

# Generative artificial intelligence and sustainable higher education: Mapping the potential

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## ABSTRACT

Generative artificial intelligence (GAI) becomes widespread in higher education, and it creates new educational possibilities, with a potential to transform the educational process and promote sustainability. This study aims to explore the potential of GAI tools such as ChatGPT in promoting sustainable higher education. ChatGPT was utilized to aid the investigation at the initial stage, while the output generated was reviewed and edited by the researcher. It is indicated that GAI's integration into higher education can lead to advancements in sustainability, such as enhancing educational practices (e.g., personalized learning, automated assessment and feedback, and educators' professional development), optimizing resource utilization (e.g., digital learning resources, and efficient energy use), supporting inclusive and accessible education, and promoting environmental awareness and sustainability. Through these contributions, GAI can assist in the creation of more efficient, inclusive, and sustainable educational environments. It is suggested that higher education policies are modified and reformulated to serve sustainable development, while empirical research on GAI implementation in higher education is a necessity (most publications are theoretical/conceptual). Limitations and ethical considerations should also be addressed. The study contributes to the ongoing debate on the role of GAI for sustainability in higher education.

**Keywords:** generative artificial intelligence, ChatGPT, sustainable higher education, university, educational technology

## INTRODUCTION

Generative artificial intelligence (GAI) tools such as ChatGPT emerge as powerful technology within the higher education environments. GAI can be harnessed to enhance pedagogical practices in higher education in different ways including personalized learning, automated assessment and feedback generation, virtual assistants and chatbots, content creation, resource recommendation, time management, language translation and support, research assistance, simulations and virtual labs (Chiu, 2024; Crawford et al., 2023; Nikolopoulou, 2024). Other educational affordances that can enhance the teaching and learning experience regard collaboration and communication, accessibility and inclusivity, as well as GAI literacy (Bender, 2024; Chiu, 2024). Apart from the advantages, potential concerns, risks, and limitations are acknowledged. For example, the potential benefit for enhancing personalized learning and automating assessments/feedback raises concerns about over-reliance on automation or potential loss of educators' input (essential for fostering critical thinking and human connection in learning).

Also, while GAI aids content creation and resource recommendation, it risks reinforcing biases from its training data and lacks context sensitivity (complex topics may be simplified, potentially undermining academic depth) (Chiu, 2024; Crawford et al., 2023; Nikolopoulou, 2024). Limitations associated with GAI's language translation and support include possible lack of cultural precision, and misinterpretations (Bender, 2024); authentic language learning experiences are important for developing intercultural competencies and language skills. Another concern corresponding to students' use of simulations and virtual labs is the lack of experiential/hands-on learning, and real-world unpredictability (Nikolopoulou, 2024). With regard to GAI-mediated interactions (communication and collaboration), these reduce authentic interpersonal skill-building because the spontaneity of face-to-face engagement is missing (Chiu, 2024).

The availability of GAI to everybody via ChatGPT has made (and is making) university students aware of GAI's rapidly developing capabilities/functionality that are useful to education. These functionalities of GAI can be combined with each other and with other digital technologies to enhance and

transform education. GAI holds a transformative potential in creating more personalized, adaptive, and engaging learning experiences for higher education students (Nguyen et al., 2024), and in promoting sustainable educational systems (Shwedeh et al., 2024; Sywelem, 2024). Indicatively, GAI's integration provides prospects for enhancing sustainable higher educational systems, achieving multiple goals (such as improving student achievements, optimizing operational efficiency, and fostering sustainability practices), ethical GAI use, establishment of standards, and data security and evaluation. GAI capabilities/functions such as content creation and personalization, or scenario modeling and simulations are linked to sustainability in education. For example, GAI can create educational content tailored to different student backgrounds and needs, thus making sustainability education more accessible. AI-powered platforms that generate adaptive lessons, quizzes, or simulations related to environmental topics, may facilitate increased student engagement and understanding of sustainability topics. Environmental simulations enable students to explore the outcomes of different sustainability strategies, such as climate models or resource management scenarios; (inter)active learning via digital technology may aid students understand better the implications of sustainable practices in real-world settings.

Considering the widespread use of GAI and the importance of incorporating sustainable practices into higher education, this study was initiated. Its purpose is to explore the potential of GAI-powered tools such as ChatGPT in promoting sustainability in higher education. This paper aims to contribute to the continuing-ongoing debate on the role of GAI for sustainable higher education. This study is important because the pervasive influence of GAI applications such as ChatGPT could shape a new era in higher education, where sustainable educational practices constitute a necessity. Sustainable higher education refers to educational practices, policies within higher education institutions that integrate sustainability principles into their curriculum, operations, and research; promoting environmental, social, and economic sustainability. Sustainable educational practices encourage environmental awareness, critical thinking about global challenges, and responsible use of resources. Among others (pedagogy, access, organizational structures, ethics, equity), the implementation of GAI into higher education is associated with sustainability (Miao et al., 2021). Also, the 2030 Agenda for sustainable development includes the so-called 'education' goal (sustainable development goal 4 [SDG-4]). Incorporating AI tools into education is in line with SDG-4 (Uğraş et al., 2024).

