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# ChatGPT as a Pedagogical Tool: Measuring Its Influence on Cognitive Engagement and Academic Achievement of Biology Students

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**Abstract:** Artificial intelligence technology has been integrated into educational practices and is considered to have a significant influence in improving the teaching and learning process. Biology is one of the science subjects considered as a complex subject and requires deep understanding. The presence of ChatGPT answers the existing problems by offering personalized explanations, interactive feedback, and structured answer recommendations to improve students' understanding and critical thinking. The application of artificial intelligence such as ChatGPT to educational practices has opened up new opportunities to improve learning processes and outcomes. This study explores the effect of using ChatGPT as a pedagogical tool on cognitive engagement and academic achievement of Biology students. This study uses a cross-sectional quantitative survey method with Structural Equation Modeling analysis. The research sample was Biology students consisting of three different batches. The results showed that ChatGPT as a pedagogical tool significantly increased students' cognitive engagement, which then could also mediate its effect on students' academic achievement. In addition, cognitive engagement also has an impact on the formation of Biology students' academic achievement. In general, these findings highlight a good relationship between ChatGPT use, cognitive engagement, and academic achievement, and underline its potential to create a student-centered adaptive learning environment. However, ChatGPT also has some drawbacks, such as over-reliance on technology by students, potential errors in assessment, and inequity related to access to computer devices. This study shows the importance of introducing and using artificial intelligence technology in learning strategies. The results can also provide recommendations for the development of AI in education from a research perspective for educators to make decisions. Further research is needed to explore the relationship in various educational contexts and populations.

**Keywords:** ChatGPT, cognitive engagement, academic achievement, biology students.

## ▪ INTRODUCTION

The development of artificial intelligence or AI has grown very rapidly in the last three years. AI provides major breakthroughs in various sectors, including in the world of education. The current innovation that is often used is the use of AI-based tools ChatGPT, a generative language model designed to understand and respond to text quickly and humanely. The presence of ChatGPT is able to provide new opportunities in the learning process, students can gain access to general information, problem solutions, and feedback interactively (Chen et al., 2020; Truong, 2023). As a pedagogical tool, ChatGPT is able to provide more effective, personal, and student-based learning facilities (Alshehri, 2023; Gökoğlu, 2024; Ibrahim, 2024). In the context of biology learning for Biology students, the challenge of understanding complex concepts such as biochemistry, genetics, and ecology becomes a complicated thing, but the use of ChatGPT is a solution to support a more efficient and in-depth learning process.

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One of the components in the learning process is cognitive engagement in which it involves the student actively thinking about ideas, processing the information and linking concepts learned. (El-Mansy et al., 2022; Jamaluddin et al., 2023; Naibert et al., 2022). Biology students are confronted with highly complex materials that demand not only analytical but also critical understanding. Previous studies suggested that technology-based learning tools increase cognitive engagement by offering access to relevant, interactive information and meaningful learning experiences (Lehmeidi Dong et al., 2023). Example is ChatGPT who can help students contextually respond to questions and provoke critical students to think about researchers being learned (Alshehri, 2023). Despite this potential, the specific impact of the use and utilization of ChatGPT in promoting cognitive engagement of biology students needs to be more widely explored, because it requires further exploration.

Another important indicator of a student's educational success is academic achievement, which is the outcome of the learning process itself (Manahan, 2024; Zhu et al., 2018). Biology students, for instance, should know how to make sense of complex material, what areas of lab research are needed and how to create new solutions to biological problems. Technological tools like ChatGPT show to be an enormous support in attaining better academic achievement via task assistance, relevant writing ideas, and the provision of customized learning the best (Dai, 2023; Huesca, 2024; Worthing, 2024). However, the causal relationship between ChatGPT use, cognitive engagement, and Biology students' academic achievement has not been widely studied empirically, especially in the context of technology-based learning design in higher education settings.

