments to effectively measure students' abilities, particularly focusing on critical thinking and creativity skills. These innovative tools provide a more comprehensive evaluation of how students tackle complex problems and express their unique ideas ([Zhao, 2024](#)).

4.4 Implementation Challenges and Shortcomings

1. Algorithmic Bias: When training datasets are unbalanced and do not represent a wide variety of linguistic and cultural groups, they can develop biases. These biases can ultimately lead to unfair assessment outcomes, which can negatively impact specific groups of people. This lack of representation can skew results and create disparities in how individuals from different backgrounds are evaluated. Furthermore, the challenge extends beyond data representation to what is known as 'pedagogical bias,' where algorithms are optimized for narrow, easily quantifiable metrics of success (e.g., test scores) at the expense of holistic, complex competencies like creativity or ethical reasoning. This may run independently toward a constriction form of learning and teaching that averts further existing disparities regardless of whether the prepared data are demographically balanced ([O'Neil, 2016](#)). This exposes a fundamental tension between the promise of personalization

-a key opportunity of AI- and the peril of algorithmic bias. Along with the idea that the AI systems would individualize the process of learning to the needs of the student, such personalization is only as unbiased as the data it uses to train. When training data reflects existing societal biases, as warned by [O'Neil \(2016\)](#), AI-driven personalization risks not only perpetuating but amplifying these inequities. It can establish automated forms of feedback that guide marginalized learners along more constrained and predetermined curricular routes that undermine the core goal of SDG 4: ensuring equitable opportunity for every learner.

2. Data Privacy and Security: The large-scale processing of massive volumes of student data necessarily creates substantial issues, including the requirement for universal data storage solutions. At the same time, it raises important issues concerning data ownership and the potential exploitation of sensitive information. Furthermore, any disclosure of user data breaches has the potential to substantially undermine students' trust in the systems that rely heavily on these technologies for their educational and personal growth. This persistent worry emphasizes the urgency of tackling these challenges ([Takona, 2024](#)).

Herein lies another critical tension: the opportunity to leverage “Big Data Analytics” for educational improvement is directly at odds with the imperative for robust data privacy and security. Even the collection of the enormous, detailed data that can result in sophisticated forecasting places a bigger target on intrusion and brings up serious ethical questions around information collection and possible abuses. This dilemma exists beyond technical level protection and requires a governance model that can anchor the

evidence of data-driven insights and the invariableness of students to protection of privacy and data dignity.

3. **Institutional Capacity:** The educational establishment sector is presently facing a serious difficulty because to a shortage of people with a thorough understanding of IT principles. Furthermore, there is an urgent demand for qualified teachers who can effectively lead and manage AI assessment systems, including their maintenance and frequent updates.
4. **Legislative Weaknesses:** Data protection frameworks that adequately address several AI application mistakes remain unclear in many jurisdictions around the world. The lack of defined criteria and standards creates substantial issues in assuring the safety and privacy of persons affected by these technologies ([Zhao, 2024](#)).

4.5 Proposals to Overcome the Challenges

1. **Create Ethical and Legal Frameworks:** To maintain fairness and the integrity of the review process, AI-based assessments must meet strict evaluation standards that have been carefully developed. Furthermore, it is crucial that students have thorough and explicit access to the proper processes and channels in the event that they feel their evaluation was unfairly or unjustly carried out. They may successfully express their issues and look for solutions according to this access, which promotes a more equal learning environment.
2. **Constant Education for Teachers and Administrators:** "Key elements of this creative and revolutionary approach to improving the learning process include providing committed and enthusiastic educators with highly effective platform management skills, necessary analytical tools, and thorough guidance about the various algorithm constraints they may encounter" ([Pesovski et al., 2024](#)).

3. **International Virtual Workshops:** To successfully establish comprehensive global guidelines, international technical specialists should collaborate closely with educators and policymakers globally. These recommendations must provide special focus on enabling emerging countries, ensuring that their technological and educational needs are sufficiently satisfied.
4. **Multi-Modal Assessment:** Customized assessment solutions seamlessly combine powerful artificial intelligence technologies and traditional assessment methods. These methods include a range of modalities, including written examinations, in-person interviews, and interactive classroom activities. This comprehensive approach ensures a full assessment of student abilities, taking into account a variety of factors of their learning and performance. Combining these many strategies, instructors can obtain a balanced assessment that accurately reflects each student's skills and knowledge ([Bai et al., 2022](#)).

