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# Integrating generative artificial intelligence in African higher education: university students' awareness, attitudes, and use of ChatGPT in Zambia

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**Background:** The rapid emergence of generative artificial intelligence (AI) tools such as ChatGPT is transforming teaching and learning practices in higher education. This study assessed the awareness, attitudes, and usage patterns of ChatGPT among university students in Zambia and examined factors associated with students' attitudes toward the technology.

**Methods:** A multi-institutional cross-sectional study was conducted among 1,829 university students in Zambia using a structured questionnaire adapted from instruments informed by the Technology Acceptance Model (TAM). Data were analysed using SPSS version 26.0, with statistical significance set at  $p < 0.05$ .

**Results:** Among the 1,829 participants, 81.7% were aged 18–25 years, 52.5% were female, and 92.4% were unmarried. Overall, 96.8% of the students had heard of ChatGPT, and 85.6% reported having used it before this study. Among AI-usage constructs, 74.8% of respondents perceived high risks associated with AI use, 73.3% perceived ChatGPT as easy to use, 64.0% perceived it as useful, and 56.8% reported behavioural intention to use AI tools. In multivariable analysis, students aged  $\geq 40$  years were more likely to report positive attitudes toward ChatGPT compared with those aged 18–25 years (aOR = 5.91; 95% CI: 1.23–28.33;  $p = 0.026$ ). Technology/social influence was also significantly associated with positive attitudes (aOR = 2.04; 95% CI: 1.55–2.68;  $p < 0.001$ ). Conversely, perceived risks were associated with lower odds of positive attitudes (aOR = 0.57; 95% CI: 0.43–0.75;  $p < 0.001$ ). Regarding ChatGPT use, perceived usefulness significantly predicted higher usage (aOR = 1.49; 95% CI: 1.17–1.89;  $p = 0.001$ ), while perceived risks were associated with reduced usage (aOR = 0.61; 95% CI: 0.45–0.84;  $p = 0.003$ ).

**Conclusion:** Awareness and use of ChatGPT are widespread among university students in Zambia, with more than four out of five students reporting prior use. Perceived usefulness and social influence were positively associated with adoption, whereas perceived risks were linked to lower attitudes and reduced use. These findings highlight the need for higher education institutions to develop clear policies and integrate AI literacy into curricula to promote responsible and effective use of generative AI technologies in academic environments.

#### KEYWORDS

artificial intelligence, ChatGPT, higher education, technology acceptance model, technology adoption, university students, Zambia

## Introduction

Artificial intelligence (AI) is a simulation of human intelligence in machines and technologies used to perform tasks (Soori et al., 2023). The advent of AI has brought about transformative changes globally, some beneficial while others present challenges. In academia and medicine, this has led to a reassessment of its use to benefit both students and patients (Bin and Kausik, 2024; Crowe et al., 2025; Traylor et al., 2025; Vidiyala et al., 2025). In recent years, numerous AI innovations have emerged, transforming various industries (Bin and Kausik, 2024; Radanliev, 2024; Shao et al., 2022). The rapid advancement of AI has transformed numerous aspects of human life, including education (Kim, 2023). AI-powered tools such as ChatGPT, developed by OpenAI, have gained widespread popularity among university students, including healthcare students (Abdelhafiz et al., 2025; Ajalo et al., 2025; George Pallivathukul et al., 2024; Tortella et al., 2025). Consequently, there are some concerns about the use of AI in higher education (Abuadas et al., 2025; Aljuraid, 2025; Rodger et al., 2025). ChatGPT is a sophisticated natural language processing (NLP) model capable of generating human-like responses, assisting users with tasks ranging from academic writing and research to problem-solving and general inquiries (Hashish et al., 2025; Kamalov et al., 2023; Mudenda, 2025).

Not surprisingly, the growing accessibility of AI-driven Chatbots has sparked considerable debate about their role in education, raising important questions about their benefits, limitations, and ethical implications (Kamalov et al., 2023; Kazley et al., 2025). AI has become a critical component of the modern academic landscape, offering significant benefits such as personalised learning, enhanced engagement, and improved access to educational resources across subject areas, including healthcare (Chen and Cheung, 2025; Gunawan et al., 2024; Hashish et al., 2025; Ning et al., 2025; Pireci Sejdiu and Sejdiu, 2025; Shishehgar et al., 2025; Vieriu and Petrea, 2025). While generative AI tools such as ChatGPT offer notable educational benefits, including improved access to information and enhanced learning efficiency, their use in higher education has raised important concerns (Jin et al., 2025; Mortlock and Lucas, 2024; Mudenda, 2025; Pireci Sejdiu and Sejdiu, 2025; Yusuf et al., 2024). These include concerns about the accuracy and reliability of AI-generated outputs, the risk of student over-reliance on automated assistance, and the potential erosion of critical thinking and independent problem-solving skills (Ali et al., 2024; Klimova and Pikhart, 2025; Zhai et al., 2024). If students rely on inaccurate information from these tools, it could lead to misunderstandings and hinder their overall academic growth (Mudenda, 2025; Vieriu and Petrea, 2025; Zhai et al., 2024). Additionally, ethical challenges related to academic

integrity, plagiarism, and appropriate attribution of AI-assisted work remain significant (Mudenda, 2025; Nguyen, 2025; Ravšelj et al., 2025; Williams, 2023). Addressing these concerns is essential to ensure the integration of generative AI in higher education to support meaningful learning while safeguarding academic standards and ethical practice (Hasanein and Sobaih, 2023; Ravšelj et al., 2025; Vieriu and Petrea, 2025).

Consequently, successfully integrating AI into education demands a comprehensive understanding of both technology and learning processes (Daher, 2025; Funa and Gabay, 2025). This complexity is further compounded by ethical issues, particularly with the growing use of generative AI (Al-kfairy et al., 2024; Dhirani et al., 2023; Radanliev, 2025). For example, there is a risk of students misusing AI tools in dishonest ways, such as submitting AI-generated content without proper credit (Akgun and Greenhow, 2021; Kazley et al., 2025; Williams, 2023). Therefore, it is critical that higher education institutions develop guidelines and policies that clearly define how AI should be used in student learning (Funa and Gabay, 2025; Hasanein and Sobaih, 2023; Vieriu and Petrea, 2025; Wainaina and Sun, 2025). To ensure the ethical use of ChatGPT in higher education, institutions should implement comprehensive training, guidelines, and policies that promote responsible adoption by addressing academic integrity, privacy, and misinformation while fostering awareness among students and educators to maximise benefits and mitigate risks associated with the use of AI (Acosta-Enriquez et al., 2024; Zhao et al., 2025).

Globally, several studies have documented the increasing use of ChatGPT among university students, with evidence suggesting that it is becoming a common academic tool (Abdaljaleel et al., 2024; Sallam et al., 2024; Wood and Moss, 2024). This was reported in a study conducted in the United Arab Emirates (UAE) among university students, showing increased usage of ChatGPT (Allam et al., 2024a). However, there is still limited knowledge, concerns and use among healthcare students in some low- and middle-income countries (LMICs) (Al Omari et al., 2024; Allam et al., 2024a; Chakri et al., 2025; Hasan et al., 2024). Perceived academic benefits, such as enhanced research efficiency, and concerns, including ethical and academic integrity issues, have been reported (Balalle and Pannilage, 2025; Ravšelj et al., 2025), which must be addressed going forward.

