

Exploring AI-Driven Cognitive Conflict in Teaching Quantum Physics (A Case Study in Indonesian Senior High School)

Fathiah Damri Said^{1*}

¹SMAN 2 Kabupaten Tangerang, Mauk, Kabupaten Tangerang, Banten

*fathiah.damri.said@gmail.com

Abstract

This study explores the use of generative AI, specifically ChatGPT, as a tool to facilitate cognitive conflict during quantum physics learning in an Indonesian high school classroom. Employing an exploratory case study design, the research involved 200 12th-grade students from a public secondary school. A set of conceptual questions rooted in quantum phenomena (e.g., time travel, superposition) were designed to trigger students' misconceptions and stimulate metacognitive reflection. Students explored these questions using ChatGPT before engaging in classroom discussion and reflection. While the approach successfully sparked curiosity and deep engagement, analysis revealed that a majority of students relied entirely on AI-generated responses, even for prompts requiring personal opinion. The triangulation analysis combined heuristic linguistic features, response similarity checks, and follow up interview to determine whether student responses were likely generated by AI or written personally and identified key themes of wonder, cognitive ambiguity, and cultural connection in student reflections. Overall, the study highlights both the opportunities and challenges of integrating generative AI into science education.

Keywords: *Cognitive conflict, generative AI, ChatGPT, quantum physics*

Background

Generative AI is becoming an increasingly prevalent tool in educational contexts, particularly in supporting personalized learning and inquiry-based instruction. While many studies focus on its role in automation or content delivery (Luckin et al., 2016; Holmes et al., 2022), its potential in promoting conceptual conflict and critical thinking remains underexplored. Research by Hadzigeorgiou (2005) emphasized that creating a sense of wonder and conflict in science learning can trigger deeper cognitive processing, especially in abstract domains like quantum physics. Similarly, Karpicke & Blunt (2011) emphasized that learning activities that stimulate active retrieval and reinterpretation of information are more effective than passive information consumption.

Quantum physics, often regarded as counterintuitive and conceptually complex, presents unique opportunities to engage students' imaginations and analytical skills using novel tools. Concepts like superposition or entanglement defy everyday experience, so learners often hold naive models (for example, picturing electrons as tiny planets orbiting an atom) that must be confronted and revised. Prior work on cognitive conflict (Posner et al., 1982; Lee & Byun, 2012) suggests that students change their preconceptions most effectively when they encounter evidence that contradicts their prior beliefs. Educational theorists have long used discrepant events and thought experiments to create such conflict (Limón, 2001). For instance, a demonstration of electrons behaving like waves can prompt students to question their classical assumptions. By designing activities that deliberately evoke confusion or surprise, educators can create the disequilibrium necessary for conceptual change.

Furthermore, culturally responsive teaching posits that connecting new science concepts to students' cultural experiences can enhance engagement (Gay, 2002). In our context, linking quantum ideas to familiar elements, such as *santet* (a form of Indonesian folk magic), reincarnation, or popular science fiction narratives invites students to integrate new knowledge with existing cultural schemas. This approach aligns with sociocultural constructivism, which emphasizes the use of familiar tools and symbols in learning (Vygotsky, 1978). Generative AI like ChatGPT can be viewed as a mediating tool or "cognitive partner" in this process, offering explanations that students can interrogate and relate to their own background knowledge.

In sum, although AI chatbots have been used in higher education to supply information and spur inquiry, few studies have examined their potential to actively induce conceptual conflict at the K–12 level (Luckin et al., 2016; Holmes et al., 2022). This study addresses that gap by investigating how ChatGPT-driven activities affect students' thinking and affect during an introductory quantum physics lesson. We build on three theoretical frameworks:

- (1) Cognitive Conflict Theory (Posner et al., 1982): Suggests that conceptual change is most likely to occur when students encounter ideas that challenge their existing beliefs, forcing them to reconstruct their understanding.
- (2) Sociocultural Constructivism (Vygotsky, 1978): Emphasizes the role of tools (in this case, AI) and social interaction in knowledge construction. AI acts as a mediating artifact that can guide students through conceptual ambiguity.
- (3) AI as Cognitive Scaffolding (Holmes et al., 2022): Proposes that well-designed AI tools can support learning not just by providing information, but by prompting questions, modeling reasoning, and encouraging self-explanation.