4.6 A Preliminary Prototype for an AI-Driven Assessment Platform in Light of SDG4

A successful implementation of AI-based assessment requires participatory design from stakeholders combined with inclusivity and fairness from the beginning. Key steps may include:

1. **Requirement Elicitation**
 - Facilitate comprehensive brainstorming sessions that bring together students, educators, and various marginalized groups, including individuals with disabilities as well as those from remote communities, to thoroughly articulate and discuss their unique needs and concerns related to digital assessment methods.
 - Emphasize the importance of user-interface design, making it intuitive and

user-friendly, while also highlighting accessibility features that cater to a wide range of users, including compatibility with various screen readers. Additionally, ensure that users can easily customize font styles and sizes to suit their personal preferences and needs for an optimal reading experience ([Wongmahesak et al., 2025](#)).

- More importantly, the process should proactively address power structures and communication barriers between technical experts, educators, and members of marginalized communities to ensure that co-design remains genuinely participatory rather than merely consultative ([Hussain et al., 2012](#)).

2. Collaborative Design

- Involve educators in the development of intelligent test scenarios that are perfectly in sync with established curricular standards as well as adhere to ethical guidelines. Collaborating with teachers ensures that the assessments are meaningful, fair, and promote an enriching learning experience for all students.

This co-design process is an actual strategic measure to deal with the aforementioned challenges of pedagogical bias and algorithmic bias as this will ensure that cultural-relevance of assessment scenarios and holistic definitions of success metrics are ensured.

- Work closely with technical experts in the field to carefully fine-tune algorithms and significantly reduce any potential bias present, for instance, by broadening the dataset in order to effectively capture diverse student populations. This collaborative effort is essential to ensure that the algorithms

work fairly for all groups ([Schiff, 2021](#)).

3. Development and Pilot Testing

- Begin the process by constructing an initial prototype on a suitable online platform, utilizing straightforward machine learning algorithms at the outset (for example, implementing auto-grading features specifically designed for multiple-choice items). This foundational step serves to streamline the assessment process and improve user experience.
- Evaluate the system thoroughly with a carefully selected small group of diverse students across various educational levels in order to effectively identify technical glitches and uncover potential biases that may impact the learning experience ([Bello, 2023](#)).

4. Evaluation and Enhancement

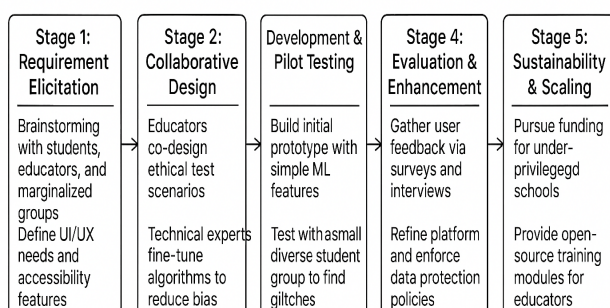
- Gather user feedback through comprehensive surveys and in-depth interviews to enhance and refine the platform significantly, while also diligently addressing any challenges that emerged during the pilot testing phase. This thorough approach will ensure a more robust and user-friendly experience for all users, contributing to the overall effectiveness and satisfaction with the platform.
- It is essential to enforce robust and effective data protection measures by establishing clearly stated and thoroughly detailed policies that pertain specifically to user accounts. Additionally, it is critical to implement comprehensive and well-structured practices regarding data privacy that effectively ensure the ongoing security and confidentiality of sensitive user information at all times ([Karunarathna et al., 2024](#)).

5. Sustainability and Scaling

- Expand the platform's accessibility to underprivileged schools by actively pursuing targeted funding opportunities while also delivering the essential institutional support that guarantees all schools have fair and equitable access to the crucial resources they require to not just survive, but to truly thrive and succeed in their educational endeavors. This initiative will contribute significantly to forging a more balanced and inclusive educational landscape for all students involved.

To address the critical challenge of institutional capacity, providing these open-source training modules is imperative. This model empowers local educators to become self-reliant in managing, modifying, and maintaining the system long-term, thereby addressing the lack of trained personnel in under-resourced settings. Provide a diverse range of comprehensive open-source training modules designed to genuinely empower local educators. These resources will enable them to efficiently administer, manage, and consistently refine the educational system, particularly in scenarios where resources are both limited and constrained. This approach ensures that educators are well-equipped to face challenges and adapt to varying situations effectively ([Karunarathna et al., 2024](#)).

