Understanding ChatGPT dependency in Science student learning: a structural model approach

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Abstract

ChatGPT, an AI-based tool for generating text responses, has become popular among university students to aid in understanding complex subjects. This study explores factors influencing ChatGPT adoption among Indonesian science students, focusing on ease of use (EU), perceived usefulness (PU), hedonic motivation (HM), satisfaction of use (SU), and dependency of use (DU). A quantitative method was used to collect data from 205 students across 22 provinces via convenience sampling, analyzed using "Partial Least Squares - Structural Equation Modeling" (PLS-SEM). Results show that the EU significantly affects SU but not DU. PU and HM significantly influence SU and DU, indicating their key roles. However, SU does not significantly affect DU, suggesting that satisfaction alone does not drive dependency. These findings highlight the importance of balanced ChatGPT integration in education to support learning without encouraging over-reliance. This study offers empirical insights from a developing country for educators and policymakers on responsible AI use in science education.

Keywords

ChatGPT, science students, technology dependency, higher education, AI in education

Résumé

ChatGPT, un outil basé sur l'IA permettant de générer des réponses textuelles, est devenu populaire auprès des étudiants universitaires pour les aider à comprendre des sujets complexes. Cette étude explore les facteurs influençant l'adoption de ChatGPT parmi les étudiants en sciences indonésiens, en se concentrant sur la facilité d'utilisation (EU), l'utilité perçue (PU), la motivation hédonique (HM), la satisfaction d'utilisation (SU) et la dépendance à l'utilisation (DU). Une méthode quantitative a été utilisée pour collecter des données auprès de 205 étudiants dans 22 provinces via un échantillonnage de commodité, puis analysées à l'aide de "Partial Least Squares - Structural Equation Modeling" (PLS-SEM). Les résultats montrent que l'UE a une incidence significative sur la SU, mais pas sur la DU. La PU et la HM ont une influence significative sur la SU et la DU, ce qui indique leur rôle clé. Cependant, la SU n'a pas d'incidence significative sur la DU, ce qui suggère que la satisfaction seule ne favorise pas la dépendance. Ces résultats soulignent l'importance d'une intégration équilibrée de ChatGPT dans l'éducation afin de soutenir l'apprentissage sans encourager une dépendance excessive. Cette étude offre aux éducateurs et aux décideurs politiques des informations empiriques issues d'un pays en développement sur l'utilisation responsable de l'IA dans l'enseignement des sciences.

Mots-clés

ChatGPT, étudiants en sciences, dépendance à la technologie, enseignement supérieur, IA dans l'éducation

Cite this article

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Introduction

In the last decades, the development of digital technologies has brought great changes in the field of education as digital tools are increasingly becoming objects of research on the subject of learning on the one hand and on the other hand they are being used in teaching (Fadillah et al., 2025a; Otero et al., 2024). These rapid technological developments have improved efficiency and effectiveness in various sectors, including education, with artificial intelligence (AI) innovations proliferating and having far-reaching impacts (Ooi et al., 2025). One prominent AI in education is Chat Generative Pre-trained Transformer (ChatGPT), which uses a Large Language Model (LLM) to serve as a generative chatbot that can communicate in human language, provide relevant answers, and main-

tain dialog consistency (Mai et al., 2024). ChatGPT has become an essential tool in education, aiding various aspects of learning such as answering specific questions, generating new content, summarizing text, generating programming code, and deciphering language with natural responses (Castillo et al., 2023; Festiyed et al., 2024; Rahman & Watanobe, 2023). These advantages make ChatGPT a valuable tool in various fields, such as education, psychology, and sociology (Khlaif et al., 2023).

However, the use of ChatGPT raises concerns regarding potential misuse in education (Cai et al., 2023) and research (Farrokhnia et al., 2023). Several studies have shown risks related to academic honesty and plagiarism using ChatGPT in academic assignments and exams (Khlaif et al., 2023). The use of ChatGPT in assignments and exams can compromise academic integrity and student learning outcomes (Joshi et al., 2024). In addition, using ChatGPT may limit the development of learners' communication, writing, and critical thinking competencies (Vázquez-Cano et al., 2023).

Research on the impact of AI and ChatGPT in education continues to grow. Mai et al. (2024) found that ChatGPT can optimize the teaching and learning process if used carefully, leveraging the strengths and overcoming the weaknesses of this technology. The effectiveness of using ChatGPT depends mainly on the learner's metacognitive skills in assessing the assistance provided and the limitations of this technology (Hartley et al., 2024). Models such as the Technology Acceptance Model (TAM) were used to analyze the relationship between user perception and ease of use of ChatGPT (Tahar et al., 2020). AI's ability to save time and cost makes it attractive as it simplifies various human tasks (Benvenuti et al., 2023; Pradana et al., 2023). Therefore, the convenience offered by ChatGPT makes it increasingly considered in educational contexts (Lo, 2023).

