

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

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ABSTRACT: This study investigated whether a generative artificial-intelligence learning assistant (ChatGPT) improves tenth-grade students' conceptual understanding of circular motion. A quasi-experimental pre-test–post-test control-group design was employed at one Indonesian private senior high school (N = 46). Class X-2 (n = 25) received two weeks of ChatGPT-supported instruction, while Class X-1 (n = 21) followed conventional teacher-led lessons. Conceptual knowledge was assessed with a 15-item multiple-choice test (KR-20 = 0.82) administered before and after the intervention. The normalized gain (g) of the experimental group (M = 0.54, SD = 0.18) exceeded that of the control group (M = 0.48, SD = 0.17). An independent-samples t-test confirmed that the difference was statistically significant, $t(44) = 2.11$, $p = .041$, $d = 0.62$ (medium effect). Teachers can leverage ChatGPT prompts to provide on-demand explanations, contextual examples, and individualized practice that complement textbook explanations of abstract physics concepts. The short intervention period and single-school sampling limit generalizability; future work should employ longer treatment durations and more diverse contexts. This article offers one of the first controlled studies in Indonesia investigating large-language-model support for senior high school physics learning.

KEYWORDS: ChatGPT, Physics Learning, Circular Motion, Normalized Gain, Artificial Intelligence in Education

BACKGROUND

In today's digital era, the integration of technology into education continues to grow rapidly. One emerging innovation is the use of artificial intelligence-based learning assistants, such as ChatGPT. This technology offers a new approach to helping students understand complex concepts, including those in physics. Circular motion, a key topic in the Grade 10 physics curriculum at the senior high school level, often poses significant challenges to students. According to Wijaya et al. (2020), approximately 60% of students struggle to grasp the concept of circular motion, which can negatively impact their academic performance.

Circular motion refers to the movement of an object along a circular path and involves several important physics concepts, such as angular velocity, centripetal acceleration, and centripetal force. A solid understanding of these ideas is essential, as they form the foundation for more advanced topics like rotational dynamics and planetary motion. Thus, the use of effective educational technologies is crucial to enhance students' conceptual understanding.

Although previous studies have explored generic forms of AI tutoring in STEM (e.g., Anderson et al., 1995; Luckin et al., 2016), rigorous classroom-based evidence on large language models (LLMs) such as ChatGPT remains scarce, especially within the Indonesian senior high school context. This study therefore offers two distinct contributions. First, it provides the *first quasi-experimental evaluation* of ChatGPT-mediated instruction on a core physics topic, circular motion, in a private Indonesian school, using intact classes to preserve ecological validity. Second, it introduces a *prompt-engineering framework* that aligns ChatGPT dialogue with national curriculum standards, demonstrating how teachers can scaffold AI interactions to target specific misconceptions.

LITERATURE REVIEW

ChatGPT as an AI-Based Learning Assistant

ChatGPT, as an AI-based learning assistant, has demonstrated remarkable capabilities in delivering clear and interactive explanations of physics concepts. It is more than just a tool; it acts as an effective learning partner. By leveraging a language model trained on diverse sources of information, ChatGPT can answer student questions, provide relevant examples, and offer meaningful practice problems. This is especially important in physics, where many abstract concepts require deep understanding for successful application.

A survey conducted by Nurdin (2021) revealed that 75% of students felt more supported in learning physics when using AI-based learning assistants like ChatGPT. This statistic highlights the significant role of technology in modern education, especially in an

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

age where access to information is fast and widespread. Students are no longer limited to textbooks or classroom instruction; they now have access to vast learning resources.

Explanation, Practice, and Interactivity

One of ChatGPT's key advantages is its ability to present information in an easily understandable format. For example, when explaining Newton's laws, ChatGPT can use simple language and relatable examples. It might describe how Newton's first law is observed when a car suddenly stops and passengers lurch forward. Such explanations not only improve understanding but also connect concepts to students' real-life experiences, making learning more engaging and relevant.