This paper aims to investigate the potential of generative AI, particularly ChatGPT, to serve as a cognitive partner in science education. The study explores how AI can be used to create cognitive dissonance, stimulate curiosity, and support students' conceptual understanding of quantum physics through reflective engagement. By presenting culturally relevant and philosophically provocative questions (e.g., time travel, *santet*, multiverse), the research seeks to:

- (1) Analyze students' cognitive and emotional responses to AI-driven cognitive conflict.
- (2) Examine the risks of overreliance on AI for reflective tasks.
- (3) Propose pedagogical recommendations for integrating AI in inquiry-based science learning.

Research Method

This study adopts an exploratory qualitative case study design, following the framework suggested by Yin (2014), which allows in-depth exploration of complex phenomena in real-life educational settings. The research focuses on understanding how generative AI can facilitate cognitive conflict and conceptual reflection in high school quantum physics learning.

Participants:

The study was conducted in a public senior high school in Indonesia, involving a class of 12th-grade students ($n = 200$) who were learning quantum physics as part of their standard curriculum. Participants were selected through random sampling, and ethical considerations were ensured through informed consent. The class was diverse in ability and included both students who were enthusiastic about physics and those who typically found the subject challenging. All participants were Indonesian speakers with similar cultural backgrounds.

Procedures:

The intervention took place over two class sessions. First, the teacher introduced the concept of generative AI by demonstrating ChatGPT on the projector, asking a simple question (e.g., "Explain three quantum-physics phenomenon which can't be explained by classical physics?") to show how AI responds. The teacher began a stimulus lesson covering three classic quantum experiments: the Photoelectric Effect, the Double-Slit Experiment, and the Delayed Choice Experiment. These demonstrations, supported by brief videos and illustrations, were chosen for their counterintuitive results (e.g., electrons behaving like waves) and to elicit initial confusion and curiosity about quantum behavior. The goal was to prime students for conceptual dissonance.

Following the stimulus, students were assigned 16 open-ended questions:

- Six questions focusing on core quantum concepts (for example, “What do you think superposition means?”), aiming to assess baseline understanding.
- Nine questions designed to create cognitive conflict by linking scientific ideas with culturally familiar or philosophical concepts (e.g., *santet*, reincarnation, time travel, multiverse, supernatural powers). Examples included: “Could the idea of quantum randomness explain *santet*?” “If time travel were possible, how would quantum theory need to change?” “Is there a quantum explanation for reincarnation or ghosts?” These prompts intentionally connected the curriculum to local beliefs and science fiction themes, anticipating that some student answers or questions would reveal misconceptions or wonder.

Students were instructed that they could use any generative AI platform to help answer the questions; in practice, all students independently chose ChatGPT and Meta AI. They typed their questions into the AI and then wrote down the answers along with any additional thoughts they had. Students submitted their written answers through Google Forms, allowing for easy collection. During this phase, the teacher circulated in the room but refrained from answering students’ content questions. The teacher took observational notes but did not influence the students’ use of AI, so as to capture authentic student-AI interaction. The next day, the class held a debriefing discussion. The teacher asked students to share interesting or confusing parts of generative AI’s answers and ended by emphasizing core concept of quantum physics.

Instruments:

The primary data sources were the students’ written responses to the AI-assisted prompts and the teacher’s field notes from the classroom discussions. The question prompts were researcher-designed to elicit conceptual understanding and reflective thinking. The Google Form collected timestamped answers for each student. No standardized test was used; instead, learning was assessed through thematic analysis of student language and behaviors.