A Conceptual Flowchart Guiding Sustainable EdTech Innovation



Fifth: Conclusion and Recommendations

It reviewed the contemporary environment of AI in educational assessment, assessing how it could help achieve the high-stakes objectives of Sustainable Development Goal 4 (SDG 4) through its 2030 deadline. Over the last two decades, we've seen a landscape full with both potential and obstacles. Overall, despite some focused efforts, progress has been limited and disappointing, demanding targeted and strategic interventions to genuinely meet the high targets outlined in the fourth sustainable development goal (SDG 4). Some of the key issues we identified include the urgent need for reducing stark inequalities in education access and improving overall access to quality education for all learners. At the same time, it is crucial to actively promote gender equality and strengthen global partnerships that can help tackle these pressing challenges more effectively and collaboratively.

5.1 Main Findings

This thorough research presents significant findings related to AI-based assessments that are specifically designed to enhance learning outcomes in various educational settings. It emphasizes essential principles drawn from the United Nations Sustainable Development Goal 4 (SDG4), which aims to ensure inclusive and equitable quality education for all. The following sections of this research will carefully explore these key findings in more detail, as well as their far-reaching implications in the current educational landscape, which is increasingly influenced by technology and innovative teaching methods ([Ejjami, 2024](#)).

1. AI as a Tool to Enhance Measurement Accuracy and Educational Quality

International studies along with previous research demonstrate that artificial intelligence and its machine learning and predictive analytics components provide advanced diagnostic abilities which surpass traditional assessment methods. This assessment technique enables teachers to identify student

points of weakness and provide prompt corrective information that leads to targeted intervention strategies.

2. Institutional and Legislative Frameworks Are Essential for Equity and Inclusion

The achievement of inclusive education as described in SDG4 demands a combination of technological implementation with additional policy measures. Success requires complete policies regarding infrastructure needs while also safeguarding data privacy and promoting fair algorithms through open and responsible legislation.

3. Algorithmic Bias and the Need for Diverse Datasets

Numerous studies and extensive research indicate that the reduction of student representation within training datasets leads to significant and negative repercussions for these specific populations. The problem of systemic risk will persist if adaptive testing platforms do not introduce a repetitive verification procedure. These processes should make sure that datasets are the true representations of various groups of people or that algorithms are precise and effective.

4. Educational expertise should collaborate with technical innovation to reach optimal educational results.

AI-based assessment design needs collaboration between pedagogical experts and teachers together with curriculum experts for creating measurement tools that match educational outcomes and hold meaning within specific contexts.

5. The process of creating prototypes with participatory design approaches leads to higher system acceptance rates.

The expectation of successful adoption alongside performance improvements increases when developers jointly build pilot systems with students and educators during partial development stages. When organizations involve their users in designing their collective authority strengthens combined with a perception of mutual accountability.

6. Developing Nations Require Particular Attention

Non-industrialized areas demand immediate worldwide attention because their systems lack essential digital components while training staff remain limited and regulatory programs operate inadequately. Fundamental support and strategic public-private funding helps bridge the educational gap while making Artificial Intelligence accessible to democratize learning opportunities.

7. Assessing 21st-Century Skills

Through innovative approaches AI systems demonstrate potential for measuring student abilities in critical thinking alongside creative skills and problem-solving capacity. Beyond rote memorization the system provides assessments which undertake complete evaluation of student readiness both for workplace and life challenges of contemporary society.

With the appropriate ethical, legal, and pedagogical framework firmly established, Artificial Intelligence truly emerges as an incredibly valuable and strategic tool in the realm of education. It plays a significant and transformative role in assisting educators and institutions around the world in building educational systems that are not only more equitable, accessible, and inclusive but also of higher quality overall. This remarkable advancement helps pave the way for creating an enriching environment that is highly conducive to learning, growth, and development for all learners involved. By harnessing the potential of AI, we can enhance the educational experience and ensure that students receive the support they need to thrive in their academic pursuits.

5.2 Practical and Research Recommendations

1. Encourage Field Research: Researchers should perform quantitative and qualitative examinations throughout educational institutions at school and

university and vocational education levels. They should focus on understanding how AI-assessment influences student performance particularly for marginalized groups and people with disabilities. Researchers should conduct comparisons between educational settings located in urban and rural areas.