Globally, various studies have shown that digital learning technologies can have a positive impact on students' learning motivation and engagement. AI technologies, such as ChatGPT, provide easy access to learning resources, accelerate information retrieval, and encourage learning autonomy (Niraula, 2024; Park & Kwon, 2023; Samala, 2024; S. Xu & Li, 2022). However, challenges remain, such as the potential for technology dependence and minimal development of critical thinking skills if technology is not optimally integrated. For Biology students, who require deep analytical skills and data-driven approaches, it is important to explore how ChatGPT can be used to enhance cognitive engagement without sacrificing the depth of the scientific learning process.

The local context, Biology students in Indonesia face more obstacles, such as limited access to information sources and limited quality educational curriculum due to the lack of adequate technological support. However, in complex courses, such as biology, ChatGPT can make the learning process easier and more efficient. ChatGPT can help Biology students not only have continuous knowledge by increasing more specific and structured knowledge, but can also provide quality and more appropriate advice for students who are in the process of achieving optimal academic success and learning success. However, empirical research is needed to measure how ChatGPT technology has the potential to support students' learning processes at various universities in Indonesia.

This study seeks to address the gap in the literature by investigating the impact of ChatGPT use on the level of cognitive engagement and academic achievement of Biology students. Using SEM, this study will not only investigate the impact of ChatGPT adoption on learning outcomes (academic achievement), but also explain the mechanisms used by cognitive engagement to mediate this relationship.This study will also identify factors that can maximize the benefits of ChatGPT in learning, such as integration with

pedagogical strategies that are appropriate for Biology courses. The research hypothesis states that there is a synergistic relationship between the influence of;

1. H1 ChatGPT as a pedagogical tool towards cognitive engagement,
2. H2 ChatGPT as a pedagogical tool towards academic achievement,
3. H3 Cognitive engagement towards academic achievement,
4. H4 ChatGPT as a pedagogical tool towards academic achievement through cognitive engagement.

The results of this study are expected to not only contribute to scientific literature, but also become the basis for developing technology-based education policies in Indonesia. By emphasizing the importance of integrating AI technology into learning, this study aims to support improving the quality of higher education, especially in the field of Biology, and to help students overcome learning challenges in the digital era. It is also expected to provide practical recommendations for lecturers and educational institutions to optimize the potential of AI technology in supporting more adaptive and innovative learning.

## ▪ METHOD

### Types and Research Design

This study used a quantitative approach with a cross-sectional survey design (Hair et al., 2019) to evaluate the relationship between ChatGPT usage, cognitive engagement, and students' academic achievement (Figure 1). This approach was chosen because it is able to identify causal relationships empirically at a certain time. Structural Equation Modeling (SEM) is used as an analysis method to test direct and indirect relationships between variables in the research model.

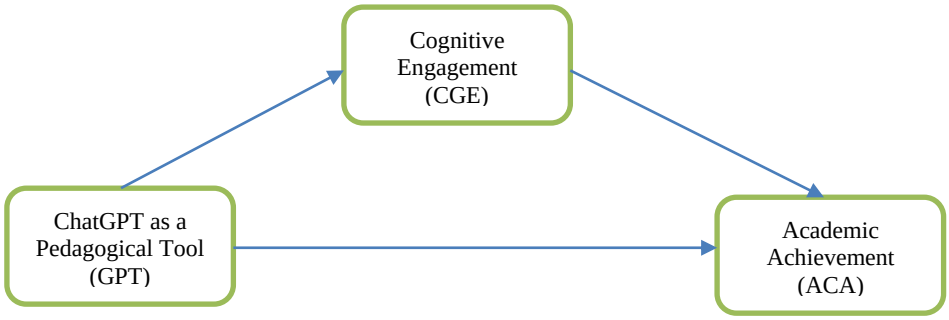


**Figure 1**. SEM model diagram

### Population and Sample

The population of the study was Biology students of FMIPA, Makassar State University (UNM) consisting of three different batches, namely the 2022-2023, 2023-2024, and 2024-2025 batches (Table 1). Samples were taken using stratified random sampling techniques based on gender and batch year so that the research sample can truly represent the characteristics of the entire population and, so that the research results are more accurate and reliable. The sample was taken using a stratified random sampling technique based on gender and batch year. The research subjects were required to be active students, have used ChatGPT for learning purposes for at least the last three months, and are willing to participate voluntarily by providing written consent. A total of

352 students qualified as respondents from 614 students. The sample size was determined based on the rule of at least 10 times the number of indicators in the SEM model to ensure the accuracy of the analysis results.