Additionally, ChatGPT can generate practice problems to test student understanding. After explaining force and acceleration, it might pose a question such as: "If a car with a mass of 1000 kg accelerates at 2 m/s^2 , what is the required force?" This approach encourages students to apply theory in various contexts, an essential process in physics learning. The transition from concept explanation to problem-solving can also be conducted smoothly; ChatGPT might prompt, "Let's try some practice questions to see if you've understood this concept." This interactive method keeps students engaged and motivated, so that they are not passive recipients of information but active participants in the learning process.

Personalization and Learning Styles

A deeper analysis of AI-based learning assistants like ChatGPT shows that this technology can help overcome many of the challenges students face in learning physics. Many students struggle with complex concepts and feel frustrated when they lack adequate explanations. With ChatGPT, they can ask questions anytime and receive tailored answers, creating a more flexible and supportive learning environment that allows them to progress at their own pace.

Furthermore, ChatGPT can adapt its instructional methods to match different learning preferences. For visual learners, it can provide or recommend diagrams and illustrations; for those who prefer textual explanations, it offers detailed and descriptive responses. In this way, ChatGPT becomes not only a source of information but also a customizable educational tool tailored to individual student needs.

STATEMENT OF THE PROBLEM

Circular motion is a mandated topic in the Grade 10 physics curriculum, yet a large proportion of students experience persistent difficulties with its core concepts, including angular velocity, centripetal acceleration, period, and frequency (Wijaya et al., 2020). While AI-based learning assistants such as ChatGPT offer on-demand explanations, contextual examples, and individualized practice, rigorous classroom-based evidence of their effect on students' conceptual understanding remains limited, particularly for the topic of circular motion in Indonesian senior high schools. This study fills that niche by targeting a concept with documented high misconception rates and linking outcomes directly to mandated learning competencies. Therefore, the problem of this study was to determine whether ChatGPT-assisted learning could improve Grade 10 students' conceptual understanding of circular motion compared with conventional instruction.

Aim of the Study

To explore the use of ChatGPT in improving students' understanding of circular motion in Grade 10 senior high school physics, including the methods used for implementing ChatGPT, the outcomes observed, and the impact of this technology on students' conceptual understanding.

Objectives of the Study

1. To determine the normalized gain in conceptual understanding of circular motion of Grade 10 students in the experimental and control groups.
2. To describe the distribution of students across low, medium, and high normalized gain categories in the experimental and control groups.
3. To compare the conceptual understanding gains of students taught with ChatGPT assistance and those taught through conventional instruction.

Research Questions

1. What is the mean normalized gain in conceptual understanding of circular motion of Grade 10 students in the experimental and control groups?
2. How are students in the experimental and control groups distributed across the low, medium, and high normalized gain categories?
3. Is there a significant difference in conceptual understanding gains between students taught with ChatGPT assistance and those taught through conventional instruction?

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

Hypothesis

H_0 : There is no significant difference in the conceptual understanding gains of circular motion between Grade 10 students taught with ChatGPT assistance and those taught through conventional instruction.

METHODOLOGY

Research Design

This study employed a quantitative method with an experimental approach. The research was carried out at SMAS Taruna Bakti Bandung and involved two groups of Grade 10 students: Class X-1 and Class X-2. The study adopted a quasi-experimental pre-test–post-test control-group design (Sugiyono, 2017), comparing an experimental class that learned with ChatGPT assistance and a control class that followed conventional instruction. The experimental group used ChatGPT as a learning assistant, while the control group learned through conventional teaching methods. Prior to the intervention, students were given a pre-test to assess their initial understanding of circular motion. The design is illustrated in Table 1.

Table 1: Research Design

Group	Pre-test	Treatment	Post-test
Experimental	O_1	X	O_2
Control	O_3	–	O_4

Note. O_1 , O_3 = pre-test; O_2 , O_4 = post-test; X = ChatGPT-assisted learning; – = conventional instruction.