2. **Develop National Policies:** Nationwide and regional implementation strategies should be developed for AI-driven assessment systems while establishing precise quality benchmarks which protect privacy and maintain accountability and prevent discrimination. Educational institutions must receive future mandates to provide continuous professional development for all their staff members.
3. **Support for Teachers and Administrators:** Substantial professional development should equip instructors with the skills to manage AI platforms, analyze student data, and navigate the technology's limitations. The institutions should complement their readiness through supplementary digital resources and guidebooks.
4. **Foster International Partnerships:** Universities and World Bank partners such as UNESCO should lead fundamental AI examination projects across low-income areas by promoting transparent collaboration between enterprise and educational stakeholders operating without monopolies.
5. **Design Integrated Assessment Platforms:** The fusion of AI-based evaluation technology with conventional assessments created from written examinations and oral testing systems produces an effective assessment combination for student competence evaluation. A blended assessment platform prevents users

from trusting automated models exclusively which minimizes technical flaws and algorithmic mistakes.

5.3 Suggestions for Future Research

- **Qualitative Studies on the Student Experience:** Through case studies and in-depth interviews researchers must examine how AI-based assessment practices affect learner motivation and engagement while generating different achievement results within diverse educational backgrounds.
- **Cross-Context Comparative Studies:** A study needs to investigate AI assessment technology across various territories with different digital infrastructure setups to measure their performance qualitative assurance of diverse settings.
- **Simulation Models:** The development of predictive simulation tools measures AI-powered assessment performance for students with unique learning needs alongside remote students with localization recommendations for platform adaptations.
- **Data Diversity and Bias Mitigation:** Examine typical dataset patterns and discover methods for incorporating diverse linguistic and cultural elements which will minimize bias in predictions while improving their prediction accuracy.

Statement of Derivation:

The authors explicitly declare that this study is an original and independent research work, and is **not derived**, in whole or in part, from any master's thesis, doctoral dissertation, or any academic degree requirement.

Disclosure Statement:

- **Ethical approval and consent to participate:** Not applicable. As this study is a descriptive literature review

based entirely on published secondary sources, it does not involve any direct experiments or interventions on human subjects.

- **Availability of data and materials:** Data sharing is not applicable to this article as no new primary data were created or analyzed in this study.
- **Statement of derivation:** The authors explicitly declare that this research is an independent study and is not derived from any master's thesis or doctoral dissertation.
- **Author contribution:** Both authors contributed to the conceptualization, methodology, analysis, and writing of the manuscript. Both authors read and approved the final manuscript.
- **Conflict of interest:** The authors declare that they have no competing interests.
- **Funding:** This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
- **Acknowledgments:** The authors would like to thank their respective institutions for providing the academic support necessary to conduct this research.

References:

- Adamu, A. (2022). Evaluation of sustainable development goal 4 on basic science and pupils' academic achievement in Sokoto State, Nigeria. *International Journal of Research Findings in Engineering, Science and Technology*, 4(12). <https://doi.org/10.48028/iiprds/ijrfest.v4.1.2.02>
- Algahtani, A. (2024). A comparative study of AI-based educational tools: Evaluating user interface experience and educational impact. *Journal of Theoretical and Applied Information Technology*, 102(5), 1746–1758. <https://www.jatit.org/volumes/Vol102No5/7Vol102No5.pdf>
- Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.
- Bai, J. Y. H., Zawacki-Richter, O., & Müskens, W. (2022). Developing strategic scenarios for artificial intelligence applications in higher education. In *Proceedings of the 5th International Open and Distance Learning Conference* (pp. 47–70). Anadolu University. <https://iodl.anadolu.edu.tr/proceedings-iodl-2022>
- Bello, O. A. (2023). Machine learning algorithms for credit risk assessment: An economic and financial analysis. *International Journal of Management Technology*, 10(1), 109–133. <https://doi.org/10.37745/ijmt.2013/vol10n1109133>
- Bhatia, A., Bhatia, P., & Sood, D. (2024). Leveraging AI to transform online higher education: Focusing on personalized learning, assessment, and student engagement. *International Journal of Management and Humanities*, 11(1), 1–6. <https://doi.org/10.35940/ijmh.A1753.11010924>
- Chamba, L. T., & Chikusvura, N. (2024). Future-proofing quality education using integrated assessment systems. *Quality Education for All*, 1(1), 240–255. <https://doi.org/10.1108/QEA-11-2023-0014>
- Ejjami, R. (2024). The future of learning: AI-based curriculum development. *International Journal for Multidisciplinary Research*, 6(4). <https://doi.org/10.36948/ijfmr.2024.v06i04.24441>
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107–115. <https://doi.org/10.1111/j.1365-2648.2007.04569.x>
- Ferrer-Estévez, M., & Chalmata, R. (2021). Integrating sustainable development goals in educational institutions. *The International Journal of Management Education*, 19(2), 100494. <https://doi.org/10.1016/j.ijme.2021.100494>
- Fitria, T. N. (2021). Artificial intelligence (AI) in education: Using AI tools for teaching and learning process. *Prosiding Seminar Nasional & Call for Paper STIE AAS*, 4(1), 134–147. <https://prosiding.stie->