In developing countries like Indonesia, integrating AI tools into education is often viewed as a double-edged sword. While studies in similar contexts highlight ChatGPT's potential to democratize access to information (Fadillah et al., 2024; Hamad & Shehata, 2024; Pradana et al., 2023), they also caution against uncritical adoption due to infrastructural limitations and pedagogical readiness (Khlaif et al., 2023; Sallam, 2023). Issues such as limited internet access, digital literacy gaps, and overcrowded classrooms further complicate the integration of AI tools like ChatGPT (Choczyńska, 2024; Sain et al., 2024). These challenges are not unique to science education but affect the broader educational landscape in developing countries.

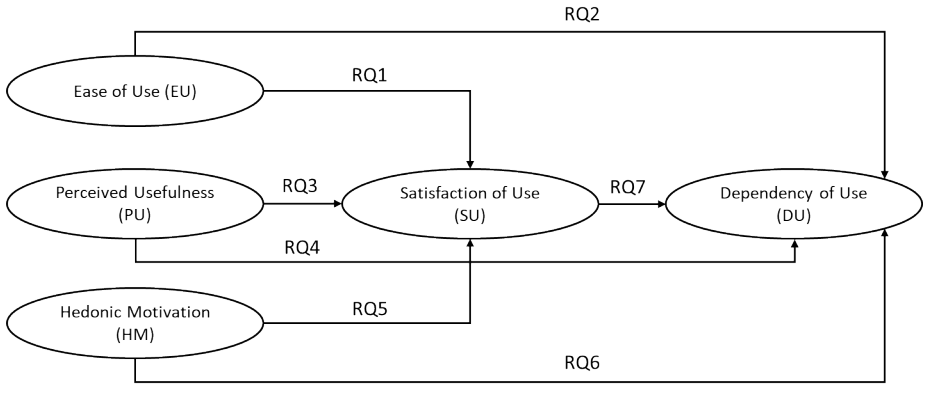
Although many studies address the use of ChatGPT in education (Lo et al., 2024; Montenegro-Rueda et al., 2023; Sallam, 2023), there is a research gap regarding users' satisfaction and dependence on ChatGPT. Most previous studies used models such as TAM to analyze the relationship between users' perceptions with the ease of use of ChatGPT (Shoufan, 2023) or emphasized additional external factors and hedonic motivations (Habibi et al., 2023; Qu & Wu, 2024). However, satisfaction factors and dependence on ChatGPT have yet to be studied in depth. Dependence on ChatGPT

can influence students', especially science students, views and attitudes, especially in critical thinking, creativity, and appreciation of human content (Ray, 2023).

To better understand dependency, this study expands beyond traditional acceptance models by incorporating insights from habit formation theory, which explains how repeated usage and reinforcement can lead to automated behaviors over time (Limayem et al., 2007). Moreover, sociomateriality theory highlights how technologies like ChatGPT are not neutral tools but actively shape and are shaped by the learning practices and environments in which they are embedded (Orlikowski, 2007). This theoretical extension allows a deeper exploration of ChatGPT dependency, which may emerge not only from usefulness or satisfaction but also from behavioral habituation and sociotechnical entanglements.

This study aims to explore the use of ChatGPT in science education, focusing on ease of use (EU), perceived usefulness (PU), hedonic motivation (HM), satisfaction of use (SU), and dependency of use (DU). Rather than relying solely on the TAM, this study incorporates habit formation theory (Limayem et al., 2007), sociomateriality (Orlikowski, 2007), and emotional engagement (Hirschman & Holbrook, 1982) to capture the behavioral, pedagogical, and affective dimensions of ChatGPT use in learning contexts. Figure 1 illustrates the conceptual framework developed for this study. The model examines five key constructs. Drawing from the TAM and extending it with constructs related to emotional motivation and behavioral reinforcement, the model explores how perceptions of ease, usefulness, and enjoyment affect user satisfaction and potential over-reliance on ChatGPT. Seven research questions are derived from this model, as represented by the directional arrows in the diagram.