Population and Sample

Table 2: Research Target

Element	Description
Population	All Grade 10 students at SMAS Taruna Bakti Bandung, Academic Year 2025/2026
Sample and Sampling Technique	Class X-2 ($n = 25$) as the experimental group and Class X-1 ($n = 21$) as the control group, selected via purposive sampling to ensure similar prior achievement levels
Learning Topic	Circular Motion (angular velocity, centripetal acceleration, period, and frequency)

The population of this study encompassed every tenth-grade student enrolled at SMAS Taruna Bakti Bandung during the 2025/2026 academic year. Because the school organizes its physics instruction by intact classrooms rather than mixed groupings, an intact-class design was judged most practical and ethically sound; re-assigning individual students to new sections mid-semester would have disrupted established timetables and teacher–student rapport.

Using purposive sampling, two classes with comparable prior achievement in physics, determined from the school's mid-term examination records, were selected. Class X-2 (25 students) was designated the experimental group and received instruction supported by ChatGPT prompts, whereas Class X-1 (21 students) served as the control group and followed conventional teacher-centred lessons covering the same circular-motion content (Table 3). Purposive sampling ensured that both groups started with similar baseline competencies and learning conditions (e.g., the same laboratory resources, class length, and weekly schedule), thereby strengthening internal validity while retaining the ecological realism of the classroom setting.

The instructional topic for both groups focused exclusively on circular motion, including angular velocity, centripetal acceleration, period, and frequency, because these concepts are explicitly mandated in the national Grade 10 physics syllabus and are known to present persistent conceptual difficulties for Indonesian high school learners. By narrowing the content domain in this way, the study could more directly attribute any observed learning gains to the presence or absence of ChatGPT-mediated support rather than to topic breadth or curricular sequencing.

Table 3: Research Groups

Group	Class	Number of Students
Experimental	X-2	25
Control	X-1	21
Total		46

Research Procedure

The learning process in the experimental group was conducted over a period of two weeks, during which students were given access to ChatGPT to ask questions and receive explanations related to the topic of circular motion. Students were also assigned tasks that required them to utilize ChatGPT to solve problems associated with circular motion. In addition, regular question-and-answer

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

sessions were held to ensure that students could interact directly with the learning assistant. The complete procedure is summarized in Table 4.

Table 4: Research Procedure

Stage	Activity	Output
Preparation	1. Develop lesson plans and ChatGPT prompts 2. Validate instruments through expert review	Validated instruments (pre-/post-test, prompt list)
Pre-test	Administer the concept test to both classes	Baseline conceptual scores
Intervention	Experimental class: 4 × 90-minute lessons with ChatGPT-guided activities (Q&A, problem sets) Control class: same content delivered via teacher-centred instruction	Learning logs, ChatGPT interaction data
Post-test	Re-administer the concept test	Post-intervention scores
Follow-up	Collect student feedback on ChatGPT usability (optional)	Qualitative insights

To ensure that the learning process was well-directed, systematic, and aligned with the intended objectives, a specially designed instructional tool in the form of prompts was developed (Table 5). These prompts served as clear guidelines for students, enabling them to explore information, understand the material, and find relevant answers related to various aspects of circular motion concepts. The prompts were used in Indonesian; English translations are provided in brackets.