**Tabel 1.** Research samples from three different levels

| Items | Year | Amount | Percentage (%) |
|---|---|---|---|
| Male Student | 2022-2023 | 59 | 16.76 |
| | 2023-2024 | 51 | 14.49 |
| | 2024-2025 | 58 | 16.48 |
| **Total** | | **168** | **47.73** |
| Female Students | 2022-2023 | 49 | 18.47 |
| | 2023-2024 | 54 | 16.19 |
| | 2024-2025 | 50 | 17.61 |
| **Total** | | **184** | **52.27** |

**Research Instrument**

The research instrument was a structured questionnaire using a 4-point Likert scale, ranging from strongly disagree (1), disagree (2) agree (3), and, strongly agree (4). The questionnaire was developed based on relevant literature and has been validated by three education experts, biology education, and education practitioners. The average validation of the instrument is in the valid category with a score of 3.83 (scale 1-4). After the instrument was validated, the instrument was tested on 30 students to see the ease of filling in order to avoid anomalies. The instrument can be seen in Table 2.

**Table 2.** Statement of each variable item in the research instrument

| Variable Items | Survey Item Statement |
|---|---|
| GPT1 | I use ChatGPT to understand difficult concepts in lessons |
| GPT2 | ChatGPT helps me find answers to questions I don't understand while studying. |
| GPT3 | I feel that ChatGPT provides clear and easy-to-understand explanations. |
| GPT4 | ChatGPT motivates me to learn more about the topics I study. |
| GPT5 | I often use ChatGPT as a primary reference in completing schoolwork. |
| GPT6 | Using ChatGPT makes it easier for me to plan my study strategies. |
| GPT7 | ChatGPT helps me improve my critical thinking skills in understanding learning concepts. |
| CGE1 | I actively think about the best way to understand the subject matter. |
| CGE2 | I analyze the information I receive before using it to complete assignments. |
| CGE3 | I try to connect new concepts with the knowledge I already have. |
| CGE4 | I process the information I learn deeply to understand it thoroughly. |
| CGE5 | I use specific strategies to help me understand complex material. |
| CGE6 | I frequently evaluate my understanding of the subject matter that has been studied. |
| CGE7 | I feel actively involved in the learning process, both in class and independently. |

| | |
|---|---|
| ACA1 | I get better grades on exams after using certain study methods. |
| ACA2 | I can complete schoolwork on time with satisfactory quality. |
| ACA3 | I am able to understand the subject matter better than before. |
| ACA4 | I often achieve the academic goals I have set for myself. |
| ACA5 | I receive recognition or appreciation from my teachers for my improved academic performance. |
| ACA6 | I feel more confident in answering questions or taking tests in class. |
| ACA7 | I am able to apply the concepts I have learned to solve problems or case studies. |
| ACA8 | I feel motivated to continue improving my academic performance each semester. |

**Data Collection Procedure**

Data were obtained by distributing questionnaires online. Before filling out the questionnaire, respondents were given a detailed explanation of the purpose of the study and instructions for filling out the questionnaire to ensure adequate understanding. The data collection process lasted for 3 weeks, accompanied by regular monitoring to ensure an optimal response rate. Only questionnaires that were completely and validly filled out were used in the analysis, in order to maintain the accuracy and quality of the data obtained.