In Zambia, the adoption of AI technologies in higher education is still at an early stage. However, students are increasingly exploring ChatGPT to support their academic work (Mudenda et al., 2024; Mudenda et al., 2025a; Mudenda et al., 2025b). This is part of a general strategy for the Government of the Republic of Zambia to take full advantage of AI (Ministry of Technology and Science, 2024). While some view AI as a valuable learning resource that can enhance understanding and efficiency, others in Zambia raise concerns about academic integrity, reliability, and potential over-reliance on AI-generated content (Mudenda et al., 2024; Mudenda et al., 2025b). Despite its potential benefits, the utilisation of ChatGPT among university students in Zambia is mediated by several factors, including internet accessibility, levels of digital literacy, institutional regulations, and students' attitudes towards AI (Mudenda et al., 2024; Mudenda et al., 2025a; Mudenda et al., 2025b). While a proportion of students use the tool to facilitate research and enhance their learning experiences, others may use

AI in ways that raise concerns regarding academic misconduct, including plagiarism or unauthorised assistance with coursework (Mudenda et al., 2025a). These divergent patterns of use underscore the need to adopt a balanced framework that enhances the pedagogical value of ChatGPT while minimising the risks associated with its misuse. Alongside this, understanding students' attitudes and usage patterns regarding ChatGPT is key for informing future strategies among universities and other higher education facilities that ensure its responsible and effective integration into higher education.

Despite the rapid uptake of generative AI tools globally, there remains no large multicenter study examining university students' attitudes, usage patterns, and determinants of ChatGPT adoption across Zambian universities. Existing studies in the Zambian context have largely focused on single institutions or specific health-related student groups (Mudenda et al., 2024; Mudenda et al., 2025a; Mudenda et al., 2025b). Given this background, this study was guided by the Technology Acceptance Model (TAM), which explains how users come to accept and use new technologies (Davis, 1989; Liu et al., 2026; Sallam et al., 2023a). The model proposes that technology adoption is primarily influenced by perceived usefulness and perceived ease of use, which subsequently shape users' attitudes and behavioural intentions toward technology utilisation (Granić and Marangunić, 2019; Sallam et al., 2023a).

In the context of generative AI tools such as ChatGPT, the Technology Acceptance Model Edited to Assess ChatGPT Adoption (TAME-ChatGPT) tool provides a useful framework for examining how students perceive the usefulness, risks, and social influences associated with these tools in academic environments (Adam, 2020; Al-Adwan et al., 2023; Dahri et al., 2024; Pham et al., 2025; Saihi et al., 2024). The present study adapted constructs from the TAM and related extensions to assess students' awareness, attitudes, perceived benefits, perceived concerns, and patterns of ChatGPT use in higher education institutions in Zambia. By assessing these constructs, this study sought to better understand factors associated with students' awareness, attitudes and usage of generative AI technologies in academic settings. The findings provide evidence to inform institutional policy, curriculum development, and responsible integration of AI in higher education.

## Materials and methods

### Study design, site, and population

A cross-sectional study was conducted from December 1, 2024, to March 31, 2025, among students enrolled at five universities in Zambia, including the University of Zambia (UNZA), Copperbelt University (CBU), Mulungushi University (MU), Levy Mwanawasa Medical University (LMMU), and Eden University (EU). These universities were selected to reflect a range of public and private institutions, geographic regions, and academic program profiles within Zambia, thereby providing a broad representation of the national higher education landscape. Nevertheless, the purposive selection of study sites may limit the generalizability of the findings to all universities in Zambia. University students were selected as the study population due to their anticipated use of ChatGPT, as this is the age group

typically associated with its high use based on local and global evidence (Mudenda et al., 2024; Mudenda et al., 2025a; Mudenda et al., 2025b; Ravšelj et al., 2025). This also transcends into their potential use of technologies that are being integrated into society at large, notwithstanding AI tools. The eligibility criteria included all registered students who were enrolled at the time of study across the five universities, while those unavailable during data collection were excluded.

## Sample size estimation and sampling criteria

The sample size was calculated using Cochran's formula (Adam, 2020). For each university, the calculation assumed a 95% confidence level, a 5% margin of error, and a 50% expected proportion, yielding a minimum required sample size of 385 participants per study site, hence, giving a sum of 1,925 participants across all study sites. Stratification was based on the institution, year of study and academic program within each participating university. Student enrolment lists were obtained from the respective academic departments, and proportional allocation was applied to each stratum. Participants were then selected using simple random sampling within each stratum to ensure equal probability of selection among eligible students. However, participation in the study was voluntary, which may have influenced the distribution of the sample across the different universities and academic programs.

## Study instrument and data collection

The study utilised an adopted previously developed and preliminarily validated questionnaire (Sallam et al., 2023a). The application of this questionnaire in subsequent studies has been documented (Abdaljaleel et al., 2024; Parikh et al., 2023). To ensure face and content validity and contextual appropriateness of the questionnaire, it was reviewed by public health experts from the University of Zambia. After face and content validation, the questionnaire was pilot tested among 40 university students to assess its clarity and reliability. Following the pilot study, no modifications were required, and the questionnaire was retained in its original form for the main study. The questionnaire comprised two sections: Section A captured the sociodemographic characteristics of the students, while Section B contained 35 items assessing attitudes and usage of ChatGPT among university students (See questionnaire in the [Supplementary Appendix](#)).

Data collection was conducted by a team of ten trained data collectors (trained research assistants). The data were collected in classroom environments during scheduled academic sessions without interference from academic members of staff. It took approximately 20–30 min per participant to complete the questionnaire in a face-to-face setting, ensuring accuracy and completeness of responses.

## Statistical analysis

Data were entered into Microsoft Excel 2013 and exported to the Statistical Package for Social Sciences (SPSS) version 26.0

(IBM Corp., Armonk, NY, USA) for statistical analysis. Descriptive statistics were used to summarise participants' socio-demographic characteristics and responses to study variables. The primary outcome measure was participants' perception of ChatGPT, assessed using four items: (1) expected extent of ChatGPT's impact in 2025 ("Up to 50%" = 1; "More than 50%" = 2); (2) anticipated influence on educational progression ("Not positively" = 1; "Positively" = 2); (3) plans to make substantial changes in education or career due to ChatGPT or other AI chatbots ("Yes" = 1; "No" = 2); and (4) belief in the prediction by Stephen Hawking that uncontrolled AI could lead to the end of civilization within one's lifetime ("Yes" = 1; "No" = 2). The items were coded and summed to generate a composite perception score, which was categorised as negative (4–6) or positive (7–8) to facilitate interpretation and logistic regression analysis. To evaluate the robustness of this categorisation, additional sensitivity analyses were conducted. First, the composite attitude score was treated as a continuous variable in regression models. Second, alternative cut-points were explored to assess whether different thresholds would substantially alter the observed associations. These analyses produced results that were broadly consistent with the primary findings, suggesting that the observed relationships were stable across different model specifications. The four items capture key dimensions of attitudes towards AI, including perceived societal impact, perceived educational influence, behavioural intentions regarding career or educational changes, and perceived long-term risks associated with AI development. This approach aligns with established frameworks of attitude measurement, which conceptualise attitudes as comprising cognitive evaluations, perceived consequences, and behavioural intentions (LaCaille, 2013).