## METHOD

The approach used was of qualitative nature, and ChatGPT was used because it is freely accessible and it was harnessed in a previous study (Nikolopoulou, 2024). ChatGPT was treated as a 'subject' (non-human interviewee) by applying the 'thing ethnography' approach, similarly to the study of Michel-Villarreal et al. (2023). The researchers adopted 'thing ethnography' approach in order to explore ChatGPT's

perspective on the challenges and opportunities it represents for higher education; it was applied as a novel/innovative approach to engage with GAI (a methodological framework to collect its perspectives). Nikolopoulou (2024) utilized it as a research assistant to explore ways of harnessing pedagogical practices. In this study, ChatGPT was used as a research assistant, at the initial stage to aid the investigation, while the output generated was reviewed and edited by the researcher. This type of approach (asking a GAI tool instead of a human subject) is new, and there is a small number of studies that applied-employed it (e.g., Michel-Villarreal et al., 2023; Nikolopoulou, 2024).

The initial-main query submitted was 'What is the potential of GAI tools to promote sustainability in higher education?' Since using ChatGPT as an interviewee provides the opportunity to ask consecutive questions/prompts for further clarification and detail (Michel-Villarreal et al., 2023), additional prompts were submitted such as 'Provide some examples of sustainable educational practices in higher education', and 'What are main sustainability principles in higher education?' The responses (output) produced were reviewed and filtered by the author in order to formulate the main distinct topics (thematic categories), on the potential of GAI tools to promote sustainability in higher education. During the process of evaluation and editing, responses that overlap (e.g., similar patterns) were eliminated. The categories were retained/modified based on the new data obtained via asking follow-up questions; this process was repeated till no new categories emerged. The distinct topics were then verified (and explored) by academic studies; the direction was to identify publications related to sustainable higher education. The classifications were enhanced and discussed with relevant recent publications identified/located via Google Scholar; the searches were performed by using main keywords of the categories. Since most findings from research studies are theoretical and conceptual, the discussion includes both claims/opinions (based on GAI's output, which is supported by and synthesized with recent literature) and empirical evidence (which derives from recent research publications).

The 'thing ethnography' approach was selected as a useful, novel methodology that allows for structured, consistent questions-prompts to be asked to capture GAI's responses. However, it is recognized that there are limitations and ethical concerns related to using such tools in educational research. A non-human tool contributed to knowledge construction process, and since GAI tools are trained on existing data, it may include biases or inaccuracies. Treating it as an 'interviewee' is associated with lack of human experience and context (often basic elements to ethnographic research). The interactions with ChatGPT were part of the methodological approach, and an effort was made to carefully and responsibly interpret the tool's insights, verify and supplement responses with recent research studies (theoretical and empirical), and build upon the output generated. Next section is about mapping the potential of GAI in promoting sustainability in higher education, followed by the discussion and the conclusions.

## MAPPING THE POTENTIAL OF GAI IN PROMOTING SUSTAINABILITY IN HIGHER EDUCATION

### Enhancing Educational Practices

Researchers highlight the transformative role of GAI tools in improving teaching and learning efficacy and effectiveness (Lameras & Arnab, 2022; Lyanda et al., 2024; Salinas-Navarro et al., 2024; Zhu et al., 2023). Enhancement of educational practices is associated with personalized learning, intelligent tutoring systems, automated assessment and feedback, and educators' professional development; such issues are reported in recent studies (e.g., Ilieva et al., 2023; Lameras & Arnab, 2022, Lyanda et al., 2024; Nikolopoulou, 2024; Zawacki-Richter et al., 2019).

With regard to personalized learning, GAI-driven platforms can adapt to individual students' learning preferences and paces, providing customized educational experiences and feedback that help students grasp concepts more effectively (with the potential to improve learning outcomes). For instance, chatbots such as ChatGPT can provide tailored answers and personalized support, by addressing students' individual learning needs, offering additional resources, or helping them understand complex concepts (Ilieva et al., 2023; Zhu et al., 2023). Students are at the forefront of the personalized learning process in GAI environments (Lameras & Arnab, 2022). GAI's function in providing personal assistance and support connects to Vygotsky's work and the zone of proximal development which highlights the degree that students can quickly develop when assisted (Crompton & Burke, 2023). GAI in personalized learning aligns with socio-constructivism by fostering adaptive, interactive environments that support collaborative knowledge-building; aligning with Vygotsky's emphasis on social interactions/learning. Cognitive theories (e.g., by Piaget and Bruner) can be associated with GAI's role in scaffolding, adjusting content to match learners' cognitive-developmental stages, and enhancing individual cognitive processing through tailored feedback. Personalization has the potential to improve learning opportunities for students, and contribute to sustainable educational practices/strategies, understanding course-specific materials.