**Data Analysis Technique**

Measurement and structural models were assessed with SmartPLS 3.0 software in this study. The analysis was conducted in two principal parts. The first part is the assessment of the measure model, where construct validity is performed using Outer Loading >70, Average Variance Extracted (AVE) with a cut-off value >0.5, whereas reliability is evaluated using Composite Reliability (CR) and cronbach's alpha with a cut-off value >0.7 (Hair et al., 2019). Furthermore, the discriminant validity is tested through the Fornell-Larcker criteria (Barclay & Thomson, 1995; Fornell & F. larcke, 1981). The second stage is the assessment of the structural model, testing of which path is significant with the use of the bootstrapping method at a 95% confidence level ($p < 0.05$) (Henseler, 2012). The $R^2$ value is used to capture the degree of predictive power of endogenous variables, with the categories of low (0.25), moderate (0.50) and strong (0.75). Additionally, the direct, indirect and total effects between exogenous and endogenous variables were evaluated to assess mediation pathways in the research model. This yields a full analysis of the relationships between the various variables within the research model.

**Research Ethics**

This study adheres to the principles of research ethics, including voluntary participant consent, data confidentiality, and use of data for academic purposes only. A research permit was submitted and approved by the relevant institution prior to implementation.

## ▪ RESULT AND DISSCUSSION

The statistics of the GPT variable presented in Figure 2 indicate a relatively stable average score, GPT5 having the highest and GPT6 having the lowest score (3.38 and 3.19, respectively), suggesting variances in how the ChatGPT influences the process of learning. In the Cognitive Engagement (CGE) variable, CGE2 has a score of 3.34, which means that it is the variable with the highest level of cognitive engagement among the rest. In addition, the Academic Achievement (ACA8) variable item is the highest. Overall, these data reflect that using ChatGPT can bolster cognitive engagement among students and potentially impact students academic achievement.

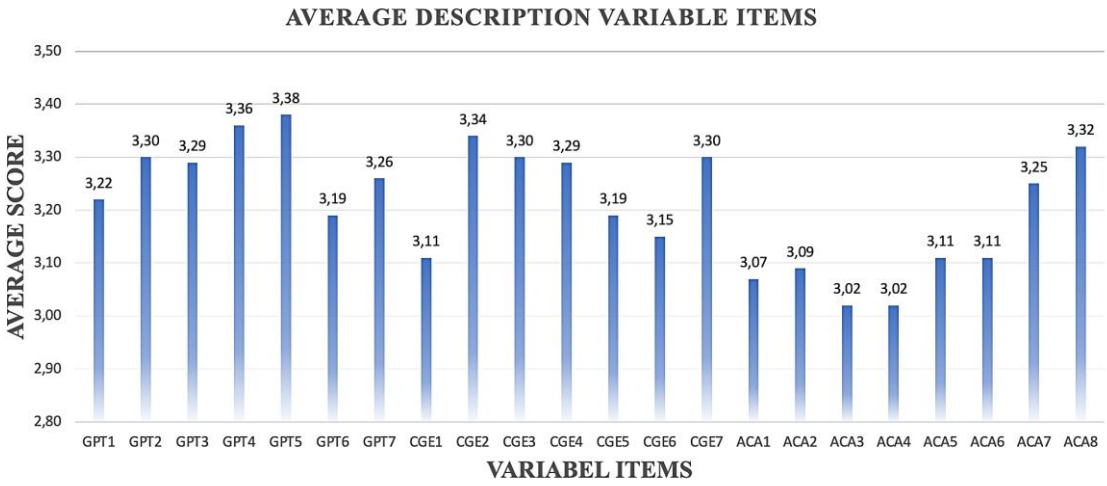


**Figure 2**. Average description variable items

Table 3 shows that all Outer Loadings item values have values >0.7, indicating that these indicators have a strong contribution to each latent variable. In addition, the Cronbach's Alpha and Composite Reliability values for the three variables are above 0.7 (range 0.926–0.948), indicating a very good level of internal consistency reliability. Construct validity is also confirmed by the Average Variance Extracted (AVE) value >0.5 for each variable, namely 0.696 for ChatGPT as a Pedagogical Tool and Academic Achievement, and 0.693 for Cognitive Engagement. These results indicate that the measurement model has adequate validity and reliability, so it can be used to analyze the relationship between variables in the structural model.