FIGURE 1



Conceptual framework of the structural model examining ChatGPT dependency among Science students

Research questions development

Ease of use to satisfaction of use and dependency of use

EU refers to the extent to which users can be confident they can do anything without interference or obstacles when utilizing a technology (Tahar et al., 2020). Ngo (2023) found that students' perception of ChatGPT's EU had the highest score, indicating that students prefer ChatGPT because of its ease. Malureanu et al. (2021) stated that cognitive factors such as the EU strongly influence the perception of digital benefits. Zuniarti et al. (2021) added that the EU can be obtained through the intensity of use and interaction with the system. When users can accept and adapt to technology, their perception of it will improve (Tahar et al., 2020). Therefore, the EU is a vital factor in ChatGPT adoption. Research by Joo et al. (2018) showed that the EU positively influences student satisfaction with K-MOOC courses. Students who positively perceive the ease of technology will feel more satisfied. Calvo-Porral et al. (2017) also found that increased satisfaction with the use of digital technology occurs due to the ease and attractiveness of the content. So, the easier a technology is to use and the more interesting the content, the higher the user satisfaction.

Additionally, Abdaljaleel et al. (2024) revealed that ChatGPT has many uses and is easy to use. Better perceptions and feelings towards the use of ChatGPT, such as that the technology is easy to operate, use, and enjoy, resulting in satisfaction with ChatGPT, will be better, too. This effect was also obtained by Calvo-Porral et al. (2017) on using digital outlets. In addition, Pitafi et al. (2020) stated that PU moderates the relationship between EU, addiction (dependence), and psychological dependence on the internet. In the study, it was found that Pakistani students' addiction to SNSs (Social networking sites) was higher due to the EU. Therefore, this study proposes the following research questions:

- **RQ1:** How is the relationship between EU and SU among science students using ChatGPT?
- **RQ2:** How is the relationship between EU and DU among science students using ChatGPT?

Perceived usefulness to satisfaction of use and dependency of use

PU is the belief that a system benefits its users. It describes the user's perceived benefits (Yousaf et al., 2021). According to Wilson et al. (2021), perceived usefulness is the user's perception of the ease and speed of understanding and using a new product or service without difficulty, influencing their decision. However, this perception is closely related to EU, which has been discussed earlier. Since EU reflects how easily users can operate a system without obstacles, it directly influences PU by shaping their perception of the system's usefulness (Malureanu et al., 2021; Tahar et al., 2020). If users find

technology easy to use, they tend to see it as beneficial because ease of use reduces effort and cognitive load (Al-Sharafi et al., 2016). Thus, PU and EU are interconnected, where a higher EU reinforces PU, ultimately affecting user satisfaction and dependence.

PU can improve learning experiences, outcomes, and academic achievement. Tran and Le (2020) found that product quality significantly positively affects customer satisfaction, indicating that PU affects customer satisfaction. Joo et al. (2018) also found that PU positively influences student satisfaction in K-MOOC courses. Students with a positive view of the PU tend to feel more satisfied. Previous researchers (Castillo et al., 2023; Khlaif et al., 2023; Rahman & Watanobe, 2023) stated that ChatGPT offers many features that help users, such as generating content, summarizing, translating languages, and providing complex answers. Shao and Xia (2023) found that the level of satisfaction with the use of ChatGPT in foreign language learning is at a neutral level. However, a higher depth of use can significantly increase satisfaction.

Additionally, Linden et al. (2021) stated that increased use of smartphones indicates an increase in dependence. The relationship between PU and DU can also be analyzed in the acceptance of ChatGPT. Mhlanga (2023) stated that using ChatGPT in the scope of education in developing countries can extend dependence on AI technology rather than encourage critical thinking and problem-solving skills because ChatGPT is designed to facilitate communication with users through the chatbot feature. While ChatGPT can cover various subjects, the understanding provided needs more depth. This study explores how perceived usefulness can impact satisfaction and dependence in using ChatGPT among science students. Therefore, this study proposes the following research questions:

- **RQ3:** How is the relationship between PU and SU among science students using ChatGPT?
- **RQ4:** How is the relationship between PU and DU among science students using ChatGPT?

Hedonic motivation to satisfaction of use and dependency of use

HM is defined as the pleasure derived from the use of technology. Zefreh et al. (2023) demonstrated that hedonic motivation significantly affects user acceptance of technology. Zhou et al. (2022) also demonstrated that students' hedonic motivation influenced their continued use of travel apps. During the pandemic, hedonic motivation influenced the intensity of live-streaming selling applications (Zhao & Bacao, 2021). Koenig-Lewis et al. (2015) posit that enjoyment influences hedonic motivation. Chang et al. (2023) posited that pleasurable experiences enhance hedonic motivation, with the ease of use of technology also playing a role. Qu and Wu (2024) posit that the convenience and benefits offered by ChatGPT can increase users' satisfaction and hedonic motivation, suggesting that ChatGPT may enhance intrinsic motivation during English language

learning. Tyrväinen et al. (2020) demonstrated that hedonic motivation is associated with user satisfaction and loyalty. In the context of hedonic motivation, perceived usefulness is more closely aligned with satisfaction than practical functions (Deng & Yu, 2023). Dienlin and Johannes (2020) posit that hedonic well-being is an affective state centered on emotions and pleasure. Joo et al. (2018) posit that autonomous motivation positively influences satisfaction, whereas controlled motivation exerts a negative influence. In using ChatGPT in education, hedonic motivation can make learning more exciting and enjoyable, increasing the likelihood of continued use (Qu & Wu, 2024). Nevertheless, a high level of motivation in using SNSs can result in dependence (Pitafi et al., 2020), which may also apply to using ChatGPT. Therefore, this study proposes the following research questions:

- **RQ5:** How is the relationship between HM and SU among science students using ChatGPT?
- **RQ6:** How is the relationship between HM and DU among science students using ChatGPT?

Satisfaction of use to dependency of use

Satisfaction is the key to industry success because it affects whether consumers will continue to use a service (Al Halbusi et al., 2022). Gupta et al. (2021) add that satisfaction involves meaningful experiences and emotions. According to Smutny and Schreiberova (2020), satisfaction is influenced by accessibility, influence, behavior, and ethics. ChatGPT, with its high accessibility and chatbot-based, can provide satisfaction through ease of use (Kuhail et al., 2023). Since EU has been previously identified as a key factor influencing satisfaction, it is important to recognize that EU contributes to user satisfaction not only directly but also by enhancing PU, which in turn affects satisfaction (Joo et al., 2018; Malureanu et al., 2021). Kashive et al. (2020) stated that satisfaction determines the success of a technology system. Kar (2021) found that the acceptance of mobile payments is highly dependent on the usage experience, where convenience, perceived quality, and satisfaction play an important role. In conclusion, user satisfaction can lead to dependence if they continue to use the technology (Fan et al., 2017). Therefore, this study proposes the following research question:

- **RQ7:** How is the relationship between SU and DU among science students using ChatGPT?

Methods

Data collection and participants

This study uses a quantitative approach to examine science students' satisfaction of use and dependence on ChatGPT usage. The research sample consists of undergraduate

students from various universities in Indonesia. The sample selection used convenience sampling, a non-probability sampling method, due to the vast number, diversity, and geographical dispersion of universities across Indonesia, which made it challenging to apply a representative sampling approach (Etikan, 2016). To support the research sample, we used a digital research platform (https://tsurvey.id/) because it has hundreds of millions of respondents spread across Indonesia, thus ensuring the accuracy of the data.

Two hundred five science students (ranging in age from 16 to 27 years old) from 22 provinces that we grouped based on six major islands in Indonesia, such as Sumatra, Java, Kalimantan, Sulawesi, Bali, and Nusa Tenggara, and Papua, took part in this study. The relatively wide age range in this study is due to the use of an online survey platform, which allowed for a diverse group of participants, including students who might have taken gap years, enrolled in extended academic programs, or pursued their degrees at varying paces. As shown in Table 1, all participants involved in this study were ChatGPT users, consisting of 48.78% male students and 51.22% female students.

TABLE 1

Sample characteristics

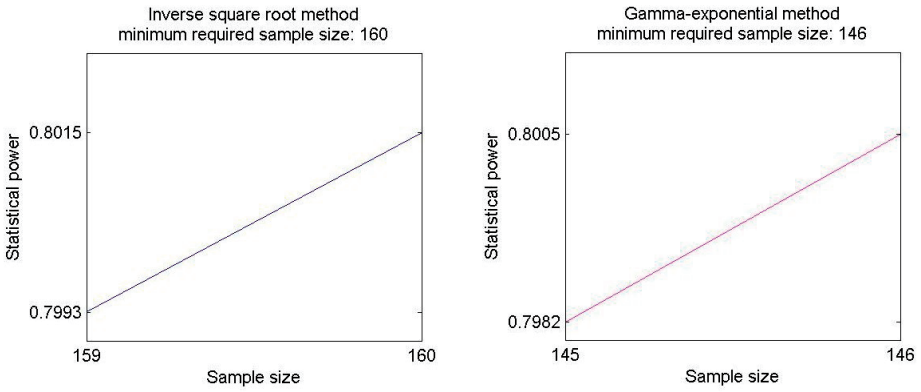
Criteria	Distribution	Frequency	Percentage (%)
Gender	Male	100	48.78
	Female	105	51.22
Regional distribution	Sumatra	18	8.78
	Java	161	78.54
	Kalimantan	4	1.95
	Sulawesi	17	8.29
	Bali and Nusa Tenggara	4	1.95
	Papua	1	0.49
ChaGTP Users	Yes	205	100
	No	-	-

Minimum sample

To ensure the sample size was satisfactory, we used the inverse square root and the gamma-exponential method to determine the minimum sample size (Kock & Hadaya, 2018). We conducted this analysis using WarpPLS 7.0 software and showed that the minimum sample sizes required for this study were 160 and 146, respectively (see Figure 2). We generated estimates based on the minimum acceptable absolute path coefficient

value of 0.197, with a significant p-value level of 0.05, and 0.80 is considered the required power level (Kock & Hadaya, 2018). Therefore, the sample in this study is adequate.