Data Analysis:

The analysis uses triangulation method, combined heuristic linguistic features, response similarity checks, and follow-up interviews (Denzin, 2012; Patton, 1999) to determine whether student responses were likely generated by AI or written personally.

First, each student’s written answer was examined to determine whether the ideas presented were original student thinking or clearly taken (verbatim or paraphrased) from ChatGPT, using a set of indicators such as tone, structure, and vocabulary density. AI-generated responses were often formal, consistently grammatical, and lacked contextual references. In contrast, student-generated responses frequently included informal expressions, culturally specific terms, or emotive language.

Secondly, similar answers across different students were examined. If multiple students submitted near-identical responses, these were flagged as likely copied from ChatGPT or another AI tool. Finally, the researcher conducted brief, random follow-up interviews with selected students. Students were asked to explain their reasoning or to confirm whether they had used generative AI to construct their answers. This allowed for data triangulation, adding credibility to the categorization of responses.

Result and Discussion

In total, the students provided 200 written responses to the open-ended prompts. To investigate the extent of conceptual convergence and possible reliance on generative AI tools, students responses were analyzed for identical or near-identical phrases across both conceptual and speculative (cognitive conflict) questions). In the six conceptual questions and nine cognitive conflict questions, students were asked to use any generative AI to answer. However, student responses to the opinion-based questions in last two questions: summary and personal impressions were qualitatively assessed to distinguish between AI-generated and personally written text. The classification was based on structure, language style, and specificity. AI-generated answers typically features complex sentences, formal academic tone, and references to theoretical concepts, whereas personal reflections were more expressive, concise, and informal, often containing typos or personal information.

Table 1

Authorship Indicators in Reflections

Category	Summary question	Impression question
AI-generated	166 (83%)	153 (76.5%)
Personally written	34 (17%)	47 (23.5%)

Source: Research data, 2025

Based on data in Table 1, only 47 responses (23.5%) contained original student-generated thinking; the remaining 153 responses (76.5%) were clearly derived from ChatGPT's output. This quantitative finding indicates that the majority of students relied on AI-generated text even when tasks explicitly solicited personal reflections or opinions. Only about a quarter of responses showed students actually engaging their own ideas, highlighting a tension between the intended reflective task and the convenience of the AI.

Table 2 summarizes the key themes identified in those 47 authentic student reflections, along with illustrative quotes. Each response was coded into its primary theme, and the table lists the number and percentage of responses per theme.

Table 2
Key themes from student reflections (N = 47 original responses)

Theme	Original Responses (n, %)	Representative Quote
Wonder & Engagement	15 (32%)	"The topic felt <i>exciting</i> and <i>mysterious</i> , like watching a sci-fi movie."
Cognitive Ambiguity	10 (21%)	"I feel excited but also a bit confused about how this works."
Cultural Connection	12 (26%)	"Linking it to something like <i>santet</i> made quantum more interesting."
AI Perception	10 (21%)	"Sometimes I wish I had a brain like ChatGPT."

Source: Research data, 2025

Many students expressed a strong sense of *wonder and engagement* with the quantum prompts. For example, one student noted (in English translation) that learning about quantum phenomena through ChatGPT was "exciting" and "mysterious, like watching a sci-fi movie." Another wrote in Indonesian, "*Saya senang tapi juga terkejut, rasanya seperti menonton film fiksi ilmiah*" ("I'm happy but also amazed, it feels like watching a science-fiction film"). This aligns with prior work emphasizing that eliciting wonder can drive deeper cognitive processing in science (Hadzigeorgiou, 2022). The prevalence of this theme suggests that the unusual, counterintuitive nature of the questions (such as time travel and supernatural phenomena) effectively sparked student interest and linked abstract concepts to imaginative thinking. In essence, students were drawing on the "sense of wonder" that Hadzigeorgiou describes, which may prime them for learning even if full understanding is not yet achieved.