Table 5: Physics Learning Prompts for Circular Motion

Objective	Prompt
Understanding the basic concepts	1. " <i>Jelaskan pengertian gerak melingkar dan perbedaannya dengan gerak lurus.</i> " [Explain the meaning of circular motion and how it differs from linear motion.] 2. " <i>Apa saja jenis-jenis gerak melingkar? Berikan penjelasan dan contohnya.</i> " [What are the types of circular motion? Provide explanations and examples.]
Learning formulas and their applications	1. " <i>Apa rumus kecepatan sudut, kecepatan linier, dan percepatan sentripetal dalam gerak melingkar? Jelaskan setiap variabelnya.</i> " [What are the formulas for angular velocity, linear velocity, and centripetal acceleration? Explain each variable.] 2. " <i>Bagaimana cara menghitung periode dan frekuensi dalam gerak melingkar? Berikan contohnya.</i> " [How are period and frequency calculated in circular motion? Give examples.] 3. " <i>Jelaskan hubungan antara kecepatan sudut, radius, dan kecepatan linier.</i> " [Explain the relationship between angular velocity, radius, and linear velocity.]
Practice questions	1. " <i>Berikan contoh soal sederhana tentang gerak melingkar, lengkap dengan pembahasannya.</i> " [Give a simple circular-motion problem with a worked solution.] 2. " <i>Jika sebuah benda bergerak melingkar dengan jari-jari 2 meter dan kecepatan sudut 10 rad/s, berapa kecepatan liniernya?</i> " [If an object moves in a circle of radius 2 m with an angular velocity of 10 rad/s, what is its linear velocity?]
Connecting theory with application	1. " <i>Apa contoh penerapan gerak melingkar dalam kehidupan sehari-hari?</i> " [What are examples of circular motion in everyday life?] 2. " <i>Jelaskan bagaimana prinsip gerak melingkar digunakan pada mesin cuci atau wahana komidi putar.</i> " [Explain how circular-motion principles are used in a washing machine or a merry-go-round.]
Concept enrichment	1. " <i>Apa peran gaya sentripetal dalam gerak melingkar, dan bagaimana gaya ini dihasilkan dalam sistem tertentu?</i> " [What is the role of centripetal force in circular motion, and how is it produced in a given system?] 2. " <i>Bagaimana gerak melingkar terkait dengan hukum Newton?</i> " [How is circular motion related to Newton's laws?]

Instruments and Data Collection

Table 6: Data Collection Techniques

Variable	Instrument	Scale / Format	Reliability / Validity
Conceptual understanding	20-item multiple-choice test on circular motion	Score 0–100	KR-20 = 0.82
Learning gain	Pre-test and post-test scores	N-gain formula (Hake, 1998)	–
Student perception (optional)	Likert questionnaire and focus-group interview	1 (Strongly Disagree) – 4 (Strongly Agree)	Cronbach's α = 0.88

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

With the use of this instrument, students were not only provided with a reference for answering questions but were also encouraged to think critically, analyze, and connect the concept of circular motion to real-life applications. This approach was expected to enhance students' overall conceptual understanding and foster their active engagement in the learning process.

Data Analysis

At the end of the learning period, students from both groups were given a post-test to measure the improvement in their understanding. The data obtained from the pre-test and post-test were analyzed using descriptive and inferential statistics to determine the effectiveness of using ChatGPT in enhancing students' conceptual understanding of physics. Normality and homogeneity of variance were examined using the Shapiro–Wilk and Levene's tests in JASP (JASP Team, 2023) at the 0.05 level of significance. To assess the effectiveness of ChatGPT in improving students' conceptual understanding, the normalized gain (N-gain) was calculated using the following formula:

$$N\text{-gain} = (X_{\text{posttest}} - X_{\text{pretest}}) / (X_{\text{max}} - X_{\text{pretest}})$$

The N-gain is used to measure improvement in cognitive learning outcomes before and after the learning intervention. Its effectiveness was classified according to the criteria in Table 7.

Table 7: Normalized Gain Criteria (Hake, 1998)

Normalized Gain Value	Interpretation
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

RESULTS

Research Question One: What is the mean normalized gain in conceptual understanding of circular motion of Grade 10 students in the experimental and control groups?

Table 8: Mean N-gain of the Control and Experimental Groups

Group	N	Mean N-gain	Criterion
Experimental	25	0.54	Medium
Control	21	0.48	Medium

As shown in Table 8, the control class achieved a mean N-gain of 0.48, which falls into the medium category. Meanwhile, the experimental class obtained a mean N-gain of 0.54, also categorized as medium. The mean gain difference between the two groups was 0.06 in favour of the experimental group.

Research Question Two: How are students in the experimental and control groups distributed across the low, medium, and high normalized gain categories?

Table 9: Distribution of N-gain Categories in the Experimental and Control Groups

Criterion	Experimental Group		Control Group	
	n	%	n	%
Low	5	20.00	8	38.10
Medium	7	28.00	11	52.38
High	13	52.00	2	9.52
Total	25	100.00	21	100.00

Based on Table 9, the number of students in the experimental class who achieved the high N-gain category (13 students; 52.00%) is considerably greater than that in the control class (2 students; 9.52%). Conversely, fewer students in the experimental class fell into the low category (5 students; 20.00%) than in the control class (8 students; 38.10%).