aas.ac.id/index.php/prosenas/article/view/106

- Halagatti, M., Gadag, S., Mahantshetti, S., Hiremath, C. V., Tharkude, D., & Banakar, V. (2023). Artificial intelligence: The new tool of disruption in educational performance assessment. In *Smart analytics, artificial intelligence and sustainable performance management in a global digitalised economy* (pp. 261–287). Emerald Publishing Limited. <https://doi.org/10.1108/S1569-37592023000110A014>
- Hooda, M., Rana, C., Dahiya, O., Rizwan, A., & Hossain, M. S. (2022). Artificial intelligence for assessment and feedback to enhance student success in higher education. *Mathematical Problems in Engineering*, 2022, Article 5215722. <https://doi.org/10.1155/2022/5215722>
- Huan, Y., Liang, T., Li, H., & Zhang, C. (2021). A systematic method for assessing progress of achieving sustainable development goals: A case study of 15 countries. *Science of the Total Environment*, 752, 141875. <https://doi.org/10.1016/j.scitotenv.2020.141875>
- Hussain, S., Sanders, E. B.-N., & Steinert, M. (2012). Participatory design with marginalized people in developing countries: Challenges and opportunities experienced in a field study in Cambodia. *International Journal of Design*, 6(2), 91–109. <https://www.ijdesign.org/index.php/IJDesign/article/view/1054/455>
- Jokhan, A., Chand, A. A., Singh, V., & Mamun, K. (2022). Increased digital resource consumption in higher educational institutions and the artificial intelligence role in informing decisions related to student performance. *Sustainability*, 14(4), 2377. <https://doi.org/10.3390/su14042377>
- Karunarathna, I., Gunasena, P., Hapuarachchi, T., & Gunathilake, S. (2024). Comprehensive data collection: Methods, challenges, and the importance of accuracy. *Uva Clinical Research*, 1–24. <https://doi.org/10.13140/RG.2.2.13134.47689>
- Khan, I., Ahmad, A. R., Jabeur, N., & Mahdi, M. N. (2021). An artificial intelligence approach to monitor student performance and devise preventive measures. *Smart Learning Environments*, 8, Article 17. <https://doi.org/10.1186/s40561-021-00161-y>
- Khlaif, Z. N., Alkhouk, W. A., Salama, N., & Abu Eideh, B. (2025). Redesigning assessments for AI-enhanced learning: A framework for educators in the generative AI era. *Education Sciences*, 15(2), 174. <https://doi.org/10.3390/educsci15020174>
- Knowledge Sourcing Intelligence LLP. (2025, February). Artificial intelligence in education market—Forecasts from 2025 to 2030 (Report No. 6014292). Research and Markets. <https://www.researchandmarkets.com/report/education-ai>
- Koivisto, M., & Grassini, S. (2023). Best humans still outperform artificial intelligence in a creative divergent thinking task. *Scientific Reports*, 13, 13601. <https://doi.org/10.1038/s41598-023-40858-3>
- Laak, K. J., & Aru, J. (2024). AI and personalized learning: Bridging the gap with modern educational goals. *arXiv*. <https://doi.org/10.48550/arXiv.2404.02798>
- Lambert, J., & Stevens, M. (2024). ChatGPT and generative AI technology: A mixed bag of concerns and new opportunities. *Computers in the Schools*, 41(4), 559–583. <https://doi.org/10.1080/07380569.2023.2256710>
- Lin, J. C. (2024). Promoting education about and for sustainable development: Assessing the incorporation of SDGs in Chinese higher education. *International Journal of Sustainability in Higher Education*, 25(7), 1469–1483. <https://doi.org/10.1108/IJSHE-09-2023-0444>
- Murtaza, M., Ahmed, Y., Shamsi, J. A., Sherwani, F., & Usman, M. (2022). AI-based personalized e-learning systems: Issues, challenges, and solutions. *IEEE Access*, 10, 81323–81342. <https://doi.org/10.1109/ACCESS.2022.3193938>
- Nyika, F. (2024). Challenges of incorporating sustainable development