Intelligent tutoring systems is another example that GAI can provide on-demand tutoring, answer student queries, provide instant feedback, and offer supplementary materials, reducing the need for additional human resources. Intelligent tutoring systems that personalize learning hold the power to transform education, leading to a more sustainable one. A review by Zawacki-Richter et al. (2019) stressed the potential of GAI in facilitating personalization, adaptive learning and intelligent tutoring systems, by also highlighting the lack of critical reflection of the pedagogical and ethical implications, as well as risks of implementing GAI applications in higher education. Artificial intelligence (AI) systems/applications may be designed and developed in pedagogically ways that could scaffold students' acquisition of 21<sup>st</sup> century competencies and skills (Lameras & Arnab, 2022); learning and innovation skills, such as critical thinking, problem

solving, communication, collaboration and creativity are 21<sup>st</sup> century sustainable development skills.

With regard to automated assessment and feedback, GAI can grade assignments and exams, provide instant feedback, and identify areas where students need improvement, making the evaluation process more efficient. Automated assessment (marking of questions, grading thesis statements, essay grading, etc.) was found to be widely used (Crompton & Burke, 2023). GAI can transform traditional teaching methods and assessment strategies, creating an environment that fosters student learning and better academic outcomes (Lyanda et al., 2024). For example, when ChatGPT aids educators in grading assignments or providing instant feedback, educators save time. Specific areas such as personalized learning and adaptive assessment need to be identified for improvement through GAI implementation (Sywelem, 2024).

Most publications report positive findings, but a few studies report negative links between AI usage and sustainability (e.g., Okulich-Kazarin, 2024). The researchers explored students' opinions on the impact of AI tools on the 'safe' learning environment and reported possible negative impact on achieving sustainability in higher education; it was suggested the empirical findings to formulate a basis for planning and implementing organizational and pedagogical measures with regard to specific SDGs (Okulich-Kazarin et al., 2024).

Educators' professional development is important since they must be ready to promote sustainable GAI-enabled education. Their role continues to be important since GAI will not replace them; they will decide when and how GAI tools such as ChatGPT will be integrated. Teacher training facilitates the exercise/development of new digital skills to use intelligent tools in a pedagogical and meaningful way. Indicatively, educators should be competent to support their students, apply innovative practices-pedagogies in their courses, organize and manage face-to-face, online, and blended teaching with the inclusion of GAI tools. Empowering teachers will hopefully facilitate-optimize students' experiences such as personalized learning in GAI environments. Teachers' role will grow in complexity and importance, and they need to be well equipped to aid students develop various skills and dispositions such as critical thinking, advanced problem solving, as well as ethical values (Bower et al., 2024). Lameras and Arnab (2022) indicate that AI may enhance teachers' roles as catalysts in designing and visualizing AI-enabled teaching and learning, and they call for more qualitative studies to explore the ways in which educators experience the use of AI for designing/delivering teaching and learning.

### Optimizing Resource Utilization

Optimizing resource utilization (reducing resource consumption) is linked to digital learning resources, efficient energy use, virtual classrooms, labs, and meetings, as well as efficient administrative tasks. Efficient use of resources (such as energy, water, and materials, and implementing policies to reduce waste through recycling, reusing, and sustainable purchasing) is a principle for sustainable higher education (Leal Filho et al., 2018). Regarding digital learning resources, GAI tools can curate and recommend digital textbooks,



articles, and other resources (Boscardin et al., 2024) reducing the dependency on printed materials and thereby decreasing paper waste. For instance, ChatGPT, by promoting the use of digital educational materials, contributes to less paper waste, thus facilitating sustainability. Resource allocation ensures effective and efficient deployment of educational resources.

As far as efficient energy use is concerned, specialized machine learning models can optimize the energy consumption of campus facilities by managing lighting, heating, cooling, and other utilities based on real-time usage patterns (optimizing energy efficiency impacts on the ecological footprint). AI technologies in buildings can assist in reducing energy consumption through enhanced control, automation, and reliability (Yussuf & Asfour, 2024). For example, a study from the United Arab Emirates (Shwedeh et al., 2024) reported commitment to sustainable development, with the aim to utilize GAI to manage energy consumption on campus autonomously; advancing energy conservation and efficiency within higher education campuses through real-time energy data analysis, and automated energy-saving interventions. GAI-powered simulations can model waste generation patterns and optimize recycling or waste reduction strategies. For instance, GAI tools could generate predictive models for food waste management in cafeterias or paper usage across the campus.