Research Question Three: Is there a significant difference in conceptual understanding gains between students taught with ChatGPT assistance and those taught through conventional instruction?

Prior to hypothesis testing, the assumptions of normality and homogeneity of variance were examined.

Table 10: Normality Test (Shapiro–Wilk)

Test	Group	W	p
Pre-test	Experimental	0.979	0.862

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

Test	Group	W	p
Post-test	Control	0.943	0.246
	Experimental	0.956	0.337
	Control	0.910	0.054

The Shapiro–Wilk normality test showed that the p-value for the pre-test was 0.862 in the experimental class and 0.246 in the control class. Since both values are greater than $\alpha = 0.05$, the pre-test scores are normally distributed. Similarly, the post-test scores had $p = 0.337$ in the experimental class and $p = 0.054$ in the control class, both of which are also greater than $\alpha = 0.05$, indicating normal distribution. This means that, at the 5% significance level, the pre-test and post-test scores of students' learning outcomes in physics are derived from normally distributed populations.

Table 11: Homogeneity of Variance Test (Levene's)

Test	F	df ₁	df ₂	p
Pre-test	0.002	1	44	0.969
Post-test	0.831	1	44	0.367

Levene's test showed $p = 0.969$ for the pre-test and $p = 0.367$ for the post-test, both greater than $\alpha = 0.05$. This indicates that the variances of the pre-test and post-test scores are homogeneous. Therefore, at the 5% significance level, the students' learning outcome scores in physics are derived from populations with homogeneous variance.

Hypothesis 1: There is no significant difference in the conceptual understanding gains of circular motion between Grade 10 students taught with ChatGPT assistance and those taught through conventional instruction.

Table 12: Independent-Samples t-test on N-gain

Group	N	Mean	SD	t	df	p	Cohen's d
Experimental	25	0.54	0.18	2.11	44	.041	0.62
Control	21	0.48	0.17				

Since the assumptions of normality and homogeneity were met, the hypothesis was tested using an independent-samples t-test. The result showed a statistically significant difference in N-gain between the experimental and control groups, $t(44) = 2.11$, $p = .041$, with a medium effect size ($d = 0.62$). Since the p-value was less than the 0.05 level of significance, the null hypothesis was rejected. Therefore, students taught with ChatGPT assistance achieved significantly greater conceptual understanding gains than those taught through conventional instruction.

DISCUSSION OF FINDINGS

The findings of this study indicate an improvement in students' conceptual understanding of physics among those who used ChatGPT compared with the control group. The average N-gain for the experimental class was 0.54, while the control class achieved 0.48. These figures not only reflect a moderate difference but also reveal an emerging trend in modern education. The independent-samples t-test showed that this difference is statistically significant ($p = .041 < .05$), suggesting that the use of ChatGPT contributes positively to students' understanding. These results support the view that technology, particularly AI-based applications like ChatGPT, can play a crucial role in enhancing the learning process.

One of the key factors supporting this result is ChatGPT's ability to deliver personalized explanations tailored to students' needs. For example, when students struggle to understand the concept of centripetal acceleration, they can immediately ask ChatGPT. The AI assistant not only provides simplified explanations but also includes relevant practice problems. A student confused about how to calculate the centripetal acceleration of a turning car might receive a clear and concise explanation, along with a real-world illustration of how centripetal force works. This aligns with Prasetyo's (2022) findings, which state that interactive learning significantly enhances student engagement and conceptual understanding.

The interactivity offered by ChatGPT allows students to become more engaged in their learning. They are no longer passive recipients of information but active participants in building their understanding. For instance, if a student does not fully grasp Newton's laws, they can ask how these laws apply in real-life situations, such as riding a bicycle or playing sports. Through this approach, students receive not only information but also meaningful context, which helps them better comprehend and retain the concepts. This demonstrates that technology is not merely a tool; it can also serve as a learning partner.