**Table 3.** Results of the analysis of the measurement model with validity and reliability indicators

| Variable/ Construct | Variable Items | Outer Loadings | Cronbach's Alpha | Composite Reliability | AVE |
|---|---|---|---|---|---|
| ChatGPT as a Pedagogical Tool | GPT1 | 0.837 | 0.927 | 0.941 | 0.696 |
| | GPT2 | 0.842 | | | |
| | GPT3 | 0.877 | | | |
| | GPT4 | 0.815 | | | |
| | GPT5 | 0.832 | | | |
| | GPT6 | 0.812 | | | |
| | GPT7 | 0.821 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Cognitive Engagement | CGE1 | 0.835 | 0.926 | 0.940 | 0.693 |
| | CGE2 | 0.823 | | | |
| | CGE3 | 0.865 | | | |
| | CGE4 | 0.829 | | | |
| | CGE5 | 0.821 | | | |
| | CGE6 | 0.800 | | | |
| | CGE7 | 0.853 | | | |
| Academic Achievement | ACA1 | 0.839 | 0.937 | 0.948 | 0.696 |
| | ACA2 | 0.874 | | | |
| | ACA3 | 0.874 | | | |
| | ACA4 | 0.864 | | | |
| | ACA5 | 0.835 | | | |
| | ACA6 | 0.824 | | | |
| | ACA7 | 0.831 | | | |
| | ACA8 | 0.726 | | | |

Table 4 shows the results of the diagonal value test (square root of AVE) for each variable is greater than the correlation value with other variables, namely 0.858 for ChatGPT as a Pedagogical Tool (GPT), 0.887 for Cognitive Engagement (CGE), and 0.832 for Academic Achievement (ACA). This shows that each construct has adequate discriminant validity, because the construct is stronger in explaining its own indicator variable than in relation to other constructs. The correlation value between variables, such as between GPT and CGE (0.835) or between GPT and ACA (0.834), shows a strong relationship but does not exceed the diagonal value, thus supporting the integrity of the measurement model. This discriminant validity ensures that the constructs in the study can be distinguished conceptually and analytically.

**Table 4.** Descriptive fornell-larcker criterion

| Variable | GPT | CGE | ACA |
|---|---|---|---|
| GPT | 0.858 | | |
| CGE | 0.835 | 0.887 | |
| ACA | 0.834 | 0.834 | 0.832 |

Table 5 indicates that the loading values of all items are greater than the loading values of the other constructs. That means that each item represents a greater value of the intended construct versus other constructs. These findings bolster the convergent validity of findings that the indicators utilized possess the capability to differentiate between the investigated variables.

**Table 5.** Item variable cross-loading

| Variable Items | GPT | CGE | ACA |
|---|---|---|---|
| GPT1 | 0.872 | 0.818 | 0.684 |
| GPT2 | 0.705 | 0.799 | 0.751 |
| GPT3 | 0.715 | 0.918 | 0.745 |
| GPT4 | 0.717 | 0.842 | 0.791 |
| GPT5 | 0.700 | 0.823 | 0.759 |
| GPT6 | 0.892 | 0.419 | 0.715 |

| | | | |
|---|---|---|---|
| GPT7 | 0.873 | 0.949 | 0.725 |
| CGE1 | 0.764 | 0.835 | 0.740 |
| CGE2 | 0.689 | 0.823 | 0.680 |
| CGE3 | 0.734 | 0.865 | 0.692 |
| CGE4 | 0.729 | 0.829 | 0.718 |
| CGE5 | 0.752 | 0.821 | 0.680 |
| CGE6 | 0.734 | 0.800 | 0.734 |
| CGE7 | 0.757 | 0.853 | 0.748 |
| ACA1 | 0.674 | 0.680 | 0.839 |
| ACA2 | 0.740 | 0.728 | 0.874 |
| ACA3 | 0.667 | 0.717 | 0.874 |
| ACA4 | 0.664 | 0.687 | 0.864 |
| ACA5 | 0.714 | 0.733 | 0.835 |
| ACA6 | 0.675 | 0.714 | 0.824 |
| ACA7 | 0.736 | 0.750 | 0.831 |
| ACA8 | 0.691 | 0.704 | 0.726 |