GAI-enabled virtual classrooms and meetings can reduce the need for physical travel, lowering carbon emissions associated with commuting and campus operations. GAI can be used to create virtual reality to make learning experiences more engaging, interactive, and immersive (Sandhu et al., 2024). For example, ChatGPT can facilitate online discussions, virtual labs, and simulations, reducing the need for physical infrastructure and travel, thereby lowering the carbon footprint. Also, efficient administrative tasks could be facilitated. Automating administrative tasks such as scheduling, resource allocation, timetabling, and managing student records (Miao et al., 2021) can lead to more efficient use of resources and reduced operational costs (educators may stay organized and focused on teaching). Appropriately designed systems aid in managing/administering aspects of an education system more efficiently; e.g., developing cost-effective plans, monitoring educational outcomes, or maximizing the impact of available resources. Broadly, financial, infrastructure, and administrative resources are needed to ensure the sustainable implementation of GAI-powered solutions at a university. For the aforementioned, it needs to be considered that GAI systems are not essentially 'free' in terms of resources, and it would need to be weighed against the very real cost of running the GAI systems themselves.

### **Promoting Environmental Awareness and Sustainability**

Under promotion of environmental awareness and sustainability, sustainable education, research support, sustainable campus management, projects and research could be involved. Embedding social, environmental, and economic sustainability topics into curricula and pedagogy are aspects/principles of sustainable higher education. That is, courses that address sustainability topics, across various disciplines, constitute sustainable educational practice

(aiming to equip students with the knowledge-skills to address sustainability challenges). Regarding sustainable education, GAI can integrate sustainability topics into the curriculum, providing students with knowledge about environmental issues and sustainable practices (Shang et al., 2024). GAI-driven dynamic simulations can allow students to engage with real-world sustainability challenges; e.g., by simulating climate change scenarios, ecosystem models, offering students interactive learning experiences. Integrating environmental education and sustainability principles across curricula will equip students to tackle environmental issues such as climate change, biodiversity, and resource losses. Sustainability topics into the curriculum may be applicable across various disciplines (not just environmental studies); for example, teaching about climate change, or social equity, in order to equip future professionals with relevant knowledge/awareness. Indicatively, a recent study that embedded sustainable development topics into the information and computer technology curricula indicated students' positive attitudes and awareness (Angelaki et al., 2024). When ChatGPT generates educational content on sustainability, or it is programmed to include information and modules on environmental sustainability, awareness can be raised among students and staff about sustainable practices.

Research support can be provided by GAI. GAI tools can assist in environmental research by analyzing large datasets, identifying trends, and providing insights that contribute to sustainability studies. With regard to sustainable campus management, GAI tools can assist in managing waste, water, and other resources on campus more effectively (promoting a more sustainable environment). GAI tools have the potential to assist sustainability projects and research. That is assist students in researching and developing projects focused on sustainability, guiding them through data collection, analysis, and presentation. For instance, students (and staff) can work on real-world sustainability projects such as using the campus' infrastructure, energy systems, water management, and food services as models for sustainable practices.

### **Supporting Inclusive and Accessible Education**

GAI development should not deepen existing inequalities and divides but incorporate disadvantaged population in GAI-powered education. Inclusion and equity means to overcome barriers such as technological, economic and social divides. For instance, basic technological infrastructure must be faced to establish the basic conditions for implementing educational practices that take advantage of GAI to improve learning. Or policy makers should build sustainable and equitable conditions to digital rights in terms of internet access to disadvantaged. SDG-4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (UNESCO, 2019). Inclusive learning environments have the potential to lead to academic improvement among students with disabilities, when ethics are being considered (Almufareh et al., 2024).

Support of inclusive and accessible education could be accomplished via remote learning support, language translation and accessibility, and adaptive learning technologies. GAI-powered platforms can support remote and online learning, providing access to quality education for

students in remote or underserved areas. For example, ChatGPT can provide access to educational resources without the need for physical infrastructure, thus transcending geographical or socio-economic limitations. Online and blended learning allow students to access education from a distance (without the environmental costs) and constitute sustainable educational practices; an example is the Open University in the UK that provides online courses.

Regarding language translation and accessibility, GAI can offer real-time translation services and support for students with disabilities, ensuring that educational resources are accessible to a broader audience. Provision of translations and explanations in multiple languages facilitates overcoming/breaking language barriers, thus making education more accessible to non-native speakers. Regarding adaptive learning technologies, GAI can adjust the difficulty level of content in real-time, ensuring that all students can achieve their educational goals.

Ensuring inclusive and equitable use of GAI in higher education, fostering inclusive pedagogical practices, and ensuring representative-accessible content to students from diverse cultural, socio-economic, and linguistic backgrounds, constitute key challenges. Since exclusion in education is persistent, researchers highlight the importance of a sustainable, large-scale and inclusive GAI for the education ecosystem that facilitates equitable, high-quality lifelong learning opportunities for all (Bulathwela et al., 2024).

