Exploring the effect of Generative AI on social sustainability through integrating AI attributes, TPB, and T-EESST: A deep learning-based hybrid SEM-ANN approach

Abstract

The swift progress of Generative Artificial Intelligence (AI) tools offers remarkable potential for revolutionizing educational methods and enhancing social sustainability. Despite its potential, understanding the factors driving its adoption and how that affects social sustainability remains underexplored. This study aims to address this gap by integrating AI attributes ("perceived anthropomorphism", "perceived intelligence", and "perceived animacy") with the Theory of Planned Behavior (TPB) and the Technology-Environmental, Economic, and Social Sustainability Theory (T-EESST) to develop a theoretical research model. Utilizing a hybrid Structural Equation Modeling (SEM) and Artificial Neural Network (ANN) approach, we analyzed data collected from 1048 university students to evaluate the developed model. Our findings revealed that while perceived behavioral control has an insignificant impact on Generative AI use, attitudes emerge as the most critical factor, further reinforced by the significant role of subjective norms. Perceived anthropomorphism, perceived intelligence, and perceived animacy were also found to influence students' attitudes significantly. More importantly, the findings supported the role of Generative AI in positively affecting social sustainability, aligning with the principles of T-EESST. This study's significance lies in its holistic examination of the interplay between technological attributes, motivational aspects, and sustainability outcomes, offering valuable insights for various stakeholders.

Keywords: Generative AI; social sustainability; AI attributes; TPB; T-EESST; SEM-ANN.

1. Introduction

Generative Artificial Intelligence (AI) is a subfield of AI that creates content such as text, images, music, and videos using deep learning techniques (Dwivedi et al., 2023). There is significant enthusiasm for the applications of large language models (LLMs), including ChatGPT, Gemini, and Claude. These tools replicate the intricacies of human language patterns and can be utilized for tasks demanding advanced processing, such as text summarization, language translation, and dialogue systems (Khan et al., 2023). The technology's capability to produce content that is

virtually indistinguishable from that created by humans signifies a monumental shift in the sociotechnical environment, with potentially significant macroeconomic implications (Ooi et al., 2023). Significant advancements and widespread adoption across various industries have marked the rise of Generative AI. The market size of Generative AI is anticipated to expand at an annual growth rate of 46.47% from 2024 to 2030, achieving a market volume of US$356.10 billion by 2030 (Statista, 2024). These statistics underscore the increasing importance and potential of Generative AI as a transformative technology in numerous fields.

Generative AI can transform the educational landscape significantly. It offers tremendous potential for improving both learning experiences and outcomes. By facilitating personalized learning, AI tools can customize educational content to suit the unique needs of each student, catering to diverse learning styles and speeds (Ooi et al., 2023). For instance, Generative AI tools can offer interactive content creation and adaptive assessments (Kadaruddin, 2023). It can enhance student engagement, automate administrative tasks, and provide customized feedback (Alali & Wardat, 2024). AI-provided instant feedback on student work encourages ongoing improvement and fosters a more profound comprehension of the subject matter. These tools can also serve as virtual interactive tutors, offering real-time explanations and responses to student inquiries (Qadir, 2023). Additionally, they provide continuous learning support beyond the confines of traditional classroom hours. By serving as research assistants, these tools can summarize relevant scholarly articles and highlight essential findings, thereby improving the efficiency of researchers in navigating the vast amount of data available in the digital domain (Khan et al., 2023).