Hypotheses H1-H4 are accepted. Shown in Figure 3 and Table 6, when using ChatGPT as a pedagogical tool (GPT), it had a considerable direct effect on cognitive engagement (CGE) with a path coefficient of $\beta = 0.887$, T-statistic value of 36.980, and $p < 0.001$. These results are indicative of the cognitive engagement can be increased by technology that promotes interactivity since it shares useful information, provides immediate feedback, and flexible access to learning resources that affect cognitive engagement among students (Nkomo & Daniel, 2021; Soffer et al., 2019). The results also suggest a significant direct effect of GPT on academic achievement (ACA), $\beta = 0.349$, T-statistics: 6.319, $p < 0.001$, suggesting that through the use of ChatGPT, students will help enhance their learning outcomes such as understanding the material, quality of assignments, and exam performance. This effect was in line with the findings of Celik (2024), which reported that AI-based tools foster problem solving and enhance the analytical abilities of students.

In cognitive engagement (CGE) it is also proven to significantly affect academic achievement (ACA) with a path coefficient of $\beta = 0.548$, a T-statistic value of 10.256, and $p < 0.001$. This finding strengthens the cognitive motivation theory, which states that students with high levels of cognitive engagement tend to achieve better academic results because they are more active in analyzing, evaluating, and applying information in various contexts (Hesam & Abedi, 2020; Huesca, 2024). Thus, cognitive engagement not only functions as a result of technology use, but also as a determining variable in improving academic achievement.

These results are in line with previous studies highlighting the role of AI-based tools in enhancing cognitive engagement and academic achievement. Studies such as Mayarni & Nopiyanti (2021) showed that interactive digital tools significantly improved students' critical thinking and analytical skills, in line with the strong direct relationship between GPT and CGE observed. Similarly, the finding that CGE is a significant predictor of ACA is in line with Khan et al., (2023), who showed that higher cognitive engagement contributes to improved academic achievement. However, the relatively weaker direct effect of GPT on ACA (compared to the effect of CGE on ACA) contrasts