### Facilitating Collaboration and Innovation

Facilitation of collaboration and innovation may be achieved via collaborative platforms, innovation in curriculum design, as well as interdisciplinary research. Collaborative platforms can facilitate online collaboration between students, educators, and researchers, promoting the sharing of ideas and resources; for example, students and educators can work together on projects, share resources, and innovate solutions for sustainability. Interdisciplinary learning, and collaboration (e.g., between different academic departments) constitute sustainable educational practices. Universities could increase collaboration and partnerships with various parties in realizing sustainable development. GAI can help advance collaborative learning via, for example, GAI systems that monitor (asynchronous) discussion groups (UNESCO, 2019). Opportunities for human-machine GAI-mediated interactions are, in particular, associated with online education; a mode that was accelerated in higher education post-pandemic (Bearman et al., 2023).

Regarding innovation in curriculum design, GAI can help develop and update curricula to include the latest advancements and best practices in sustainability, ensuring that educational content remains relevant. Curricula could be re-designed and transformed for the digital and GAI-enabled world, to incorporate GAI digital literacy skills. Skills and competencies regarding learning 'about' and 'with' GAI, skills that enable students to solve problems using digital technologies, and computational thinking skills are a necessity. It is also essential to identify specific skills or goals that may be enabled only via GAI technology.

Interdisciplinary research and approaches may be also facilitated by GAI. For example, ChatGPT can connect

researchers from different fields, fostering interdisciplinary studies that address complex sustainability challenges. When interdisciplinary learning is encouraged, sustainability is linked to different fields such as engineering, business, and the arts. Collaboration among educational institutions, the private sector, and research institutions is important for developing and implementing GAI-driven educational solutions (Sywelem, 2024). GAI-based models can help researchers simulate the outcomes of various environmental policies or sustainable practices, while modelling complex systems (e.g., climate and biodiversity) allows researchers to explore the impact of different interventions.

### Data-Driven Decision Making

Data-driven decision making is associated with predictive analytics, resource allocation, and strategic planning. Long-term planning (e.g., planning long-term sustainability goals ensuring that policies and practices are adaptable) and resilience (e.g., resilience towards changing societal/environmental conditions) are principles for sustainable higher education (Leal Filho et al., 2018). GAI can analyze student performance data to predict outcomes/trends and identify at-risk students, enabling early interventions that can improve retention and success rates (predictive analytics). Large datasets can be analyzed to provide insights into resource utilization, and areas for improvement, helping institutions make informed decisions to enhance sustainability. Institutions can be assisted to allocate resources more efficiently, ensuring that budgets are spent on the most impactful areas. GAI can assist in long-term strategic planning by modeling various scenarios (e.g., simulate the impact of policies on future sustainability goals) and providing data-driven recommendations for sustainable growth. GAI provides cutting-edge tools that support transparent predictive analytics and techniques for generating tailored advice for at-risk students. A recent study proposes a novel framework that unifies both transparent machine learning as well as techniques for enabling predictive analytics, while integrating the latest advances in large language models for communicating the insights to learners (Susnjak, 2024). When examining the integration of AI tools such as ChatGPT, domains such as data analytics require students' cultivation of adaptive and analytical thinking capabilities (Abulibdeh et al., 2024).

### Sustainability Principles Supported by GAI Tools

Considering the themes discussed in the aforementioned sub-sections, **Table 1** outlines some sustainability principles that can be integrated into higher education, along with examples of how GAI tools can provide support. **Table 1** is indicated as an example; it is not exhaustive of all themes.

## DISCUSSION

This paper explores the potential of GAI-powered tools in promoting sustainability in higher education. In this exploration, ChatGPT was used as an interviewee, in order to collect its perspectives (i.e., perspectives of a non-human subject), by applying thing ethnography approach; engaging in a conversation with this tool facilitated knowledge

**Table 1.** Sustainability principles with examples of support by GAI

Sustainability principles that can be integrated in higher education	Examples of support by GAI
Environmental awareness and literacy, e.g., curriculum focused on environmental issues, climate change, and sustainability	GAI-driven personalized learning platforms can analyze students' knowledge and provide tailored educational material.
Sustainable campus operations, e.g., adoption of sustainable practices in waste management, and water conservation	GAI can predict resource demand and optimize the usage of water and waste management.
Equity and inclusion, e.g., ensure equitable access to education and promotion of accessibility, inclusion	GAI can identify barriers to access, suggest interventions to increase inclusivity, and support students via personalized learning systems.
Sustainable decision-making, e.g., teach/involve students with decision-making approaches that integrate sustainability topics	GAI-driven simulations and decision-support systems can help students understand the long-term impact of various sustainability choices.
Global citizenship, e.g., foster a global perspective on sustainability, connecting students	Students connect/communicate with each other via GAI-supported virtual environments and online platforms.
Research on sustainability, e.g., encourage interdisciplinary research focused on sustainability challenges	GAI can predict resource demand and optimize the usage of water and waste management (and even suggest improvements in supply chains).
Data-driven sustainability decisions, e.g., usage of data analytics to guide sustainability policies and campus operations	GAI-driven data analytics platforms can aggregate environmental data such as energy use, to make sustainability decisions.