Given that AI tools such as ChatGPT are relatively new in health professions education, exploratory statistical techniques were used to identify latent constructs underlying students' attitudes and usage. Exploratory Factor Analysis (EFA) with principal component analysis (PCA) was performed to extract underlying factors. The suitability of the data for factor analysis was assessed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity, with KMO values >0.5 and Bartlett's test  $p$ -values <0.05 indicating that factor analysis was appropriate. Factors were retained based on Kaiser's criterion (eigenvalues >1) and visual inspection of the scree plot.

For students' attitudes towards ChatGPT, the KMO measure of sampling adequacy was 0.919, indicating excellent sampling adequacy. Bartlett's test of sphericity was statistically significant ( $\chi^2 = 11,859.354$ ,  $p < 0.001$ ), confirming that the correlation matrix was appropriate for factor analysis. Two factors were extracted with eigenvalues above 1 (5.706 and 2.337), accounting for 43.896% and 17.980% of the variance, respectively, with a cumulative variance of 61.876%. Factor loadings ranged from 0.567 to 0.852, with communalities between 0.453 and 0.708. Based on the questionnaire constructs, Factor 1 was labelled "Academic Risks and Threats" and included eight attitude variables, while Factor 2 was labelled "AI Technology Appeal" and comprised five variables. The internal consistency of these factors was high, with Cronbach's alpha values of 0.902 and 0.856, respectively.

Similarly, EFA with PCA was conducted to examine patterns in students' usage of ChatGPT, using 12 questionnaire items. The

analysis demonstrated high sampling adequacy with a KMO value of 0.917 and a statistically significant Bartlett's test of sphericity ( $\chi^2 = 10,057.556$ ,  $p < 0.001$ ). The scree plot suggested a two-factor solution with eigenvalues of 5.650 and 1.365, respectively. These two factors explained a cumulative variance of 58.460%, with the first factor contributing 47.084% of the variance. Factor loadings ranged from 0.402 to 0.877, with communalities between 0.340 and 0.672. Based on the item constructs, Factor 1 was labelled "Academic Dependence" (8 items), while Factor 2 was labelled "Careful Uptake" (4 items). The internal consistency of these factors was acceptable, with Cronbach's alpha values of 0.892 and 0.721, respectively.

Because the extracted variables were expected to be correlated, oblique Oblimin rotation was applied during factor extraction. Internal consistency of each factor was assessed using Cronbach's alpha, with values  $\geq 0.70$  indicating good reliability. Associations between categorical variables were examined using the chi-square ( $\chi^2$ ) test. Variables with  $p < 0.200$  in univariate analysis were included in a multivariable logistic regression model to identify factors associated with positive attitudes towards ChatGPT. A  $p < 0.2$  was selected for being inclusive at the initial stage, capturing variables that might be relevant but didn't quite hit the usual  $p < 0.050$  threshold in univariate analysis, thereby minimising missing out on potentially important factors. In other words, it is used in epidemiological modelling to avoid excluding potentially important variables during preliminary screening. Statistical significance was set at  $p < 0.050$ .

## Ethical approval

Ethical approval for this study was obtained from the University of Zambia Health Sciences Research Ethics Committee (UNZAHSREC; Protocol ID: 20231270128) and the Zambia National Health Research Authority (NHRA; Approval No. NHRA034/25/7/2024) before data collection. This study involved human participants and employed a cross-sectional survey design among university students in Zambia. Participation in the study was voluntary, and informed consent was obtained from all participants before completing the questionnaire. The survey collected self-reported data and did not include any personally identifiable information. To ensure anonymity, questionnaires were completed without names or student identification numbers. Data were stored securely and were accessible only to the research team. Participants were informed that their responses would be used solely for research purposes and that they could withdraw from the study at any time without any consequences. No financial incentives or compensation were provided to participants. The study was conducted in accordance with ethical principles outlined in the Declaration of Helsinki.

## Results

### Basic characteristics of study participants

The study involved 1,829 participants, giving a response rate of 95%, of whom 960 (52.5%) were females. The majority, 1,495 (81.7%), were aged between 18 and 25 years, and 1,690 (92.4%)

were not married. About nine in ten 1,671 (91.4%) were in health-related programs, and a larger proportion 691 (37.8%) were in their second year of study (Table 1). Overall, 96.8% of students had heard of ChatGPT, and 85.6% reported having used it before this study.

The findings of the study indicate that similar awareness levels were reported by all the surveyed institutions (Figure 1). On the other hand, the highest usage 92.3% was reported among students from the University of Zambia and the lowest 82.1% among students from EDEN University (Figure 1).

CBU-Copperbelt University, EDEN-Eden University, LMMU-Levy Mwanawasa University, MU-Mulungushi University, UNZA-University of Zambia. There was evidence of an association between using ChatGPT before this study and university participants ( $p < 0.001$ ).

### TAME-ChatGPT attitude constructs

Three attitude constructs from the TAME-ChatGPT were assessed among the participating students (Table 2). There was an association between sex, marital status, having heard of ChatGPT, and perceived risk of attitude construct towards ChatGPT. Additionally, sex, marital status, year of study, and having heard of ChatGPT were associated with the technology/social influence attitude construct. On the other hand, having heard of ChatGPT and the sex of the respondent were associated with the anxiety construct (Table 2).

On the AI- usage constructs, 74.8% respondents perceived a high risk for AI usage, 73.3% perceived ease of use, 64.0% perceived usefulness and 56.8% had behaviours as main AI usage constructs (Figure 2).

EFA identified two underlying attitude dimensions toward ChatGPT among students. Factor 1 ("Academic Risk and Threats") comprised eight items reflecting concerns related to plagiarism, overdependence on AI, reduced critical thinking, and privacy or security risks. Factor 2 ("AI Technology Appeal") included five items representing positive perceptions of ChatGPT, such as enthusiasm for AI use in learning and its perceived academic usefulness. Factor loadings ranged from 0.567–0.820 for Factor 1 and 0.723–0.852 for Factor 2, while communalities ranged from 0.453–0.708, indicating that the extracted factors adequately explained the variance in the attitude items (Table 3).

EFA identified two underlying usage dimensions of ChatGPT among students. Factor 1 ("Academic Dependence") included items reflecting reliance on ChatGPT for academic tasks such as searching for information, completing assignments, and perceiving the tool as reliable and time-saving. Factor 2 ("Careful Uptake") comprised items related to cautious engagement with the technology, including awareness of its potential effects on critical thinking and perceptions regarding ease of learning and use. Factor loadings ranged from 0.559–0.865 for Academic Dependence and 0.459–0.877 for Careful Uptake, while communalities ranged from 0.340–0.672, indicating that the two-factor solution adequately explained the variance in the usage items (Table 4). The factor loadings demonstrate strong clustering of related items within each factor, supporting the construct validity of the measurement instrument.

TABLE 1 Characteristics of study participants and attitude towards ChatGPT.