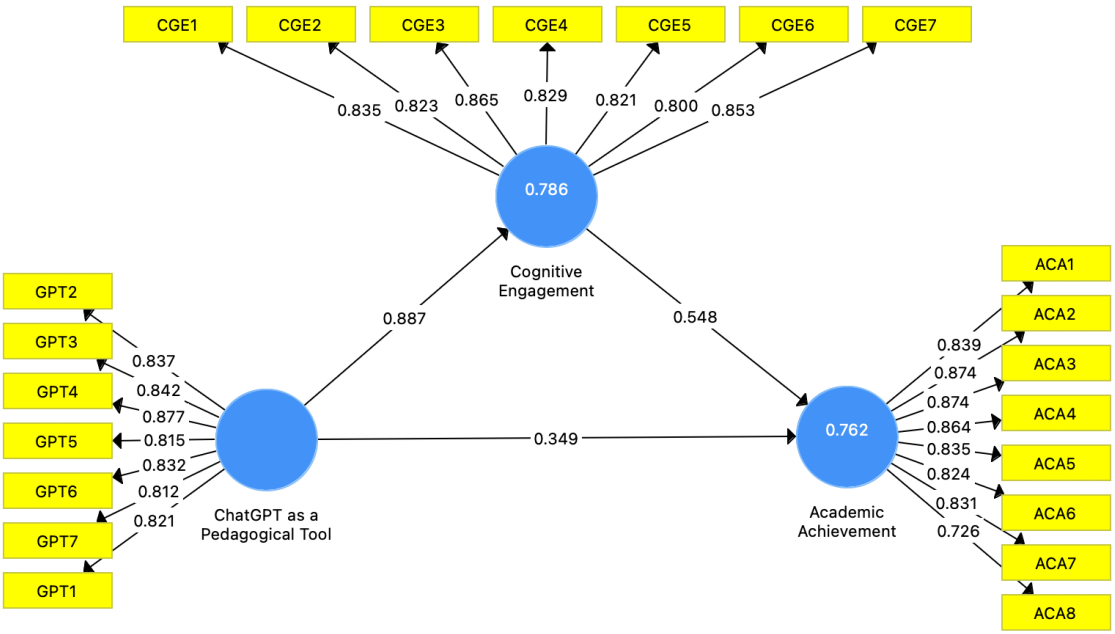


**Figure 3.** Path diagram

with studies that suggest that technology alone can directly improve learning outcomes. This difference emphasizes the importance of intermediary cognitive processes in harnessing the benefits of educational technology (Petrova et al., 2018; Wati et al., 2021).

**Table 6.** Direct path analysis

| Path | Original Sample (β) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics (\|O/STDEV\|) | P Values |
|---|---|---|---|---|---|
| ChatGPT as a Pedagogical Tool (GPT) -> Cognitive Engagement (CGE) | 0.887 | 0.885 | 0.024 | 36.980 | 0.000 |
| ChatGPT as a Pedagogical Tool (GPT) -> Academic Achievement (ACA) | 0.349 | 0.346 | 0.055 | 6.319 | 0.000 |
| Cognitive Engagement (CGE)-> Academic Achievement (ACA) | 0.548 | 0.549 | 0.053 | 10.256 | 0.000 |

Table 7 shows ChatGpt as a pedagogical tool (GPT) affects Academic Achievement (ACA) indirectly through Cognitive Engagement (CGE) (β = 0.486, T-statistic value = 9.337, $p < 0.001$). That cognitive engagement act as an important mediator in improving the relationship between usage of ChatGPT and learning outcomes of students. This finding, corroborated by the mediation theory proposed by Baron and Kenny (1986) and Jaya (2018), states that independent variables can have an indirect effect on dependent variables through mediation variables. More specifically, ChatGPT contributed to higher

cognitive engagement through interactive and responsive learning, thereby facilitating students' academic success. According to Lumsden et al., (2016), and Dao & McDonough, (2018), where significant cognitive engagement enables students to deeply process information, connecting concepts to diverse domains, and accomplish tasks more proficiently. In addition, factors that always involve active attention, reflection, and information processing, play a crucial role in optimizing learning, which is why cognitive engagement is important as a mediation tool . ChatGPT can facilitate this process by providing explanations, answering questions, and offering learning resources, but success in academic achievement depends more on how deeply students engage with the material being studied (Jacob et al., 2020; Setiawan, 2023). Therefore, cognitive engagement serves as a mediator that strengthens the relationship between ChatGPT use and better academic outcomes. This mediating effect signifies that ChatGPT's usage as a direct tool translates to improved academic achievement, but also provides a more reflective and meaningful learning experience via greater cognitive engagement, and encourages quality learning.

**Table 7.** Indirect path analysis

| Path | Original Sample (β) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics (\|O/STDEV\|) | P Values |
|---|---|---|---|---|---|
| ChatGPT as a Pedagogical Tool (GPT) -> Cognitive Engagement -> Academic Achievement (ACA) | 0.486 | 0.486 | 0.052 | 9.337 | 0.000 |

The use of ChatGPT as a pedagogical tool has a significant positive impact on the cognitive engagement and academic achievement of Biology students. ChatGPT is able to facilitate the learning process by providing contextual explanations, relevant answers, and interactive guidance, thus encouraging students to think more critically, analyze information, and connect new concepts with existing knowledge (Ajlouni, 2023; X. Xu, 2024). This increased cognitive engagement directly contributes to academic achievement, as students who are more cognitively engaged tend to have a deeper understanding of the material, better ability to complete assignments, and higher confidence in facing exams. In addition, ChatGPT also helps students develop more effective and independent learning strategies, which cumulatively have a positive impact on their learning outcomes (Shaikh, 2023; Tian, 2024). Thus, ChatGPT is not only a learning support tool, but also plays a role in creating a more productive and student-centered learning experience.