construction. The output-responses generated by ChatGPT was the starting point for the investigation, thus facilitating the research process and, in particular, by providing new insights not widely reported or studied in the literature. The output was evaluated, synthesized and improved with recent studies, both theoretical and empirical (methodological limitations, and broader GAI-related ethical concerns are discussed later in this section). It is revealed that GAI-powered tools such as ChatGPT can contribute towards sustainable higher education in several key ways, such as: enhancing educational practices (e.g., personalized learning, intelligent tutoring systems, automated assessment and feedback, educators' professional development); optimizing resource utilization (e.g., digital learning resources, efficient energy use, modeling waste generation, virtual classrooms/labs/meetings, efficient administrative tasks); promoting environmental awareness and sustainability (e.g., sustainable education, sustainability projects and research); supporting inclusive and accessible education (e.g., support remote and online learning, language translation and accessibility, adaptive learning technologies); facilitating collaboration and innovation (e.g., collaborative platforms, innovation in curriculum design, interdisciplinary research); data-driven decision making (e.g., predictive analytics, allocating resources, strategic planning). In general, ChatGPT's answers seem balanced, with the output being in line with existing literature. It is noticed that some generated topics (e.g., enhancing educational practices, supporting inclusive and accessible education) are extensively documented in the literature, while other topics (e.g., promoting environmental awareness, data-driven decision making) seem to be less studied/documentated in the existing literature.

Limitations of this study include the followings:

1. Several publications in section three (the potential of GAI in promoting sustainability in higher education) are theoretical and conceptual, with claims/opinions not necessarily supported by empirical evidence; as a consequence, the need for empirical-based research on GAI implementation in higher education is highlighted.
2. As this study is descriptive in nature and not exhaustive in terms of the topics discussed, there may be important topics/themes left out (e.g., students'

emotional competencies or engagement in GAI context).

3. ChatGPT's usage as a research aid is also linked to biases and limitations (potential inaccurate, misleading information, or biases based on the training data are concerns linked to ethical issues), so it requires careful verification of the generated output by authors-researchers. In this study, the output was reviewed and evaluated only by the researcher, and this is a methodological limitation. However, it is highlighted that GAI tools should complement rather than replace the researcher's role and expertise (human evaluation and review are necessary).
4. Another methodological limitation is that ChatGPT was the primary GAI tool, and this limits the generalizability of the conclusions. Ethical and methodological limitations inherent to using AI tools in educational research are acknowledged.

Adopting GAI to promote sustainability in higher education, to prepare students to contribute to a sustainable future, and to aid institutions to reduce their environmental impact, seems promising. At the same time, balancing the benefits of GAI with ethical considerations/issues will be crucial in achieving long-term sustainability goals. The existing literature predominantly concentrates on the technical/pedagogical aspects, often overlooking the influence of GAI on education for sustainable development (i.e., ethical dimensions linked to AI-generated content, students' critical thinking, teacher and student competencies, data privacy concerns, and potential biases) (Abulibdeh et al., 2024). Addressing ethical considerations, limitations and concerns during the process of adopting GAI tools in higher education is important, to ensure that technological advancements benefit all students equitably. GAI-related ethical concerns regard data privacy, transparency, bias in GAI algorithms, accessibility, cultural sensitivity, and possible impact on students' critical thinking and creativity. Data privacy issues arise as user interactions may involve sensitive information, insufficient anonymization, and potential misuse of personal or academic data by external parties. GAI tools may lack accessibility features for diverse learning needs and can overlook cultural sensitivities, leading to exclusion, misunderstandings, and content that may not reflect different



cultural backgrounds. Limitations are associated with biases or misleading information, false results, and lack of transparency on how data is selected/analyzed (Ding et al., 2023). Transparency issues may arise because GAI-generated responses lack clear reasoning pathways, making it challenging for learners to understand decision processes, or identify potential biases. Concerns associated with academic integrity (Bearman et al., 2023), cheating, plagiarism, and potential misuse have been reported (Crawford et al., 2023; Grassini, 2023; Moorhouse et al., 2023). Academic integrity concerns may arise, when students rely on GAI-produced answers for their assignments/essays/projects, risking plagiarism, reducing original thought, and undermining critical thinking processes; it constitutes a challenge for educators so as to maintain fair assessment standards. Educational-related risks linked to using ChatGPT include incredible, inaccurate, inappropriate output, privileging GAI-generated text over human-generated text, giving personal data and sensitive information (Trust et al., 2023). Inaccurate or misleading information may be produced due to limitations in the tool's training data (potentially confusing students, spreading misinformation, and diminishing trust in GAI's academic support/assistance). Practical and ethical challenges include low technological readiness, lack of transparency and inadequate privacy (Yan et al., 2024). Low technological readiness in higher education affects digital tools' integration, as educational institutions may lack infrastructure, training, or resources to effectively integrate GAI, leading to accessibility gaps, and/or limited support for educators and students.