Characteristic	Total population, <i>n</i> (%)	Attitude		<i>p</i> -value
		Negative, <i>n</i> (%)	Positive, <i>n</i> (%)	
<b>Age (years)</b>				
18–25	1,495 (81.7)	711 (48.7)	748 (51.3)	0.167
26–32	208 (11.4)	94 (47.2)	105 (52.8)	
33–42	113 (6.2)	50 (49.5)	51 (50.5)	
≥42	13 (0.7)	2 (16.7)	10 (83.3)	
<b>Sex</b>				
Female	960 (52.5)	448 (48.3)	479 (51.7)	0.956
Male	869 (47.5)	409 (48.5)	435 (51.5)	
<b>Marital status</b>				
Unmarried	1,690 (92.4)	804 (49.0)	838 (51.0)	0.085
Married	139 (7.6)	53 (41.1)	76 (58.9)	
<b>Institution</b>				
Copperbelt University	357 (19.5)	174 (49.7)	176 (50.3)	<b>0.001</b>
Eden University	364 (19.9)	204 (58.0)	148 (45.1)	
Levy Mwanawasa University	370 (20.2)	157 (45.5)	200 (56.0)	
Mulungushi University	351 (19.2)	157 (45.5)	188 (54.5)	
University of Zambia	387 (21.2)	165 (45.0)	202 (55.0)	
<b>Program of study</b>				
Non-health-related	158 (8.6)	71 (46.4)	82 (53.6)	0.612
Health related	1,671 (91.4)	785 (48.6)	832 (51.5)	
<b>Year of study</b>				
Second-year	691 (37.8)	325 (48.9)	340 (51.1)	0.486
Third-year	430 (23.5)	210 (50.4)	207 (49.6)	
Fourth-year	400 (21.9)	185 (48.0)	201 (52.1)	
Fifth-year	279 (15.3)	127 (46.4)	147 (53.7)	
Sixth/seventh/postgraduate	29 (1.6)	10 (34.5)	19 (65.5)	
<b>Have you used ChatGPT before this study?</b>				
No	264 (14.4)	122 (59.2)	84 (40.8)	<b>0.001</b>
Yes	1,565 (85.6)	735 (47.0)	830 (53.0)	

## Factors influencing attitude towards ChatGPT

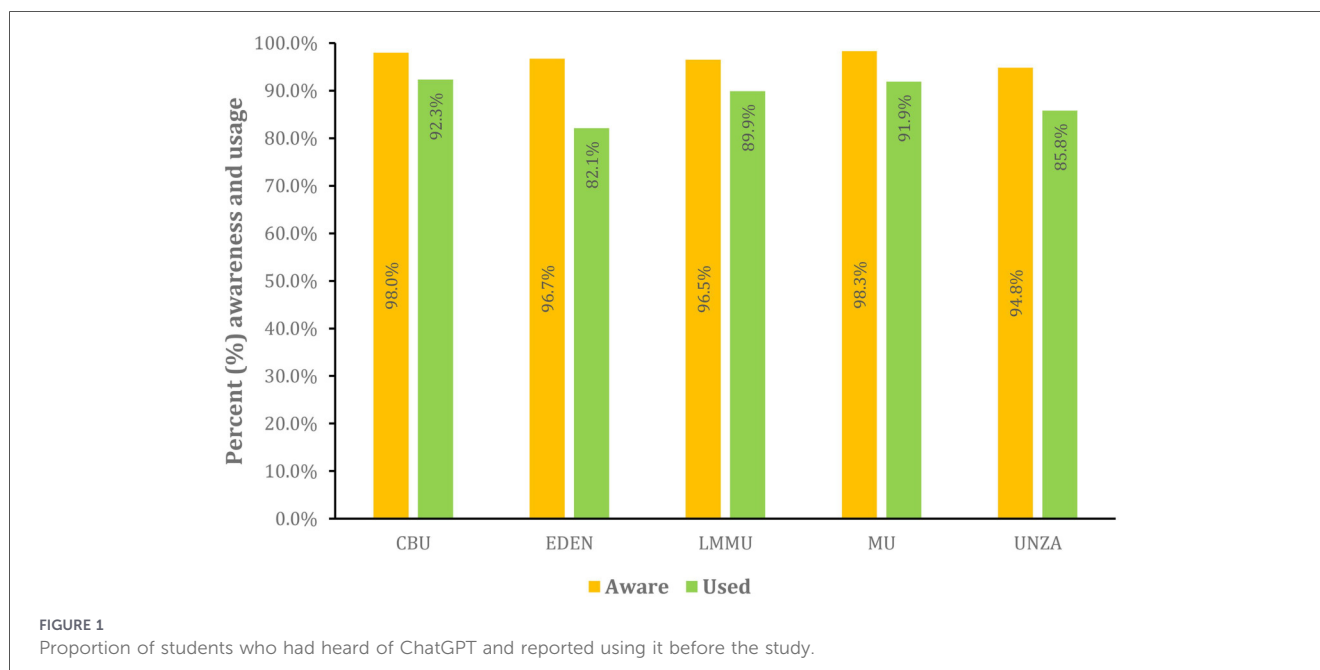
Simple and multivariable logistic regression models are presented in Table 5. From the simple regression model, factors associated with attitude towards ChatGPT were Age above 40 years than 18 to 25 years, being at EDEN University than Copperbelt University, having heard of ChatGPT and all the TAME-ChatGPT constructs on attitude and AI-usage except perceived ease of use of ChatGPT. In the adjusted analysis, only the behaviour AI-usage construct did not retain any statistical significance.

Respondents aged 40 years and above (adjusted odds ratio [aOR] = 5.91, 95% confidence interval [CI]: 1.23–28.33,  $p = 0.026$ ) were more likely to have a positive attitude towards ChatGPT than those aged between 18 and 25 years. Additionally, Technology/social influence (aOR=2.04, 95% CI:

1.55–2.68,  $p < 0.001$ ) was associated with higher odds of a positive attitude towards ChatGPT. Perceived usefulness (aOR=1.49, 95% CI: 1.17–1.89,  $p = 0.001$ ) was associated with high use of ChatGPT. On the other hand, EDEN University (aOR=0.69, 95% CI: 0.50–0.95,  $p < 0.001$ ) than Copperbelt University, perceived risk of AI-usage (aOR=0.61, 95% CI: 0.45–0.84,  $p = 0.003$ ) and perceived risk from TAME-ChatGPT construct (aOR=0.57, 95% CI: 0.43–0.75,  $p < 0.001$ ) were associated with lower odds of a positive attitude towards ChatGPT.

## Discussion

This study assessed awareness, attitudes, and usage patterns of ChatGPT among university students in Zambia, providing insight



into how generative AI tools are emerging within higher education in low- and middle-income country contexts. It is, to our knowledge, the first large-scale analysis across multiple institutions providing crucial insights into the attitudes and usage patterns of ChatGPT among all university students, building on previous studies conducted among healthcare students (Mudenda et al., 2024; Mudenda et al., 2025a; Mudenda et al., 2025b). Overall, the findings indicate substantial awareness of ChatGPT among students, with many participants reporting that the tool supports academic productivity, information retrieval, and learning efficiency. These findings suggest that generative AI technologies are rapidly becoming embedded within students' academic practices, even in settings where institutional guidance on AI use may still be evolving. Similar trends in the increasing adoption of generative AI tools among university students have been reported globally, reflecting the growing role of AI in supporting learning, research, and digital knowledge acquisition in higher education (Abdaljaleel et al., 2024; Delello et al., 2023; Habibi et al., 2023; Sallam, 2023; Sallam et al., 2023a; Sallam et al., 2024; Wood and Moss, 2024).