FIGURE 2



The minimum sample size required

Measurement

The scale utilized in this study was developed by previous research to facilitate the collection of the requisite data. As presented in Table 2, this study employed five variables with 24 items. The variables of EU and PU are adapted from Almaiah et al. (2022), HM and SU adapted from Ain et al. (2016) and Alalwan (2020), and DU adapted from Antaki et al. (2023), Fergus et al. (2023), Rahman & Watanobe (2023), and Waltzer et al. (2023). No items were deleted because all items met the 0.7 threshold for loading, as recommended by Hair et al. (2021). Each item was rated on a five-point Likert scale, with the options "strongly disagree" (1) and "strongly agree" (5), respectively.

Common method bias

We use the variance inflation factor (VIF) to assess the potential presence of multicollinearity and common method bias (CMB). Multicollinearity and CMB will not pose a significant threat if the VIF value is below 3.3, following the guidelines set by Hair et al. (2021) and Kock (2015). This study found no multicollinearity and CMB problems because the VIF value was below the predetermined threshold (See Table 2).

TABLE 2

Measurement scale, outer loading, and VIF

Constructs and items	Outer loadings	VIF
EU: Ease of Use		
EUI: My interactions with ChatGPT are easy and understandable.	0.828	1.779
EU2: It is easy to search, evaluate and select study materials through ChatGPT.	0.914	2.433
EU3: It is easy to control the information provided through ChatGPT.	0.851	1.923
PU: Perceived Usefulness		
PUI: Using ChatGPT increased my daily class contributions.	0.825	2.010
PU2: Using ChatGPT improves my understanding of the practical subjects I am enrolled in.	0.856	2.472
PU3: Using ChatGPT helps in my theory assignments and homework.	0.770	1.959
PU4: Using ChatGPT allows me to integrate my theoretical studies with everyday practical experiences.	0.804	2.011
PU5: Using ChatGPT helps in searching, evaluating and selecting digital resources.	0.750	1.631
HM: Hedonic Motivation		
HMI: I feel using ChatGPT for learning is a good idea.	0.870	2.114
HM2: I feel happy using ChatGPT for learning.	0.919	2.962
HM3: I enjoy using ChatGPT for learning.	0.913	2.825
SU: Satisfaction of Use		
SUI: I am satisfied with ChatGPT because it has a lot of important information.	0.853	2.320
SU2: I am satisfied in using ChatGPT because it is useful.	0.876	2.746
SU3: I am happy with what ChatGPT has done in helping my learning.	0.889	2.723
SU4: ChatGPT contributes effectively to my acquisition of new information in learning.	0.852	2.184
DU: Dependence on Use		
DUI: I used ChatGPT help/support to solve the problem given in the lesson.	0.800	2.004
DU2: I search for information/lesson materials using ChatGPT because it is easy.	0.780	1.947
DU3: On average I use ChatGPT in every course.	0.858	2.966
DU4: I am addicted to using ChatGPT to complete my learning tasks.	0.830	2.851
DU5: I use ChatGPT help/support to help me answer exam questions.	0.719	1.982
DU6: I use ChatGPT help/support to help me complete assignments	0.798	1.978

Note: variance inflation factor (VIF)

Analysis and results

This study uses PLS-SEM, a causal modeling approach that focuses on prediction and is designed to maximize the explained variance of dependent latent constructs. PLS-SEM was chosen because it can provide solutions even with relatively small sample sizes compared to other statistical methods and provides the flexibility to estimate conditional process models, high-level constructs, or structurally specified measurement models (Hair et al., 2021). PLS-SEM analysis was conducted using SmartPLS™ software version 4, and the strength of the structural model was evaluated using the coefficient of determination (R^2). Interpreted R^2 values, where higher values indicate better explanatory power, with criteria of 0.75 substantial, 0.50 moderate, and 0.25 weak (Hair et al., 2021).

Measurement model

A rigorous assessment of the measurement model aims to evaluate the reliability and validity of the constructs used. Table 3 shows that Cronbach's alpha and composite reliability scores, as measures of the internal consistency reliability of the measurement constructs, all exceed the minimum score of 0.7 (Hair et al., 2021). It indicates that the measurement constructs have strong internal consistency reliability, indicating a good correlation between items intended to measure the same construct.