Based on the above, the following subsections regard discussion on policy and research necessity on GAI implementation in higher education, as well as some recommendations (that may be of interest to researchers, policymakers, and stakeholders).

### **Policy on GAI For Sustainable Development**

Since GAI holds great potential for improving education systems, a comprehensive public policy on GAI for sustainable development constitutes a challenge (UNESCO, 2019). Policies should be modified, re-formulated and developed within the context of national (and international) levels to serve sustainable development. University policy is essential to guide appropriate adoption of GAI tools (e.g., balancing advantages and risks, ensuring transparency), and integrating strategic vision in alignment with the university's context/culture/values. Policymakers can develop targeted interventions and initiatives that address challenges, such as educational inequities, thus fostering sustainable development across the education sector. Examples of interventions include the organization of GAI-literacy training seminars or workshops for students (of different academic subjects), and teacher training programmes (both at the pre-service in-service level) for educators of pedagogic departments and also other disciplines/specializations. GAI tools can be harnessed by universities to simulate the long-term impact of their sustainability policies, helping them better plan.

Policies should consider the possibilities of GAI to support students and educators (e.g., personalized learning, support in

teaching and assessment) and also ensure ethical, responsible, and sustainable use of GAI. "If the potential of GAI to support education for sustainable development is to be fully realized, all of the possible benefits of the tools need to be identified and leveraged, and the risks acknowledged and mitigated" (Miao et al., 2021, pg. 16). Policies should incorporate ethical guidelines/dimensions to protect the rights and well-being of students. Issues of transparency, academic integrity, and equity are important when GAI is implemented in educational settings. Indicatively, the ethics guidelines for trustworthy AI of the European Commission (2019) mention that trustworthy GAI should ensure adherence to ethical principles, values and robustness (both from a technical and social perspective). Policies could also involve guidelines or frameworks that enable the educational institutions (educators) to evaluate their educational strategies with the use of technology and GAI-powered practices.

### **Research on GAI Implementation in Higher Education Is a Necessity**

Research on GAI in education is significant, and a rise in research studies is expected over the years. Several studies-publications are still theoretical in nature, and this may be attributed to the recent implementation of GAI tools in the educational process. As a consequence, research is suggested to focus more on empirical evidence, on sustainable educational practices, and it is useful to derive from different countries/cultures. UNESCO's (2019) report suggests strengthening of research and evaluation in the field of GAI and education:

"Enable the use of GAI to promote and improve educational research and innovation ... Review the comprehensive impacts of GAI on education ... Encourage investment and provide targeted funding in order to build an evidence-based ecosystem for GAI in education" (Miao et al., 2021, p. 40).

Various sources such as governments and private investors could provide funding for GAI research and development (Sywelem, 2024). The adoption of GAI in higher education is still in its early stages and uptake in research is very recent (Pit et al., 2024). Although GAI offers significant potential for academics and improvement of students' performance (many reported benefits are conceptual), a major gap in the literature regards lack of practical implementation of GAI guidelines and application frameworks suitable for educational institutions (Pit et al., 2024). There is also a need for research studies that examine the connections between AI and the implementation of the United Nations SDGs (Leal Filho et al., 2024).

In parallel, disseminating research findings is important in order for future studies to build and expand on what has been reported within specific contexts/environments. Research outcomes are expected to be useful for policymakers and stakeholders, to inform guidelines and design frameworks on appropriate GAI use in educational settings. Higher education policies need to be responsive to changes regarding GAI technologies, while evidence-based plans and decisions on GAI's integration into educational practices are essential. Building GAI expertise through higher education and research is one of the main approaches used by governments to address

their respective skill gaps, while several countries are seeking to make professions in GAI research and practice more attractive (UNESCO, 2019).

### Recommendations on GAI's Contribution to Sustainable Higher Education

Based on the above, some recommendations on GAI's contribution to sustainable higher education regard:

1. **Sustainable curriculum development:** Harnessing the benefit of personalized learning (adapt to each student's pace and needs, making education more efficient) and incorporating GAI into the curriculum (to teach students about sustainability issues). Sustainable practices will prepare students to face real-world sustainability challenges.
2. **Digital learning resources:** Encouraging utilization of digital learning resources/textbooks (reducing the need for paper and physical materials or creation of customized learning materials).
3. **Online and hybrid/blended modes of education:** Promoting and combining different modes of education when feasible (to reduce the need for physical campus resources) and implementing GAI to create virtual classrooms (making online learning more effective and sustainable).
4. **Policy development and ethical considerations:** Re-adjusting policy (e.g., integrate sustainability into various decision-making processes such as leadership and research), implementing GAI tools to assist in long-term sustainability planning, and using GAI to simulate the outcomes of different sustainability policies (helping policymakers choose the most effective approaches). Ensuring that GAI's usage in sustainability initiatives aligns with ethical standards avoiding biases and ensuring inclusivity and responsible decision-making.
5. **Research studies and collaboration:** Conducting longitudinal studies can provide insights on the topic across the time. GAI usage can facilitate interdisciplinary research collaborations on sustainability topics (helping students and staff work together on innovative solutions), while fostering partnerships between academia and industry, could aid solve real-world sustainability problems.
6. **Energy-efficient campus management:** Implementing GAI-driven systems to monitor and optimize energy usage in campus buildings (systems that adjust lighting, heating, and cooling based on weather conditions, reducing energy waste).
7. **Sustainable operations:** GAI can help identify patterns in campus waste production and suggest strategies to reduce it (e.g., recycling programs). Also, encouraging the adoption of GAI-driven electric/autonomous vehicles in campus transportation will reduce emissions.