Another theme, *cognitive ambiguity*, emerged in 21% of the authentic responses. Students frequently reported mixed emotions, such as feeling "excited but also a bit confused" by the AI explanations. For instance, one wrote "*senang tapi bingung*" ("happy but confused") and another said "*takjub tapi pusing*" ("astonished but my head is spinning"). These mixed feelings are characteristic of cognitive conflict: when learners encounter information that conflicts with their existing beliefs, they often feel both intrigue and puzzlement (Posner et al., 1982). In our study, this emotional dissonance indicates that the ChatGPT-driven prompts succeeded in provoking genuine cognitive conflict. Students' acknowledgment of confusion suggests they were actively grappling with the material. According to conceptual change theory, such dissonance is a necessary step toward deeper understanding; the immediate confusion may later lead students to reorganize their thinking as they seek resolution.

The *cultural connection* theme was evident in 26% of authentic responses, where students explicitly linked quantum ideas to familiar cultural or supernatural concepts. Several students mentioned that incorporating an idea like *santet* (a form of Indonesian magic) made the physics concepts more relatable. For example, one student reflected, "*Saat kuhubungkan dengan santet, quantum jadi lebih mudah dimengerti*" ("When I connected it with *santet*, quantum became easier to understand"). Another invoked the Marvel Cinematic Universe, noting that thinking of multiple worlds (multiverse) helped him imagine particle paths. This suggests that situating scientific ideas within students' cultural experiences boosted engagement and perceived relevance. It also reflects the constructivist notion of building on prior knowledge (Bransford, Brown, & Cocking, 2000): by anchoring abstract

quantum phenomena in concrete cultural narratives, students created meaningful analogies. This is consistent with Vygotsky's view that tools and signs (here, cultural symbols) mediate cognition.

The final theme, *AI perception*, captures students' attitudes toward ChatGPT itself. Several students expressed admiration for the AI's intelligence or flexibility. A common sentiment was "*Kadang saya ingin punya otak seperti ChatGPT*" ("Sometimes I wish I had a brain like ChatGPT"). In the classroom discussion, one student explicitly noted that the AI's answers changed when the question was phrased differently, demonstrating an understanding of prompt sensitivity. This insight is noteworthy: it shows students realized ChatGPT was not infallible but was influenced by how they interacted with it. Indeed, the teacher's field notes record that some students testing different prompts saw variations in responses and began asking about reliability and sources. These meta-cognitive observations illustrate a sophisticated awareness of the AI as a tool.

However, the enthusiasm also raises caution. Comments like "*I wish I had a brain like ChatGPT*" indicate that students tended to view the AI as an authoritative knowledge source. This finding reinforces the need for pedagogical framing. Indeed, literature on AI in education warns that over-reliance on AI-provided answers can impede the development of students' own reasoning and analytical skills. Teachers must emphasize that the AI is a collaborator, not an oracle, and encourage learners to critically evaluate its outputs.

In addition to these thematic findings, we observed several noteworthy patterns. During the activity, the classroom atmosphere was unusually quiet and focused as students engaged with ChatGPT, suggesting genuine interest. Afterward, however, the teacher noted an animated debate: students pointed out inconsistencies or perceived errors in the AI's answers. For example, one student observed that ChatGPT assumed an ideal physics scenario without mentioning the world's limitations, prompting discussion about real versus ideal assumptions. This spontaneous questioning is precisely the kind of metadialogue educators hope for. It indicates that some students were not passively accepting the information but actively interrogating it.

Another pattern was that a subset of students asked ChatGPT follow-up questions beyond the worksheet. For example, when ChatGPT's answer mentioned "quantum entanglement," some students independently typed, "Explain what entanglement is." While this showed curiosity, it often introduced advanced concepts prematurely. The teacher later recorded that these students became confused by terms like "nonlocality" or "photon spin" that ChatGPT brought up. In effect, unguided exploration sometimes led to cognitive overload: encountering too many new terms at once without immediate support left some students bewildered.

kesan saya adalah ngerasa tertarik sama topik diskusinya. AI juga jawabannya menarik, bikin lebih paham sama fenomena aneh yang dibahas.