Table 3

Construct Reliability and Validity

Construct	Cronbach's alpha	Composite Reliability	AVE
DU	0.886	0.913	0.638
EU	0.831	0.899	0.748
HM	0.884	0.928	0.812
PU	0.861	0.900	0.643
SU	0.891	0.924	0.753

Note: ease of use (EU); perceived usefulness (PU); hedonic motivation (HM); satisfaction of use (SU); dependence on use (DU); average variance extracted (AVE)

Furthermore, construct validity is determined by evaluating convergent and discriminant validity. From Table 3, the average variance extracted (AVE) values were evaluated and exceeded the acceptable benchmark of 0.5, indicating that convergent validity was met (Hair et al., 2021). Regarding discriminant validity (see Table 4), the square

root of the AVE of each construct was greater than its highest correlation with other constructs (located below the main diagonal) by the Fornell-Larcker criterion. In addition, to ensure the model was sufficiently structured, discriminant validity was also evidenced by checking that the Heterotrait-Monotrait correlation ratio (HTMT) was below the threshold of 0.9 (Ringle et al., 2023). Therefore, our model's discriminant and convergent validity conditions were met, indicating that the constructs and items are valid and reliable.

TABLE 4

Discriminant validity of the model – Fornell-Larcker and HTMT criteria

	DU		EU		HM		PU		SU	
	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2
DU	0.799									
EU	0.435	0.498	0.865							
HM	0.690	0.769	0.577	0.671	0.901					
PU	0.686	0.776	0.578	0.683	0.746	0.854	0.802			
SU	0.630	0.695	0.615	0.714	0.794	0.891	0.741	0.843	0.868	

Note: Fornell-Larcker criteria (C1); HTMT criteria (C2); ease of use (EU); perceived usefulness (PU); hedonic motivation (HM); satisfaction of use (SU); dependence on use (DU)

Model evaluation

After confirming construct validity and reliability through the measurement model, a structural model evaluation was conducted to assess the paths and coefficients using bootstrapping with a resampling size of 5000 (Hair et al., 2021). As presented in Table 5, path analysis was performed by examining path coefficients (β) and *p*-values. The results indicate that the EU has a positive and significant impact on SU (β=0.173, $p<0.01$). However, the EU has a negative and insignificant impact on DU (β=-0.049, $p>0.05$). Furthermore, PU has a positive and significant impact on both SU (β=0.277, $p<0.01$) and DU (β=0.370, $p<0.001$). Similarly, HM positively and significantly influences SU (β=0.487, $p<0.001$) and DU (β=0.365, $p<0.001$). On the other hand, SU does not have a significant effect on DU (β=0.097, $p>0.05$). Moreover, the strength of the structural model was assessed using the R^2. The R^2 values for SU and DU were 0.698 and 0.545, respectively, indicating that the model explains 69.8% of the variance in SU and 54.5% of the variance in DU in the context of science students using ChatGPT for learning.

TABLE 5

Path analysis testing

Research questions	Paths	β	t-statistics	Decisions
RQ1	EU→SU	0.173	2.885**	Positive and significant
RQ2	EU→DU	-0.049	0.918	Negative and insignificant
RQ3	PU→SU	0.277	3.398**	Positive and significant
RQ4	PU→DU	0.370	4.776***	Positive and significant
RQ5	HM→SU	0.487	5.975***	Positive and significant
RQ6	HM→DU	0.365	4.321***	Positive and significant
RQ7	SU→DU	0.097	1.153	Positive and insignificant

Note: $^{NS}p > 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; path coefficients (β); ease of use (EU); perceived usefulness (PU); hedonic motivation (HM); satisfaction of use (SU); dependence on use (DU)

DISCUSSIONS

In today's digital age, technology has become an integral part of the learning process in many countries and across the whole range of teaching and learning objects (Burguete & Urrego, 2023; Haleem et al., 2022; Martin et al., 2024; Ntalakoura & Ravanis, 2014). Among science students, AI-based tools such as ChatGPT are increasingly popular to extend and improve their understanding of complex subject matter (Singh et al., 2023). This study uses PLS-SEM to reveal the relationship between EU, PU, HM, SU, and DU in the context of ChatGPT among science students in Indonesia.

The study showed that although the EU did not significantly impact DU, it still positively and significantly influenced SU. In this context, students who perceive ChatGPT as easy to use tend to be more satisfied with its use, although it does not directly increase their dependence on this technology. It indicates that perceived ease of use influences users' experience and satisfaction with ChatGPT technology (Almulla, 2024; Yu et al., 2024). Furthermore, although there is no significant direct relationship between ease of use and usage dependence, this factor can influence users' attitudes toward the technology (Mahmud et al., 2024). Users who find ChatGPT easy to use may be more likely to adopt and use this technology regularly (Fadillah et al., 2025b; Niloy et al., 2024), even if their dependency does not increase significantly. Therefore, it is important to consider users' perceptions of ease of use in designing satisfying and effective user experiences.