Despite the promising applications of Generative AI in education, several research gaps persist in understanding its adoption among students. First, there is a deficiency in empirical studies examining how higher education students adopt and utilize Generative AI tools (Tiwari et al., 2023). Second, existing studies have primarily focused on AI's technical capabilities and immediate educational benefits, often overlooking the psychological and social dimensions that drive user engagement and acceptance. Consequently, it has been suggested that there is a lack of knowledge regarding the factors influencing the use of Generative AI tools in educational settings (Al-Qaysi et al., 2024). Third, despite the growing interest in Generative AI and its transformative potential across various domains, the specific impact of Generative AI on sustainable development remains underexplored (Alsharhan et al., 2023). Fourth, while several studies have highlighted the importance of AI attributes such as "perceived anthropomorphism", "perceived intelligence", and

"perceived animacy" as critical determinants for AI adoption (Balakrishnan et al., 2022; Balakrishnan & Dwivedi, 2024), the specific impact of these attributes on students' adoption of Generative AI remains insufficiently explored. These attributes contribute to how human-like, intelligent, and lifelike an AI system appears to users and are crucial in shaping user perceptions and acceptance (Aw et al., 2022). However, the question of how these factors translate into the educational context, particularly in influencing students' willingness to engage with and utilize Generative AI tools, is yet to be fully addressed.

To address the above research gaps, the main objective of this study is to develop a theoretical research model by integrating AI attributes with the "Theory of Planned Behavior (TPB)" and the "Technology-Environmental, Economic, and Social Sustainability Theory (T-EESST)" to understand the factors driving students' use of Generative AI and its subsequent effect on social sustainability. Involving the TPB offers a thorough understanding of the motivational aspects of behavior (Ajzen, 1991). While the TPB primarily emphasizes motivation, incorporating T-EESST in this research provides a more comprehensive view of how Generative AI can foster long-term social sustainability through inclusive and equitable educational practices. Besides, by integrating TPB with AI attributes, we aim to capture a holistic view of the psychological and social factors driving AI adoption among students. This study holds significant value as it aims to bridge existing research gaps by providing comprehensive insights into the interaction between AI attributes, motivational aspects, and sustainability outcomes within educational contexts.

2. Research model and hypotheses development

This research develops a theoretical model by integrating AI attributes with the TPB and T-EESST to understand the factors driving students' use of Generative AI and its subsequent effect on social sustainability (see Figure 1). The application of TPB in the proposed research model arises from multiple considerations. First, the TPB is a prominent social psychology framework for predicting and explaining behavior across various domains. It posits that behavioral intentions, which directly influence actual behaviors, result from evaluations of "attitudes", "subjective norms", and "perceived behavioral control" (Yan, 2014). Numerous studies have utilized the TPB to investigate users' behaviors regarding various technologies, including ChatGPT (Al-Qaysi et al., 2024), mobile English learning (Bali et al., 2024), and e-health services (Fan et al., 2024). The TPB is widely favored in both research and practical applications due to its adaptability, empirical

validation, and practical utility (Morren & Grinstein, 2021). In this research, TPB provides a robust foundation for exploring the psychological factors influencing students' attitudes and actual use of Generative AI tools. By understanding these motivational aspects, we can gain insights into the determinants of Generative AI usage in educational settings.

While TPB offers a comprehensive understanding of the motivational aspects of behavior, it has limitations when applied to the broader context of technology use and sustainability. TPB primarily focuses on individual-level factors, often overlooking the wider implications of technology use on sustainability. To address this limitation, we integrate the T-EESST with TPB. T-EESST hypothesizes that technology use impacts the three pillars of sustainability: environmental, economic, and social (Al-Emran, 2023). By incorporating T-EESST, we extend the TPB framework to consider the broader sustainability impacts of Generative AI use, specifically focusing on social sustainability in this study. This integration allows us to explore how Generative AI use in education can create inclusive, equitable, and supportive learning environments, thus addressing a critical aspect of social sustainability.