- goals into South African higher education curricula. *Indonesian Journal of Education and Social Sciences*, 3(2), 192–200. <https://doi.org/10.56916/ijess.v3i2.749>
- OECD. (2026). PISA 2025 assessment and analytical framework. OECD Publishing. <https://doi.org/10.1787/86c36975-en>
 - O'Neil, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy*. Crown.
 - Palomares, I., Martínez-Cámara, E., Montes, R., García-Moral, P., Chiachio, M., Chiachio, J., Alonso, S., Melero, F. J., Molina, D., Fernández, B., Moral, C., Marchena, R., de Vargas, J. P., & Herrera, F. (2021). A panoramic view and SWOT analysis of artificial intelligence for achieving the sustainable development goals by 2030: Progress and prospects. *Applied Intelligence*, 51(9), 6497–6527. <https://doi.org/10.1007/s10489-021-02264-y>
 - Pesovski, I., Santos, R., Henriques, R., & Trajkovik, V. (2024). Generative AI for customizable learning experiences. *Sustainability*, 16(7), 3034. <https://doi.org/10.3390/su16073034>
 - Pigola, A., da Costa, P. R., Carvalho, L. C., Silva, L. F. D., Kniess, C. T., & Maccari, E. A. (2021). Artificial intelligence-driven digital technologies to the implementation of the sustainable development goals: A perspective from Brazil and Portugal. *Sustainability*, 13(24), 13669. <https://doi.org/10.3390/su132413669>
 - Pineda, P., & Sandoval-Hernández, A. (2023). Guidelines for reviewing and integrating education assessments into the evaluation of SDG4 indicators. In *Global Alliance to Monitor Learning (GAML)*. UNESCO Institute for Statistics. <https://doi.org/10.13140/RG.2.2.34896.69128>
 - Schiff, D. (2021). Out of the laboratory and into the classroom: The future of artificial intelligence in education. *AI & Society*, 36(1), 331–348. <https://doi.org/10.1007/s00146-020-01033-8>
 - Shafiee Rad, H., Alipour, R., & Jafarpour, A. (2024). Using artificial intelligence to foster students' writing feedback literacy, engagement, and outcome: A case of Wordtune application. *Interactive Learning Environments*, 32(9), 5020–5040. <https://doi.org/10.1080/10494820.2023.2208170>
 - Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
 - Swiecki, Z., Khosravi, H., Chen, G., Martinez-Maldonado, R., Lodge, J. M., Milligan, S., Selwyn, N., & Gašević, D. (2022). Assessment in the age of artificial intelligence. *Computers and Education: Artificial Intelligence*, 3, 100075. <https://doi.org/10.1016/j.caeai.2022.100075>
 - Takona, J. P. (2024). AI in education: Shaping the future of teaching and learning. *International Journal of Current Educational Studies*, 3(2), 1–25. <https://doi.org/10.5281/zenodo.14541097>
 - Wongmahesak, K., Karim, F., & Wongchestha, N. (2025). Artificial intelligence: A catalyst for sustainable effectiveness in compulsory education management. *Asian Education and Learning Review*, 3(1), 4. <https://doi.org/10.14456/aclr.2025.4>
 - Wu, S., Cao, Y., Cui, J., Li, R., Qian, H., Jiang, B., & Zhang, W. (2024). A comprehensive exploration of personalized learning in smart education: From student modeling to personalized recommendations. *arXiv*. <https://doi.org/10.48550/arXiv.2402.01666>
 - Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education: Where are the educators? *International Journal of Educational Technology in Higher Education*, 16, Article 39. <https://doi.org/10.1186/s41239-019-0171-0>
 - Zhao, C. (2024). AI-assisted assessment in higher education: A systematic review. *Journal of Educational Technology and Innovation*, 6(4). <https://doi.org/10.61414/jeti.v6i4.209>

- Zickafoose, A., Ilesanmi, O., Diaz-Manrique, M., Adeyemi, A. E., Walumbe, B., Strong, R., Wingenbach, G., Rodriguez, M. T., & Dooley, K. (2024). Barriers and challenges affecting quality education (Sustainable Development Goal #4) in Sub-Saharan Africa by 2030. *Sustainability*, 16(7), 2657. <https://doi.org/10.3390/su16072657>