Although this study initially drew on the TAM, the findings suggest that TAM alone may be insufficient to explain the complexity of ChatGPT dependency. Therefore, we interpret the results through the lens of habit formation theory and sociomateriality to better capture the behavioral entrenchment and embeddedness of ChatGPT in students' learning routines (Limayem et al., 2007; Orlikowski, 2007). PU was identified as one of the primary factors driving science students to use ChatGPT. Students perceived ChatGPT as highly beneficial in helping them grasp complex concepts by delivering quick and precise answers. This finding aligns with the study by Uddin et al. (2024), which demonstrated that students' written responses became more thorough, detailed, and informative after utilizing ChatGPT. In this context, PU has a positive and significant impact on both SU and DU. The more students find ChatGPT useful, the more satisfied they are with its use, and the more likely they are to depend on it for their academic tasks (Playfoot et al., 2024). This relationship is further supported by studies indicating that perceived usefulness significantly enhances user satisfaction and fosters reliance on the tool for various academic activities, such as homework assistance, research, and exam preparation (Almulla & Ali, 2024; Boubker, 2024; Boubker et al., 2024).

ChatGPT's ability to provide tailored feedback and synthesize information across diverse fields enhances learning experiences, saving students time and improving their academic performance (Ngo et al., 2024). For instance, in understanding theories or solving complex problems, ChatGPT offers additional explanations that deepen students' comprehension (Polverini & Gregorcic, 2024; West, 2023). This utility not only accelerates the learning process but also contributes to improved academic outcomes, as students who perceive ChatGPT as useful report higher satisfaction levels and better learning achievements (Almulla & Ali, 2024; Boubker, 2024; Ngo et al., 2024). Furthermore, the intention to continue using ChatGPT is strongly tied to its perceived usefulness, with students who find the tool valuable more inclined to rely on it for future academic tasks (Bekturova et al., 2025; Haugland Sundkvist & Kulset, 2024; Saxena & Doleck, 2023). It underscores the critical role of PU in students' decision to adopt and sustain ChatGPT as an essential learning tool in their academic journey.

HM was also found to positively and significantly influence both SU and DU. Students who derive emotional satisfaction and enjoyment from using ChatGPT are more likely to use the technology sustainably. Many students reported that ChatGPT makes learning more engaging and interactive, contributing to their hedonic motivation (Chan & Hu, 2023; Qu & Wu, 2024). With its intuitive interface and quick responses, ChatGPT enhances overall usage satisfaction, motivating students to consistently incorporate it into their learning routines (Uddin et al., 2024). It aligns with findings from the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model, highlighting that hedonic motivation significantly impacts students' continuous intentions to use

ChatGPT, influencing their satisfaction with the tool (Arin et al., 2024; Tan et al., 2024). Additionally, hedonic motivation and habit and facilitating conditions are crucial in shaping students' continuous intentions to utilize ChatGPT (Tan et al., 2024).

The relationship between HM and DU is particularly noteworthy. Students who find ChatGPT enjoyable and emotionally satisfying are likelier to depend on it for various academic tasks, such as homework assistance, research, and exam preparation (Almulla & Ali, 2024; Boubker, 2024; Boubker et al., 2024). This dependence is further reinforced by the tool's ability to provide quick and precise answers, which not only enhances learning outcomes but also fosters a sense of reliance on the technology (Foroughi et al., 2023). For instance, students who perceive ChatGPT as useful and enjoyable are more inclined to integrate it into their daily academic activities, leading to a higher degree of dependence (Playfoot et al., 2024). It is consistent with studies showing that hedonic motivation, performance expectancy, effort expectancy, and learning value significantly influence the intention to use ChatGPT, increasing dependence on the tool (Arthur et al., 2024; Foroughi et al., 2023).

The finding that SU did not significantly affect DU underscores the limitations of conventional models like TAM in explaining complex behavioral outcomes such as technological dependency. This result suggests that dependency may be better explained through habit formation and emotional engagement, where repeated use and affective experiences play a larger role than cognitive satisfaction. According to habit formation theory (Limayem et al., 2007), behaviors reinforced over time become automatic and less dependent on rational evaluation. Similarly, hedonic consumption theory (Hirschman & Holbrook, 1982) posits that emotional gratification can drive sustained use. The significant influence of HM on DU supports this, indicating that students' enjoyment of using ChatGPT fosters continued engagement and reliance. From a sociomaterial perspective (Orlikowski, 2007), ChatGPT is not merely a neutral tool, but part of a sociotechnical system that shapes learning behaviors, routines, and dependencies. As such, dependency emerges from dynamic entanglements between human intentions, emotional responses, and the materiality of the AI tool itself.