Importantly, the EFA conducted in this study identified several underlying dimensions that structure students' perceptions and experiences with ChatGPT. The factor structure revealed that students' responses clustered around key domains related to perceived academic benefits, social influence, and concerns about risks associated with AI use. These factors provide insight into the multidimensional nature of students' engagement with generative AI technologies. The identification of these constructs suggests that students' attitudes toward ChatGPT are not shaped by a single perception but rather by a combination of perceived utility, social context, and concerns about ethical or academic implications. This is in line with previous findings, which revealed that many factors or perceptions significantly influence students' behavioural intention to use ChatGPT (Al-kfairy et al., 2024; Uludağ et al., 2025).

The factor reflecting perceived academic usefulness or benefits highlights the extent to which students view ChatGPT as a tool that enhances learning efficiency, facilitates information retrieval, and supports academic tasks. This finding aligns with the TAM, which posits that perceived usefulness is a central determinant of technology adoption (Sallam et al., 2023a; Shahzad et al., 2024; Susanto et al., 2026). Students who recognise the potential of ChatGPT to improve their academic productivity appear more likely to adopt and integrate the tool into their learning practices. Previous studies examining the adoption of digital learning technologies have similarly found that perceived usefulness, including using AI for support or assistance in research, analysis, writing, brainstorming, and personalised learning, strongly predicts students' willingness to use emerging educational technologies (Chan and Hu, 2023; George Pallivathukal et al., 2024; Idroes et al., 2023; Klimova and de Campos, 2024; Ravšelj et al., 2025). The presence of this factor in the EFA therefore reinforces the theoretical relevance of TAM for understanding generative AI adoption in higher education contexts.

A second factor identified in the analysis relates to social influence and the broader academic environment in which AI technologies are used. Students who perceived that peers or academic communities were supportive of ChatGPT use tended to express more favourable attitudes toward the tool. This finding suggests that students' perceptions of generative AI are shaped not only by individual beliefs about usefulness but also by social norms and peer practices within academic settings. Technology adoption theories extending TAM emphasise the role of social influence in shaping individuals' technology-related attitudes and behaviours (Albayati, 2024). In educational environments where AI-assisted learning tools are commonly used or openly discussed among students, these technologies may become normalised within academic workflows. Similar patterns of peer influence affecting educational technology adoption have been documented in previous research

TABLE 2 TAME-ChatGPT-attitude constructs by the study participants' characteristics.

Variable/ construct	Perceived risk			Technology/social influence			Anxiety		
	Low <i>n</i> (%)	High, <i>n</i> (%)	<i>p</i> -value	Low <i>n</i> (%)	High, <i>n</i> (%)	<i>p</i> -value	Low <i>n</i> (%)	High, <i>n</i> (%)	<i>p</i> -value
<b>Age (years)</b>									
18–25	385 (26.4)	1,074 (73.6)	0.241	329 (22.6)	1,130 (77.5)	0.510	300 (20.6)	1,159 (79.4)	0.501
26–32	57 (28.6)	142 (71.4)		40 (20.1)	159 (79.9)		50 (25.1)	149 (74.9)	
33–42	33 (32.7)	68 (67.3)		17 (16.8)	84 (83.2)		22 (21.8)	79 (78.2)	
≥42	1 (8.3)	11 (91.7)		3 (25.0)	9 (75.0)		2 (16.7)	10 (83.3)	
<b>Sex</b>									
Female	229 (24.7)	698 (75.3)	<b>0.031</b>	241 (26.0)	686 (74.0)	<b>&lt;0.001</b>	177 (19.1)	750 (80.9)	<b>0.029</b>
Male	247 (29.3)	597 (70.7)		148 (17.5)	696 (82.5)		197 (23.3)	647 (76.7)	
<b>Marital status</b>									
Unmarried	429 (26.1)	1,213 (73.9)	<b>0.011</b>	370 (22.5)	1,272 (77.5)	<b>0.039</b>	344 (21.0)	1,298 (79.1)	0.537
Married	47 (36.4)	82 (63.6)		19 (14.7)	110 (85.3)		30 (23.3)	99 (76.7)	
<b>Institution</b>									
Copperbelt University	93 (26.6)	257 (73.4)	0.166	68 (19.4)	282 (80.6)	0.293	71 (20.3)	279 (79.7)	0.143
Eden University	107 (30.4)	245 (69.6)		71 (20.2)	281 (79.8)		89 (25.3)	263 (74.7)	
Levy Mwanawasa		271 (75.9)		81 (22.7)	276 (77.3)		72 (20.2)	285 (79.8)	
University	86 (24.1)	243 (70.4)		75 (21.7)	270 (78.3)		77 (22.3)	268 (77.7)	
Mulungushi University	102 (29.6)	279 (76.0)		94 (25.6)	273 (74.4)		65 (17.7)	302 (82.3)	
University of Zambia	88 (24.0)								
<b>Program of study</b>									
Non-health-related	46 (30.1)	107 (69.9)	0.354	40 (26.1)	113 (73.9)	0.193	34 (22.2)	119 (77.8)	0.729
Health related	430 (26.6)	1,187 (73.4)		349 (21.6)	1,268 (78.4)		340 (21.0)	1,277 (79.0)	
<b>Year of study</b>									
Second-year	201 (30.2)	464 (69.8)	0.149	137 (20.6)	528 (79.4)	<b>0.004</b>	158 (23.8)	507 (76.2)	0.204
Third-year	100 (24.0)	317 (76.0)		105 (25.2)	312 (74.8)		79 (18.9)	338 (81.1)	
Fourth-year	101 (26.2)	285 (73.8)		64 (16.6)	322 (83.4)		82 (21.20)	304 (78.8)	
Fifth-year	66 (24.1)	208 (75.9)		74 (27.0)	200 (73.0)		51 (18.6)	223 (81.4)	
Sixth/seventh/ postgraduate	8 (27.6)	21 (72.4)		9 (31.00)	20 (69.0)		4 (13.8)	25 (86.2)	
<b>Have you used ChatGPT before this study</b>									
No	35 (17.0)	171 (83.0)	<b>0.001</b>	85 (41.3)	121(58.7)	<b>&lt;0.001</b>	31(15.0)	175(85.0)	<b>0.023</b>
Yes	441(28.2)	1,124(71.8)		304(19.4)	1,261(80.6)		343(21.9)	1,222(78.1)	

TAME-ChatGPT, Technology Acceptance Model Edited to Assess ChatGPT Adoption.

(Crompton and Song, 2021; Delello et al., 2023; Korchak et al., 2025; Sallam, 2023; Sallam et al., 2023b).