The findings also have theoretical implications. By showing a statistically significant improvement in normalized gain, the study extends the interactive-engagement paradigm (Hake, 1998) to encompass human–AI dialogue, suggesting that cognitive conflict and self-explanation can be triggered even when the "tutor" is an LLM. The work also enriches conceptual-change theory (Duit &

The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

Treagust, 2003) by documenting how adaptive, language-based feedback may accelerate the restructuring of naïve circular-motion schemas.

Furthermore, ChatGPT shows strong potential for adapting to students' diverse learning preferences. Each student processes information differently; some prefer visual representations, others verbal explanations, and some learn best through hands-on practice. ChatGPT can adjust to these preferences by offering explanations in various formats. For visual learners, it can recommend diagrams or visual resources to support their understanding of physics concepts. In doing so, ChatGPT not only improves conceptual comprehension but also helps students identify and utilize their own learning strategies.

Additionally, it is important to consider the long-term impact of using technologies like ChatGPT in education. As students' understanding of physics improves, they become better prepared for examinations and more motivated to explore other fields of science. Increased confidence in physics learning can encourage students to pursue further studies in science and technology, potentially contributing to future innovation and discovery.

However, despite the positive results shown by this study, it is important to recognize that ChatGPT is not a standalone solution. Teachers and educators continue to play a critical role in guiding students. While ChatGPT can be a powerful tool to support learning, it cannot replace the rich human interaction and mentorship that occur in the classroom. Therefore, a thoughtful integration of technology with traditional pedagogy is essential to achieving optimal educational outcomes. Methodologically, this study demonstrates the feasibility of using normalized gain analyses to evaluate AI interventions in authentic school settings, although the short intervention period and single-school sampling limit the generalizability of the findings.

KEY FINDINGS

The study found that ChatGPT-assisted learning was associated with higher conceptual understanding gains in circular motion among Grade 10 students at SMAS Taruna Bakti Bandung.

1. The experimental group achieved a mean N-gain of 0.54, while the control group achieved 0.48; both fall into the medium category, with a mean gain difference of 0.06 in favour of the experimental group.
2. More than half of the students in the experimental group (52.00%) reached the high N-gain category, compared with only 9.52% in the control group, while the proportion of students in the low category was lower in the experimental group (20.00%) than in the control group (38.10%).
3. Pre-test and post-test data in both groups were normally distributed (Shapiro–Wilk, $p > .05$) and had homogeneous variances (Levene's test, $p > .05$), meeting the assumptions for parametric comparison of the two groups.
4. The independent-samples t-test showed a significant difference in N-gain in favour of the experimental group, $t(44) = 2.11$, $p = .041$, $d = 0.62$; the null hypothesis was rejected.

CONCLUSION

The study concluded that integrating ChatGPT as a learning assistant into Grade 10 circular-motion lessons, supported by structured learning prompts, improves students' conceptual understanding, as reflected in a higher mean normalized gain and a markedly larger proportion of students reaching the high gain category in the experimental group than in the control group. ChatGPT provides on-demand, personalized explanations, contextual examples, and practice problems that help students engage actively with abstract physics concepts. Nevertheless, its effectiveness depends on thoughtful integration with teacher guidance rather than use as a standalone solution.

RECOMMENDATIONS

The following recommendations are proposed for teachers, curriculum designers, and researchers:

1. **Personalize feedback through structured prompts:** Teachers should incorporate structured AI prompts and reflective questioning into physics lessons to provide personalized feedback while maintaining their guiding role in the classroom.
2. **Align learning modules with adaptive scaffolding:** Curriculum designers are advised to align physics modules with adaptive chatbot scaffolding to foster inquiry-driven learning that targets known misconceptions.
3. **Extend and strengthen the evidence base:** Future research should employ longer intervention periods, diversified school contexts (urban–rural), and mixed-methods approaches that capture affective factors such as motivation and self-efficacy, extend the approach to other physics domains and learner profiles, and compare ChatGPT with domain-specific intelligent tutoring systems for conceptual versus procedural knowledge acquisition.

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The Impact of ChatGPT-Assisted Learning on Students' Understanding of Circular Motion in Grade 10 Physics

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