## CONCLUSION AND FUTURE RESEARCH DIRECTIONS

GAI technology has made extraordinary advances over the last year, it continues to evolve at an unprecedented pace (Beckingham et al., 2024), and it creates new educational possibilities with the potential to transform the educational process. Digital transformation impacts on sustainable university (Mohamed Hashim et al., 2022). For effective use of GAI in teaching and learning, such use should be sustainable, ethical, and secure (Beckingham et al., 2024). This study presents key points on the potential of GAI-powered tools such as ChatGPT in promoting sustainability in higher education. GAI tools into higher education can drive significant progress towards sustainability by enhancing educational practices, optimizing the use of resources, fostering an environmental consciousness, and supporting research. Through these contributions, GAI can help create more efficient, inclusive, and sustainable educational environments. Ethical considerations should be considered, to align with the principles of sustainability. Tools such as ChatGPT (which was applied as research aid in this study) should be used carefully, under human evaluation, to support the process. "Given the novelty of ChatGPT, existing literature about its use within higher education is limited and largely hypothetical or speculative" (Michel-Villarreal et al., 2023, p. 14). Policies should be modified and re-formulated within the context of national/international levels to serve sustainable development, while empirical research on GAI implementation in education is significant. Some recommendations are included, and these may be of interest to researchers, policymakers, and stakeholders/educators. This study is expected to contribute to the debate on the potential of GAI for sustainable higher education (an ongoing debate of international interest).

It is argued that new generative GAI tools (e.g., ChatGPT) are promising tools when their benefits/opportunities (personalized learning, provision of content/feedback tailored to student needs, etc.) are harnessed, and ethical issues are addressed. New GAI tools are coming fast and include new features; e.g., these can also accept not just text, but spoken voice inputs and visual inputs, and can make audio recordings of lectures and automatically create summaries of the material. This is likely to require financial investments for higher education institutions, and efforts to make more systematic changes in teaching and assessment. Additionally, since workplaces seem to be rapidly adopting GAI tools, it is a challenge to keep students learning in a sustainable manner.

Future research studies are suggested to focus on empirical evidence regarding the role of GAI tools such as ChatGPT in promoting/enabling sustainability in higher education; via investigating, for example, ways of enhancing learning outcomes through GAI, or suitable pedagogical practices. It is suggested to investigate how university policies and educators should educate their students to understand and make best use of GAI tools (such as ChatGPT). For instance, how could learning environments be designed and assessed through new GAI tools? What do students need to know and which skills-competencies should be exercised/developed within GAI-



supported sustainable educational environments? Which areas of education are likely to be significantly affected by GAI (learning, assessment, and management)? What policies/guidelines need to be applied to promote sustainable GAI at universities? How can GAI transform/reshape higher education across different academic subjects? It is suggested to explore different enablers and barriers towards GAI-powered sustainable higher education, within the context of different modes of university courses (e.g., face-to-face, online and hybrid/blended modes). For example, in mobile learning, GAI could be used to overcome the challenges of the small size and limited processing power of mobile devices and adapt to the learning preferences of students. Mobile technology-supported learning is a sustainable and pragmatic approach, and it is expected to have an increasingly important role in hybrid courses (Nikolopoulou, 2023). GAI integration in education can amplify and enhance mobile learning principles, leading to improved learning experiences and outcomes (Moya & Camacho, 2024). Blended learning can be considered a sustainable approach. GAI integration in education can extend beyond the formal classroom (e.g., during online/blended education), encompassing administrative functions and resource allocation. Appropriate infrastructure and digital GAI-powered resources may facilitate the sustainability of different approaches/strategies. As the integration of GAI in education has become a subject of interest with transformative opportunities in teaching, learning, and research (Bahroun et al., 2023), future research is suggested to explore the transformative prospects and impact of GAI for sustainability in higher education. Investigation of the long-term impact of GAI implementation for sustainability in higher education, as well as exploration of possibilities, uses, and risks of GAI for sustainable development across geographical and/or cultural contexts constitute future research topics.

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