In this study, the EFA also revealed a factor reflecting concerns about potential or perceived risks associated with the use of ChatGPT. Students reported concerns related to academic integrity, the reliability of AI-generated information, and the possibility that over-reliance on AI tools could undermine independent learning. These concerns mirror ongoing global debates regarding the role of generative AI in education (Acosta-Enriquez et al., 2024; Khlaif et al., 2023; Mudenda, 2025; Oc et al., 2025). While AI technologies can support learning through idea generation, summarisation, and information synthesis,

excessive reliance on such tools may weaken the development of critical thinking and academic writing skills (Chen and Cheung, 2025; Jin et al., 2025; Pireci Sejdiu and Sejdiu, 2025; Zhai et al., 2024). Ethical issues related to plagiarism, authorship attribution, and transparency in AI-assisted work have also been widely discussed in the literature examining generative AI in academic contexts (Mortlock and Lucas, 2024; Williams, 2023; Yusuf et al., 2024). The emergence of this factor in the analysis suggests that students are simultaneously aware of both the potential benefits and the risks associated with generative AI tools.

Taken together, the factor structure identified in this study highlights the complex nature of students' perceptions of

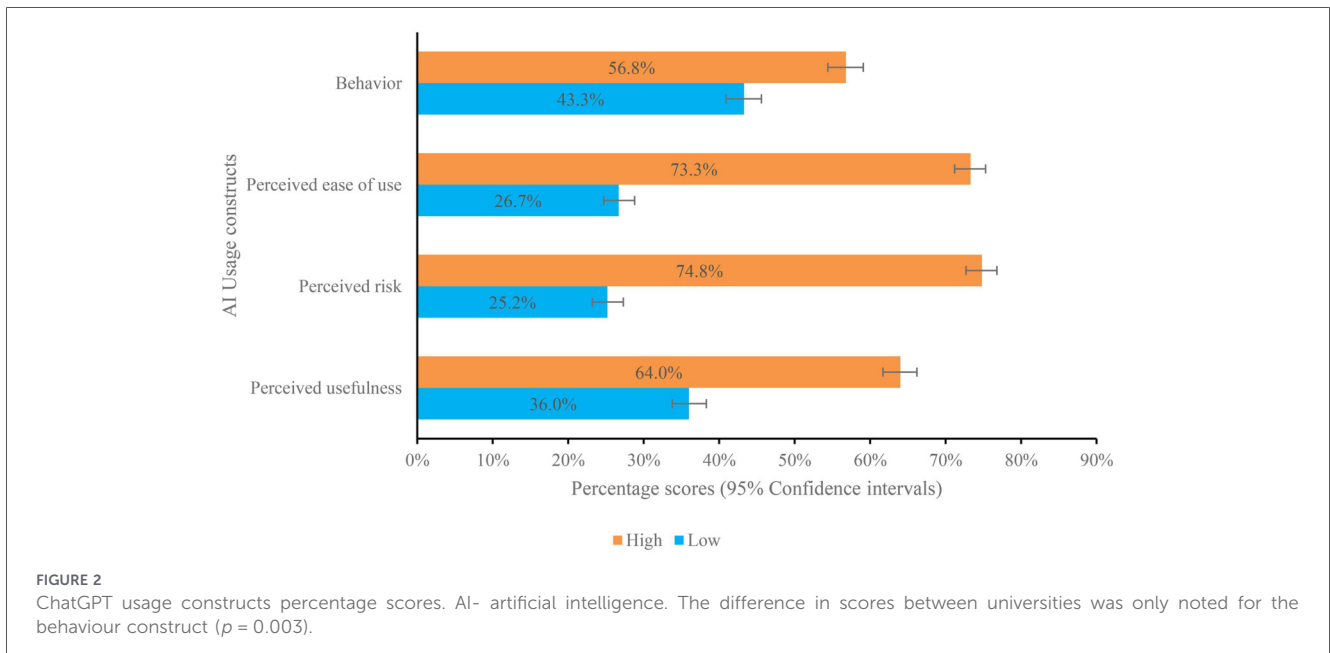


TABLE 3 Factor loading and item communalities for attitude scale by EFA ( $n = 1,829$ ).

Item	F1	F2	$h^2$
11 I am concerned about the reliability of the information provided by ChatGPT	0.567	< 0.400	0.453
12 I am concerned that using ChatGPT would get me accused of plagiarism	0.745	< 0.400	0.561
13 I am afraid of relying too much on ChatGPT and not developing my critical thinking skills.	0.799	< 0.400	0.690
14 I am concerned about the potential security risks of using ChatGPT.	0.794	< 0.400	0.635
15 I am afraid of becoming too dependent on technology like ChatGPT.	0.815	< 0.400	0.689
16 I am afraid that using ChatGPT would result in a lack of originality in my university assignments and duties.	0.820	< 0.400	0.659
17 I am afraid that the use of ChatGPT would be a violation of academic and university policies.	0.799	< 0.400	0.574
18 I am concerned about the potential privacy risks that might be associated with using ChatGPT.	0.764	< 0.400	0.577
19 I am enthusiastic about using technology such as ChatGPT for learning and research.	< 0.400	0.723	0.579
20 I believe technology such as ChatGPT is an important tool for academic success.	< 0.400	0.852	0.708
21 I think that technology like ChatGPT is attractive and fun to use.	< 0.400	0.794	0.670
22 I am always keen to learn about new technologies such as ChatGPT.	< 0.400	0.808	0.671
23 I trust the opinions of my friends or colleagues about using ChatGPT.	< 0.400	0.787	0.578

Only factor loadings > 0.4 are shown.

F1 = Factor 1 (Academic Risk and Threats), F2 = Factor 2 (AI technology appeal),  $h^2$  = Communalities.

ChatGPT. Students appear to evaluate the technology through a balance of perceived benefits, social influences, and concerns about potential misuse or academic consequences. This multidimensional perspective is consistent with broader theoretical frameworks of technology adoption, which emphasise that user acceptance is shaped by both enabling and constraining factors. Understanding these underlying dimensions is therefore important for higher education institutions seeking to develop strategies for responsible AI integration.

The increasing availability of generative AI tools such as ChatGPT has important implications for higher education governance and pedagogy. Universities may need to develop

clear institutional policies that define acceptable uses of AI-assisted technologies in academic work. Such policies should address issues related to academic integrity, transparency in AI-assisted writing, and responsible use of AI-generated content. In addition, integrating AI literacy into university curricula could help students develop the skills required to critically evaluate AI-generated information and use AI technologies responsibly. Educational institutions may therefore benefit from incorporating discussions of AI, digital literacy, and ethical technology use into teaching and learning strategies. Previous studies have similarly emphasised the importance of institutional frameworks and governance mechanisms to guide the responsible use of AI in higher education (Ali et al., 2024; An

TABLE 4 Factor loading and item communalities for usage scale by EFA (n = 1,829).