kesan saya udah berdiskusi sama AI tentang kuantum bener bener seruu dan nambah pengetahuan saya karna kebetulan saya bener bener nungguin materi tentang kuantum karna tertarik sama multiverse, time travel, reinkarnasi karna sebelumnya belum tau sedalam ini cuma tau dari film film MCU jadi sekarang tau lebih dalam lagi

SANGATT SERUU!! Saya sendiri mengenal kuantum sejak SD saat itu saya awal mengira kuantum hanyalah teori fisika yang menggunakan sihir namun saat memasuki remaja saya tau kalo teori kuantum ternyata ada yang bisa dijelaskan secara ilmiah tetapi ini bener² merubah pandangan saya terhadap dunia ini TERIMAKASIH BU FATHIAH KARNA TELAH Membahas teori ini

AI pintar banget, pengen deh punya otak kek AI. tapi lebih bagus lagi kalo ai tepat di gunakan kek belajar fisika gini Bu hehehe

Ada ai yang asik ada yang baku lalu ketika aku berdiskusi kuantum dengan AI banyak kata spontan yang terlintar di pikiran kayak "fisika bisa seruwed ini" "astaghfirullah fisika fisika" "anjay bisa time travel segala" kurang lebih sepertinya begitu lalu 1 kesan kata saya untuk AI. 1.MENAKJUBK

Menyenangkan tapi agak sedikit pusing

Intinya, diskusi ini membuat saya merasa kecil di hadapan alam semesta yang begitu luas dan kompleks, tetapi juga membangkitkan rasa kagum dan semangat untuk terus belajar.

menurut saya kuantum itu materinya menantang sulit sulit gimna gitu tapi setelah berdiskusi tentang kuantum dengan Ai, kesan yang didapatkan adalah kagum akan luasnya ilmu pengetahuan dan betapa banyak hal yang belum kita ketahui. sekian terimakasih

Image 1. Students' authentic response about learning quantum physics using AI
(Source: Research data, 2025)

A final insight emerged from student feedback on instructional sequencing. In this design, students first explored quantum ideas with ChatGPT, and only afterward received formal classroom instruction on those concepts. While this sequence clearly piqued curiosity, some students self-reported feeling confused by the advanced content. Reflecting on this, one student suggested that learning the core theory *in class before* using ChatGPT would be more helpful. In other words, providing a foundational framework first could enable students to ask more informed questions and better interpret the AI's answers. This practical suggestion aligns with scaffolded learning approaches: novices may benefit from initial guidance before open-ended inquiry. Future research should test this hypothesis by comparing whether concept learning improves when instruction precedes versus follows AI activities.

Taken together, these findings have practical implications for teaching with generative AI. On the positive side, the themes of wonder, engagement, and cultural connection suggest that ChatGPT can make abstract science content more intriguing by tapping into students' interests and prior knowledge. For instance, the cultural analogies our students made are a form of constructive assimilation of new knowledge. However, the heavy reliance on AI-generated text and the reports of confusion highlight the need for structured pedagogical support. Educators should treat ChatGPT as a collaborative partner. For example, after students use ChatGPT, class time should be devoted to critically discussing the AI's answers. Teachers can ask students to paraphrase or question the AI's responses, ensuring active engagement. This "meta-dialogue" helps ensure that students process information rather than accept it uncritically.

This case study thus illustrates both the promise and the pitfalls of integrating generative AI into science education. Carefully designed prompts can catalyze student curiosity and engagement in line with cognitive conflict theory and active-learning models. At the same time, without guidance these tools may inadvertently reinforce passive learning or introduce confusion. Educators should leverage the strengths of AI, such as providing diverse examples and instant feedback, while mitigating its risks (student overreliance on AI). By framing AI as a scaffolded tool and fostering critical reflection, teachers can harness AI to stimulate cognitive conflict and reflection, transforming potential confusion into rich learning experiences.