These findings elucidate the transformative potential of ChatGPT as a pedagogical tool, particularly in facilitating cognitive engagement, an important mediator of educational attainment. Results support the hypothesis that the incorporation of AI-based applications like ChatGPT can foster higher-order thinking and lead to improved educational results. Additionally, given the strong mediation relationship, educators should focus on designing interventions that cognitively engage students while the technology is integrated. These findings may also play a role in shaping curricula that

emphasize the complementary function of AI tools to facilitate active and quality learning (Tolentino, 2024; Williams et al., 2022; Woo et al., 2020). Future studies must assess the long-term effectiveness of GPT for enhancing academic performance and its role across various educational settings, to ensure wider relevance and lasting effect.

Though the use of ChatGPT as a pedagogical tool has its merits, it has the potential to negatively affect Biology students' cognitive engagement and their academic achievement. As positive as it can be, the presence of ChatGPT has the potential for a few negative consequences, one of the main ones being the risk of students becoming reliant on ChatGPT for discussions, which will hinder their critical thinking strategies when the tool is not present and in solve problems independently (Hasanein, 2023; Victor, 2024). Students become more dependent on ChatGPT's instant answers, and without realising they are not seeking solutions by exploring concepts in depth. Moreover, if the information provided by ChatGPT is sometimes incorrect or missing context, students run the risk of adopting misconceptions that negatively affect their academic performance (Newton, 2023; Sumbal, 2024; Zeb, 2024). While ChatGPT is a useful tool in the learning process, it is also unable to replace human interaction entirely, as it is unable to provide any emotional or in-depth feedback which is most often gained through face-to-face conversations with lecturers and peers (Haqqu, 2024; Seo et al., 2021). Finally, inequality of access to this technology particularly among students with weaker digital infrastructure threatens to widen learning outcome disparities. So while ChatGPT has much benefits, we need to balance its use with methods that foster independent learning and information validation.

## ▪ CONCLUSION

The study demonstrates that ChatGPT as an instructional tool significantly enhances cognitive engagement and academic achievement in Biology students. It was found that using ChatGPT significantly increased cognitive engagement, promoting critical thinking, analytical skills, and a deeper understanding of complex concepts. Additionally, cognitive engagement served as a mediator, further reinforcing the positive link between the use of ChatGPT and academic achievement, highlighting the crucial role of active cognitive involvement in optimizing learning outcomes.

Integrating ChatGPT in educational strategies could transform interactive and adaptive learning environments to support reflective and self-directed learning. But to ensure meaningful and equitable learning experiences, we must respond to challenges such as potential technology dependency and inequitable access to digital tools. This research complements the existing literature on AI-assisted learning and offers actionable guidance to educators and policymakers to leverage ChatGPT and similar tools effectively for fostering academic achievement and cognitive development. Future research should determine the applicability of AI-driven pedagogical tools in more diverse educational environments and their long-term effects on learning.

This study has several limitations and limitations that need to be considered. One of the main limitations is the population of students who have access to digital technology and ChatGPT, so the results of this study may not be generalizable to all students, especially those in areas with limited digital infrastructure. In addition, this study also used a cross-sectional design, which limits the ability to identify causal relationships longitudinally and evaluate changes in research variables over time. These limitations

indicate the need for caution in interpreting the results and suggest further studies with longitudinal designs and more diverse populations to provide deeper insights.

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