Item	F1	F2	h <sup>2</sup>
24 ChatGPT helps me save time when searching for information	0.559	0.402	0.669
25 For me, ChatGPT is a reliable source of accurate information	0.865	< 0.400	0.645
26 I recommend ChatGPT to my colleagues to facilitate their academic duties.	0.807	< 0.400	0.632
27 ChatGPT is more useful than other sources of information that I have used previously.	0.744	< 0.400	0.529
28 I have used tools or techniques similar to ChatGPT in the past.	<0.400	0.459	0.340
29 I spontaneously find myself using ChatGPT when I need information for my university assignments and duties.	0.697	< 0.400	0.558
30 I often use ChatGPT as a source of information in my university assignments and duties	0.697	< 0.400	0.539
31 I think that relying on technology like ChatGPT can disrupt my critical thinking skills.	<0.400	0.877	0.650
32 I appreciate the accuracy and reliability of the information provided by ChatGPT	0.743	< 0.400	0.574
33 I believe that using ChatGPT can save time and effort in my university assignments and duties.	0.600	< 0.400	0.619
34 It does not take a long time to learn how to use ChatGPT	< 0.400	0.677	0.672
35 ChatGPT does not require extensive technical knowledge.	< 0.400	0.712	0.589

Only factor loadings > 0.4 are shown.

F1 = Factor 1 (Academic Dependence), F2 = Factor 2 (Careful Uptake), h<sup>2</sup> = Communalities.

et al., 2025; Funa and Gabay, 2025; Klimova and Pikhart, 2025; McDonald et al., 2025; Nguyen, 2025; Ullah et al., 2024; Williams, 2023).

This study also contributes to the limited empirical literature on AI adoption in higher education within Sub-Saharan Africa. Much of the existing research on generative AI in education has been conducted in high-income countries, and relatively little empirical evidence exists from African contexts. By examining the perceptions and usage patterns of students across multiple universities in Zambia, this study provides valuable regional insights into how emerging AI technologies are being adopted within resource-constrained educational environments. Previous studies conducted in Zambia and similar contexts have also reported growing interest in AI technologies among students while emphasising the need for institutional guidance and policy development to ensure responsible integration of these tools (Mudenda et al., 2024; Mudenda et al., 2025a; Mudenda et al., 2025b).

## Policy and educational implications

The findings highlight an urgent need for structured AI integration within Zambian higher education. Universities should move beyond restrictive policies toward proactive engagement, developing curricula that include AI literacy, ethics, and responsible use. Institutional policies should be clear on what constitutes appropriate use, particularly concerning plagiarism and academic misconduct. At the same time, educators should be equipped to incorporate ChatGPT responsibly in teaching, assessment, and feedback. Table 6 outlines key policy and practice recommendations derived from this study.

The strong influence of technology/social influence and perceived usefulness suggests that AI adoption can be enhanced through peer learning, mentorship, and role modelling. Embedding AI literacy modules within existing courses, such as research methods, communication, or informatics, would strengthen students' capacity to use ChatGPT critically and ethically. Furthermore, policymakers and the Higher Education

Authority in Zambia should collaborate with universities to establish national guidelines for generative AI use in academia.

While ChatGPT use among Zambian university students is widespread, structured policy frameworks, faculty training, and ethical guidelines are urgently needed to ensure responsible and equitable adoption. Integrating AI literacy into curricula, strengthening institutional policies, and enhancing digital infrastructure will support informed and ethical use. Collaboration among universities, government bodies, and regulatory authorities is essential to harmonise standards and promote national alignment on AI use in higher education.

It is also important to note that ChatGPT represents only the early stages of a much broader and more transformative AI revolution. As research and innovation accelerate, more advanced, autonomous AI systems will emerge, capable of performing increasingly complex cognitive tasks across multiple sectors. In this evolving landscape, universities have a critical role to play. Beyond simply integrating tools like ChatGPT into teaching and learning, higher education institutions must foster open, forward-looking discussions about how AI will reshape industries, redefine professional roles, and potentially render some traditional career paths obsolete. Avoiding these conversations risks leaving graduates unprepared for a rapidly changing labour market.

To remain relevant, universities must begin to realign curricula with the realities of an AI-driven world. This includes embedding AI literacy across disciplines, rethinking assessment methods, and prioritising skills that complement rather than compete with automation, such as critical thinking, creativity, ethical reasoning, and interdisciplinary problem-solving. Programs that are heavily task-based or routine in nature may require restructuring, while new pathways focused on AI governance, data stewardship, and human-AI collaboration should be developed. By proactively adapting academic programs and career guidance to reflect the transformative impact of AI, universities can equip students not only to survive but to lead in a future where AI is deeply embedded in nearly every profession.

TABLE 5 Factors influencing attitude towards ChatGPT among university students.

Variable	Unadjusted OR (95% CI)	p-value	Adjusted OR(95% CI)	p-value
<b>Age (years)</b>				
18–25	Ref		Ref	
26–32	1.06 (0.79–1.43)	0.692	0.93 (0.67–1.31)	0.702
33–42	0.97 (0.65–1.45)	0.881	0.82 (0.53–1.27)	0.374
≥42	4.75 (1.04–21.77)	<b>0.045</b>	5.91 (1.23–28.33)	<b>0.026</b>
<b>Sex</b>				
Female	Ref			
Male	0.99 (0.83–1.20)	0.956		
<b>Marital status</b>				
Unmarried	Ref			
Married	1.38 (0.96–1.98)	0.086		
<b>Institution</b>				
Copperbelt University	Ref		Ref	
Eden University	0.72 (0.53–0.97)	<b>0.029</b>	0.69 (0.50–0.95)	<b>0.024</b>
Levy Mwanawasa University	1.26 (0.94–1.69)	0.127	1.38 (0.99–1.90)	0.053
Mulungushi University	1.18 (0.88–1.59)	0.267	1.20 (0.87–1.66)	0.261
University of Zambia	1.21 (0.90–1.62)	0.203	1.38 (0.99–1.90)	0.052
<b>Program of study</b>				
Non-health-related	Ref			
Health related	0.92 (0.66–1.28)	0.613		
<b>Year of study</b>				
Second-year	Ref		Ref	
Third-year	0.94 (0.74–1.20)	0.634	0.95 (0.72–1.26)	0.733
Fourth-year	1.04 (0.81–1.33)	0.768	0.95 (0.71–1.26)	0.712
Fifth-year	1.11 (0.83–1.47)	0.482	1.07 (0.77–1.50)	0.683
Sixth/seventh/postgraduate	1.82 (0.83–3.96)	0.134	2.01 (0.86–4.70)	0.108
<b>Have you used ChatGPT before this study?</b>				
No	Ref		Ref	
Yes	1.64 (1.22–2.20)	<b>0.001</b>	1.13 (0.81–1.56)	0.469
<b>TAME-ChatGPT Attitude constructs</b>				
Perceived risk	0.38 (0.30–0.47)	<b>&lt;0.001</b>	0.57 (0.43–0.75)	<b>&lt;0.001</b>
Technology/ social influence	2.94 (2.31–3.73)	<b>&lt;0.001</b>	2.04 (1.55–2.68)	<b>&lt;0.001</b>
Anxiety	0.48 (0.38–0.61)	<b>&lt;0.001</b>	0.99 (0.72–1.36)	0.945
<b>TAME-ChatGPT Usage constructs</b>				
Perceived usefulness	2.29 (1.88–2.79)	<b>&lt;0.001</b>	1.49 (1.17–1.89)	<b>0.001</b>
Perceived risk	0.38 (0.30–0.47)	<b>&lt;0.001</b>	0.61 (0.45–0.84)	<b>0.003</b>
Perceived ease of use	1.04 (0.84–1.28)	0.738	1.01 (0.80–1.27)	0.935
Behavior	1.51 (1.25–1.82)	<b>&lt;0.001</b>	1.07(0.86–1.33)	0.563

TAME-ChatGPT, Technology Acceptance Model Edited to Assess ChatGPT Adoption, OR-odds ratio, 95% CI-95% confidence intervals, the constructs for TAME-ChatGPT for attitude and Usage were fitted with "low" category as reference. Boldface indicates statistical significance at  $p < 0.005$ .