However, the study also underscores the potential risks of over-reliance on ChatGPT. While PU and HM significantly have a relationship with DU, the lack of a direct relationship between EU and DU suggests that dependency is driven more by the tool's perceived usefulness and the emotional satisfaction it provides rather than its ease of use (Almulla & Ali, 2024; Boubker, 2024; Ngo et al., 2024). This finding is critical for educators and policymakers, as it indicates that interventions to reduce dependency should address these factors. For instance, promoting critical thinking and encouraging students to use ChatGPT as a supplementary tool rather than a primary resource can help mitigate over-dependence (Hu & Lin, 2025; Murtiningsih et al., 2024).

The research also highlights the importance of a balanced approach to integrating

technology in education, which aligns with Feng (2024). Students must be trained to use ChatGPT as a support tool rather than a substitute for the learning process. Educational institutions should emphasize the critical evaluation of digital information and the responsible use of technology (Rasul et al., 2023). By integrating ChatGPT with teaching strategies that foster critical thinking, independence, and problem-solving skills, students can optimize the benefits of technology without compromising their core abilities to face future academic and professional challenges. This balanced approach ensures that students derive value from ChatGPT while maintaining their autonomy and critical thinking skills.

Conclusion

This study uses PLS-SEM to explore ChatGPT use among science students in Indonesia, focusing on EU, PU, HM, SU, and DU. It extends TAM by integrating emotional, behavioral, and sociomaterial dimensions to better understand user satisfaction and dependency. The findings reveal significant relationships among the examined factors, suggesting that while EU contributes to satisfaction, PU and HM are the strongest predictors of both satisfaction and dependency. EU positively and significantly impacts SU, but its effect on DU is insignificant. PU demonstrates a strong positive influence on both SU and DU, indicating that the perceived utility of ChatGPT enhances user satisfaction and fosters dependency. Similarly, HM significantly affects both SU and DU, suggesting that emotional satisfaction and enjoyment derived from using ChatGPT contribute to sustained usage and reliance. However, SU does not significantly influence DU, implying that satisfaction alone does not directly lead to dependency. Overall, PU and HM emerge as primary drivers of ChatGPT adoption, while EU primarily enhances user satisfaction without significantly increasing dependency. These findings underscore the importance of a balanced approach to integrating ChatGPT in education, maximizing its benefits while mitigating over-reliance risks.

Policy and Practical Implications

The findings of this study provide important empirical grounds for policymakers, educational institutions, and educational technology developers. First, universities should implement AI literacy training programs emphasizing responsible use, critical evaluation of AI-generated content, and the development of metacognitive strategies. These modules should be tailored to science students, who are more likely to replace active thinking with AI-generated outputs. Second, developing ethical guidelines for ChatGPT use in academic settings is essential. These guidelines can outline acceptable and unacceptable uses during exams, assignments, and other learning tasks. Third, partnerships between government, educational authorities, and technology developers (e.g., OpenAI)

should aim to incorporate features in AI tools that support reflective learning, such as prompt-based scaffolding and learning activity logs that highlight students' thought processes. Finally, these findings suggest the need to redesign academic assessments. As students show over-reliance, educators should incorporate more process-oriented assessments, such as portfolios, project-based learning, and oral defenses, to maintain students' autonomy and preserve critical thinking abilities in the age of AI-enhanced learning. These findings are relevant not only to local educators but also to broader educational settings, especially in developing regions undergoing rapid AI integration without robust pedagogical frameworks.

Limitations and Future Research

This study has several limitations. First, the sample was limited to science students in Indonesia, which may affect the generalizability of the findings. Second, it focused only on ChatGPT, excluding other AI tools like Google Bard or Microsoft Bing. Third, the cross-sectional design limits causal conclusions and insights into long-term effects. Future research should involve students from various disciplines and cultural backgrounds. Longitudinal studies are needed to assess the long-term impact of ChatGPT on academic performance, critical thinking, and intellectual growth. Studies comparing different AI tools and examining demographic factors—such as gender, prior knowledge, and learning styles—can offer deeper insights into students' use of AI. Another important area is developing interventions that promote responsible AI use, such as training programs to guide effective and balanced use. Finally, experimental studies comparing users and non-users of ChatGPT can provide more substantial evidence of its educational impact. Additionally, future studies should test extended theoretical models incorporating behavioral and sociomaterial elements beyond TAM to improve the explanatory power of AI use and dependency in education.

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