Conclusion and Suggestion

Generative AI tools like ChatGPT hold significant potential to enhance science learning, particularly by stimulating curiosity and exploration of complex concepts. In this study, many students described the experience with terms like "exciting" and "mysterious," indicating that the AI-driven activity captured their interest. However, the fact that most student responses were AI-generated highlights a critical concern: without careful pedagogical design, students may default to passive acceptance of AI outputs.

To address this, teachers should craft AI-mediated activities that balance open inquiry with explicit guidance. For example, prompts should be constructed to require students to add their own interpretations (e.g., "Explain in your own words how this relates to you"), and class discussions should focus on evaluating AI responses. One practical implication from the findings is the importance of instructional sequencing: several students suggested teaching core quantum concepts in class *before* exploring them with ChatGPT. Providing foundational instruction first may help students better contextualize the AI's answers and reduce cognitive overload.

Looking ahead, this study suggests several directions for future research. Subsequent studies should systematically compare different instructional sequences (AI-first vs. instruction-first) and measure actual learning outcomes (e.g., conceptual understanding on quizzes). Investigating structured reflection protocols, such as requiring students to annotate or critique AI answers, could yield insights into how to maximize AI's pedagogical

value. Research in diverse educational contexts (different grade levels, subjects, and cultural settings) would help determine how generalizable these findings are. For instance, would similar themes emerge in a biology class or in schools with different cultural backgrounds?

In conclusion, ChatGPT and similar generative AI tools can serve as powerful cognitive partners in science education, but their effectiveness depends on mindful integration. Educators must frame AI as a resource within a guided learning environment and teach students to critically engage with AI-generated information. By doing so, teachers can harness AI's ability to provoke cognitive conflict and interest while ensuring that students remain active, reflective learners.

References

1. Badan Standar Kurikulum dan Asesmen Pendidikan (2022). *Capaian Pembelajaran Mata Pelajaran Fisika Fase E – Fase F untuk SMA/MA/Paket C*. Jakarta: Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.
2. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>
3. Chin, C., & Osborne, J. (2008). Students' questions: a potential resource for teaching and learning science. *Studies in Science Education*, 44(1), 1-39. <https://doi.org/10.1080/03057260701828101>
4. Denzin, N. K. (2012). Triangulation 2.0. *Journal of Mixed Methods Research*, 6(2), 80–88. <https://doi.org/10.1177/1558689812437186>
5. Hadzigeorgiou, Y. (2022). Students' Reactions to Natural and Physical Phenomena: Documenting Wonder and Engagement with Science Content Knowledge. *Interdisciplinary Journal of Environmental and Science Education*, 18(1), e2261. <https://doi.org/10.21601/ijese/11340>
6. Gay, Geneva (2002). Preparing for Culturally Responsive Teaching. *Journal of Teacher Education*, 53 (2): 106 – 116. <https://doi.org/10.1177/0022487102053002003>
7. Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign. [Online] Retrieved from <https://curriculumredesign.org/wp-content/uploads/AIED-Book-Excerpt-CCR.pdf>
8. Holmes, W., & Porayska-Pomska, K. (2023). *The Ethics of Artificial Intelligence in Education*. New York: Taylor & Francis Group.
9. Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than elaborative studying with concept mapping. *Science*, 331(6018), 772–775. DOI: [10.1126/science.1199327](https://doi.org/10.1126/science.1199327)
10. Lasmi, N. K. (2024). *Fisika SMA Kelas XII Kelompok Mata Pelajaran Pilihan (Kurikulum Merdeka)*. Jakarta: Penerbit Erlangga.
11. Lee, G., & Byun, T. (2003). An explanation for the difficulty of leading conceptual change using a cognitive conflict strategy. *Research in Science Education*, 42, 943–965 (2012). <https://doi.org/10.1007/s11165-011-9234-5>
12. Limon, Margarita (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, 11, Issues 4-5 (357-380). [https://doi.org/10.1016/S0959-4752\(00\)00037-2](https://doi.org/10.1016/S0959-4752(00)00037-2)
13. Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence Unleashed: An Argument for AI in Education*. Pearson Education. [Online] Retrieved from https://www.researchgate.net/publication/299561597_Intelligence_Unleashed_An_argument_for_AI_in_Education
14. Mc Evoy, J. P., & Zarate, O. (2005) *Seri Mengenal dan Memahami: Teori Kuantum*. Batam: Scientific Press.
15. Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research*, 34(5 Pt 2):1189-208. [Online] Retrieved from <https://pmc.ncbi.nlm.nih.gov/articles/PMC1089059/>
16. Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211–227. <https://doi.org/10.1002/sce.3730660207>
17. Sarah, L. L., & Suwama, I. R. (2022). *Fisika Kelas 12*. Jakarta: Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

18. Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.[Online] Retrieved from <https://archive.org/details/levs.vygotskymindinsocietythedevelopmentzlib.org>
19. Yin, R. K. (2014). *Case Study Research: Design and Methods* (5th ed.). SAGE Publications. DOI: [10.3138/cjpe.30.1.108](https://doi.org/10.3138/cjpe.30.1.108)
20. Zawacki-Richter, O., et al. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1). <https://doi.org/10.1186/s41239-019-0171-0>

APPENDIX: EXAMPLE OF STUDENTS' AUTHENTIC RESPONSE

kesan saya adalah ngerasa tertarik sama topik diskusinya. Ai juga jawabannya menarik, bikin lebih paham sama fenomena aneh yang dibahas.

kesan saya udah berdiskusi sama Ai tentang kuantum bener bener seruu dan nambah pengetahuan saya karna kebetulan saya bener bener nungguin materi tentang kuantum karna tertarik sama multiverse, time travel, reinkarnasi karna sebelumnya belum tau sedalam ini cuma tau dari film film MCU jadi sekarang tau lebih dalam lagi

SANGATT SERUU!! Saya sendiri mengenal kuantum sejak SD saat itu saya awal mengira kuantum hanyalah teori fisika yang menggunakan sihir namun saat memasuki remaja saya tau kalo teori kuantum ternyata ada yang bisa dijelaskan secara ilmiah tetapi ini bener² merubah pandangan saya terhadap dunia ini TERIMA KASIH BU FATHIAH KARNA TELAH Membahas teori ini

Ai pintar banget, pengen deh punya otak kek Ai. tapi lebih bagus lagi kalo ai tepat di gunakan kek belajar fisika gini Bu hehehe

Ada ai yang asik ada yang baku lalu ketika aku berdiskusi kuantum dengan Ai banyak kata spontan yang terlontar di pikiran kayak "fisika bisa seruwed ini" "astaghfirullah fisika fisika" "anjay bisa time travel segala" kurang lebih sepertinya begitu lalu 1 kesan kata saya untuk Ai. 1. MENAKJUBK

Menyenangkan tapi agak sedikit pusing

Intinya, diskusi ini membuat saya merasa kecil di hadapan alam semesta yang begitu luas dan kompleks, tetapi juga membangkitkan rasa kagum dan semangat untuk terus belajar.

menurut saya kuantum itu materinya menantang sulit sulit gimna gitu tapi setelah berdiskusi tentang kuantum dengan Ai, kesan yang didapatkan adalah kagum akan luasnya ilmu pengetahuan dan betapa banyak hal yang belum kita ketahui. sekian terimakasih

lumayan seru karena bisa di bantu dengan Ai

seru, fisika kuantum bikin mikir hal-hal yang kelihatannya mustahil, kayak multiverse, perjalanan waktu, & dunia lain

Kesan nya bagus dan saya dapat belajar lagi tentang kuantum

bahwa dalam fisika kuantum kita belajar tentang hal hal yang tidak bisa dilihat oleh mata

fisika kuantum telah menginspirasi saya untuk terus menjelajahi misteri alam semesta.

sangat menarik guys

APPENDIX: STUDENT'S CHAT WITH GENERATIVE AI