Despite the strengths of TPB and T-EESST, these frameworks alone may not fully capture the specific attributes of AI that influence its adoption and use. AI technologies possess unique characteristics such as "perceived anthropomorphism", "perceived intelligence", and "perceived animacy" (Balakrishnan & Dwivedi, 2024), which can significantly impact users' attitudes and behaviors. Perceived anthropomorphism involves attributing human-like qualities to AI, perceived intelligence refers to the cognitive capabilities attributed to AI, and perceived animacy pertains to the lifelike and dynamic nature of AI interactions (Bartneck et al., 2009). Integrating these AI attributes with TPB and T-EESST addresses the limitation of these theories in accounting for the distinct features of AI that affect user perceptions and interactions. AI-powered chatbots are primarily recognized for their sophisticated design, facilitating engaging and effective conversations with users. The intelligence embedded in these chatbots enhances the breadth of users' interaction throughout various stages of the decision-making process (Balakrishnan et al., 2022). By incorporating "perceived anthropomorphism", "perceived intelligence", and "perceived animacy" into our research model, we can better understand how these attributes influence students' attitudes regarding Generative AI use. This comprehensive approach enables a more nuanced analysis, capturing both the motivational factors and the technological attributes that drive Generative AI adoption and its impact on social sustainability.

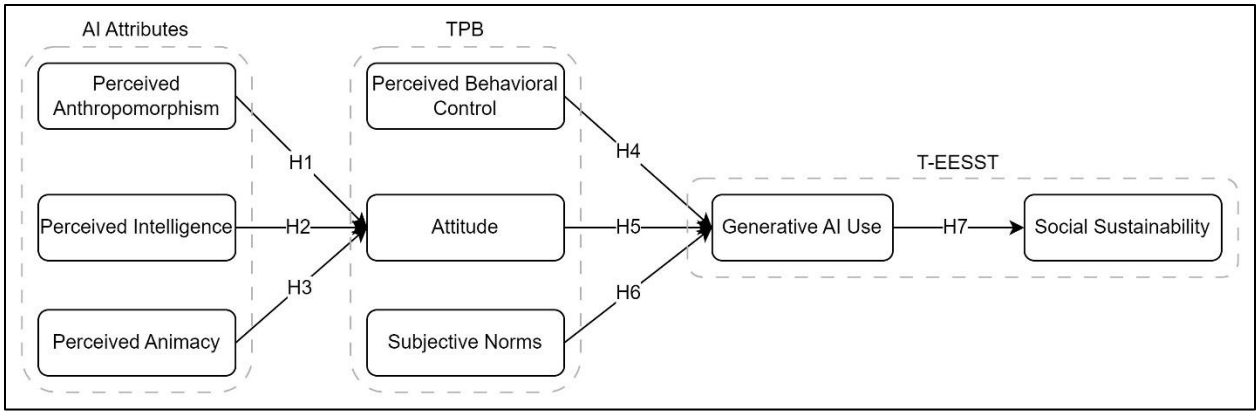

Figure 1. Theoretical research model.

2.1 Perceived anthropomorphism

Perceived anthropomorphism refers to "the attribution of a human form, human characteristics, or human behavior to nonhuman things such as robots, computers, and animals" (Bartneck et al., 2009). In this research, perceived anthropomorphism pertains to how students perceive Generative AI tools as possessing human-like qualities. This can involve viewing the AI as empathetic, relatable, and capable of understanding and responding in a human-like manner. Generative AI tools, like ChatGPT 4o, utilize both voice and chat features, incorporating human-like cues to enhance the appeal of their anthropomorphic traits. Human-like qualities exhibited by voice assistants can create a feeling of social presence and sociability, thereby fostering trustworthy, friend-like relationships (Aw et al., 2022).

Several studies have explored the impact of perceived anthropomorphism on user attitudes and behaviors. For example, a study on service robots revealed that perceived anthropomorphism substantially influences users' intention to use (Blut et al., 2021). Another study on chatbot-based services indicated that perceived anthropomorphism significantly impacts users' attitudes and continuous intentions (Balakrishnan et al., 2022). A recent study discovered that users' attitudes toward digital assistants are significantly influenced by perceived anthropomorphism (Balakrishnan & Dwivedi, 2024). When students perceive Generative AI as more anthropomorphic, it likely enhances their comfort and familiarity with the technology, fostering positive attitudes. This, in turn, can foster a more interactive and supportive educational environment, contributing to the broader goal of social sustainability. Hence, the following hypothesis is proposed:

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