## Limitations and strengths of the study

We are aware that this study has some limitations. First, its cross-sectional design only captures a snapshot in time and does not allow for the establishment of causal relationships between

the variables. While we can show associations, we cannot definitively say that a certain demographic characteristic causes a specific usage pattern. Second, the study relied on self-reported data, which may be subject to social desirability bias, where participants might over-report positive or responsible

TABLE 6 Policy and educational implications of ChatGPT adoption among university students in Zambia.

Policy/ Practice area	Key study findings informing policy	Recommended actions	Responsible stakeholders
AI Literacy and Curriculum Integration	A high proportion of students reported using ChatGPT for academic tasks such as searching for information and completing coursework, indicating growing reliance on generative AI tools in learning.	Integrate AI literacy, digital ethics, and responsible use of generative AI tools into university curricula. Universities should introduce modules on AI-assisted research, critical evaluation of AI-generated information, and ethical academic use of ChatGPT.	Ministry of Education; Higher Education Authority (HEA); University curriculum committees; Faculties and departments
Institutional Policies on AI Use	Students expressed concerns regarding plagiarism and academic integrity when using ChatGPT, highlighting uncertainty about acceptable academic use.	Develop institutional guidelines outlining appropriate and inappropriate uses of generative AI in academic work. Policies should clarify plagiarism boundaries, citation practices for AI tools, and acceptable AI-assisted learning activities.	University Senates; Academic Boards; Institutional policy units; ICT directorates
Academic Integrity and Assessment Practices	Factor analysis showed concerns related to plagiarism and the reliability of AI-generated content, suggesting perceived academic risks associated with ChatGPT use.	Universities should adapt assessment strategies to promote critical thinking and reduce over-reliance on AI tools. This may include oral assessments, project-based learning, and reflective assignments that encourage independent analysis.	University academic affairs offices; Teaching and learning centres; Lecturers and course coordinators
Digital Skills and Responsible AI Use	Students demonstrated mixed perceptions regarding the reliability and risks associated with AI tools, indicating the need for stronger digital competency training.	Provide workshops and training programs on responsible AI use, including evaluating AI outputs, identifying misinformation, and using AI tools as complementary learning resources rather than substitutes for independent work.	Universities; Teaching and learning centres; ICT departments
Future Research and Monitoring of AI Adoption	The study provides early empirical evidence of ChatGPT adoption among university students in Zambia, but findings are largely drawn from health-related programs.	Encourage continued monitoring of AI adoption in higher education across diverse disciplines and institutions to better understand evolving usage patterns and educational impacts.	Ministry of Education; Higher Education Authority; Universities; Education researchers

behaviours related to academic integrity. Third, the sample was heavily skewed towards students in human health-related programs (91.1%), which may limit the generalizability of the findings to students in other academic fields, including engineering, arts, or business. Future research should therefore consider including a broader range of academic programs and adopting longitudinal research designs to better understand how perceptions and usage patterns of generative AI technologies evolve. We acknowledge that dichotomising continuous or ordinal measures may lead to loss of information and reduced statistical power; therefore, future studies may consider modelling attitudes toward generative AI using continuous or ordinal approaches.

Despite these limitations, the large multi-institutional sample strengthens the robustness of the findings and provides a useful foundation for future research. This study offers important insights into the adoption and perceptions of ChatGPT among university students in Zambia, highlighting both the opportunities and challenges associated with integrating generative AI tools into higher education. Future research should build on these findings by employing longitudinal and qualitative approaches to better understand how patterns of AI use and student attitudes evolve. Such studies could also examine how institutional policies influence student behaviour and explore differences in AI adoption across academic disciplines. In addition, comparative studies

assessing the quality of student work produced with and without AI-assisted tools would provide valuable evidence on the educational implications of generative AI use. As AI technologies continue to evolve and become more widely accessible, universities will play an important role in guiding their responsible integration. Strengthening institutional policies, promoting AI literacy, and encouraging critical engagement with AI tools will be essential to ensure that these technologies complement, rather than replace, core academic competencies such as critical thinking, academic integrity, and independent learning.

## Conclusions

This study provides important insights into university students' awareness, attitudes, and usage patterns of ChatGPT in Zambia. The findings suggest that while many students recognise the potential academic benefits of generative AI technologies, concerns regarding ethical use and academic integrity remain prominent. These results highlight the need for universities to develop clear institutional policies, promote AI literacy, and integrate responsible AI use into higher education curricula. Future research should explore longitudinal trends in AI adoption among students and evaluate the effectiveness of institutional policies aimed at guiding responsible AI-assisted learning.

## Data availability statement

The original contributions presented in the study are included in the article/[Supplementary Material](#), further inquiries can be directed to the corresponding author.

## Ethics statement

Ethical approval for this study was obtained from the University of Zambia Health Sciences Research Ethics Committee (UNZAHSREC; Protocol ID: 20231270128) and the Zambia National Health Research Authority (NHRA; Approval No. NHRA034/25/7/2024). All participants were informed about the study's purpose and procedures, and written informed consent was obtained prior to enrollment. Ethical principles of confidentiality and anonymity were strictly maintained, and participation was entirely voluntary.

## Author contributions

SMu: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MMu: Formal analysis, Validation, Writing – original draft, Writing – review & editing. RM: Investigation, Writing – original draft, Writing – review & editing. BK: Writing – original draft, Writing – review & editing. IM: Formal analysis, Writing – original draft, Writing – review & editing. BM: Investigation, Writing – original draft, Writing – review & editing. WM: Investigation, Supervision, Writing – original draft, Writing – review & editing. MH: Investigation, Writing – original draft, Writing – review & editing. KK: Investigation, Writing – original draft, Writing – review & editing. MMw: Writing – original draft, Writing – review & editing. TM: Investigation, Writing – original draft, Writing – review & editing. CC: Writing – original draft, Writing – review & editing. MZ: Writing – original draft, Writing – review & editing. RT: Writing – original draft, Writing – review & editing. FM: Writing – original draft, Writing – review & editing. SK: Writing – original draft, Writing – review & editing. AL: Writing – original draft, Writing – review & editing. CS: Investigation, Writing – original draft, Writing – review & editing. SMo: Writing – original draft, Writing – review & editing. NM: Writing – original draft, Writing – review & editing. AS: Writing – original draft, Writing – review & editing. MM: Investigation, Writing – original draft, Writing – review & editing. PA: Writing – original draft, Writing – review & editing. NM: Writing – original draft, Writing – review & editing. RO: Writing – original draft, Writing – review & editing. JH: Investigation, Writing – original

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## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2026.1814033/full#supplementary-material>

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