

The Effect of ChatGPT Integration on Students' Scientific Argumentation Skills in Genetics Learning

Muhammad Fuad¹, Burhan², Armin Arif³, Risqah Amaliah Kasman⁴, Muhammad Fadli⁵, Rahmaniah Rahman⁶

^{1,2,4,5} Institut Teknologi dan Kesehatan permata Ilmu Maros, muhammadfuad@itkpi.ac.id

³ Universitas Megarezky

⁶ Universitas Negeri Manado

Abstrak

Scientific argumentation is an essential competency in Biology education, particularly in genetics, which requires students to analyze evidence, construct logical reasoning, and draw conclusions based on scientific concepts. However, students' scientific argumentation skills remain relatively low, highlighting the need for innovative instructional approaches that effectively facilitate scientific reasoning. This study aimed to analyze the effect of ChatGPT integration on students' scientific argumentation skills in genetics learning. The study employed a quantitative approach using a quasi-experimental design with a Nonequivalent Control Group Design. The research sample consisted of two twelfth-grade science classes at MAS Firdaus Toppobalang, designated as the experimental and control groups. Data were collected through a Toulmin-based scientific argumentation test, classroom observations, questionnaires, and documentation. The data were analyzed using descriptive and inferential statistics, including the Independent Samples t-test, Paired Samples t-test, normalized gain (N-Gain), and effect size analysis. The results revealed that the experimental group achieved a mean N-Gain score of 0.65, which was higher than that of the control group (0.35). Hypothesis testing indicated a statistically significant difference ($p = 0.001 < 0.05$) with a Cohen's d value of 0.96, indicating a large effect size. Improvements were observed across all components of scientific argumentation, including claim, evidence, reasoning, backing, and rebuttal, although the rebuttal component still requires further enhancement. Therefore, the integration of ChatGPT had a positive and significant effect on students' scientific argumentation skills and is recommended as an innovative approach to Biology instruction, while maintaining the teacher's central role in guiding the critical and responsible use of artificial intelligence.

Keywords: *Biology learning; ChatGPT; Genetics; Scientific argumentation; AI integration*

Corresponding Author:

Muhammad Fuad

✉ muhammadfuad@itkpi.ac.id

INTRODUCTION

The development of Artificial Intelligence (AI) has brought significant changes across various aspects of human life, including education. One of the AI technologies increasingly utilized in the learning process is ChatGPT, a large language model capable of generating rapid, interactive, and contextually appropriate natural language responses. The emergence of ChatGPT has created new opportunities for education, as it functions not only as an information provider but also as a learning partner that facilitates discussions, provides feedback, assists in problem-solving, and encourages students to develop higher-order thinking skills. The integration of AI technology into education aligns with the demands of twenty-first-century learning, which emphasizes critical thinking, scientific communication, creativity, collaboration, and digital literacy as essential competencies for students (Sape et al., 2025).

In Biology education, particularly in genetics, the development of scientific argumentation skills is regarded as one of the most essential learning competencies. Genetics is characterized by its

complexity because it involves abstract concepts, interconnected relationships among concepts, biological processes that cannot be directly observed, and the application of scientific evidence to explain various inheritance phenomena (Salamah, 2025). Understanding genetics cannot rely solely on memorization; rather, it requires students to analyze evidence, evaluate alternative explanations, connect scientific concepts, and construct arguments based on empirical data and scientific principles. Therefore, genetics provides an ideal context for fostering students' scientific argumentation skills (Alberida et al., 2024).

Scientific argumentation refers to the ability to formulate claims, utilize evidence, provide scientific reasoning, and defend or revise arguments based on available evidence. This competency constitutes a fundamental component of science education because it enables students to develop deeper conceptual understanding, strengthen critical thinking skills, and make evidence-based decisions (Taher et al., 2025). Toulmin's Argumentation Model explains that high-quality arguments are constructed through the integration of claims, supporting data, reasoning, backing, rebuttals, and qualifiers. Consequently, argumentation-oriented science learning emphasizes not only the correctness of answers but also the quality of the reasoning processes underlying those answers (Alfaraby, 2026).

Nevertheless, numerous studies indicate that students' scientific argumentation skills remain relatively low. Many students are able to answer scientific questions but struggle to provide logical justifications, relate their responses to scientific concepts, or use relevant evidence to support their arguments (Maharani & Faizah, 2025). In genetics, students often encounter difficulties in explaining inheritance mechanisms, analyzing genetic crosses, interpreting pedigree diagrams, and connecting concepts such as genes, chromosomes, DNA, and gene expression with real-life biological phenomena. As a result, classroom instruction tends to emphasize factual knowledge acquisition rather than the development of scientific reasoning skills (Nurwenda & Sari, 2025).

The integration of ChatGPT offers a promising alternative for addressing these challenges. ChatGPT can facilitate students' exploration of genetic concepts through interactive dialogue, provide examples of scientific arguments, assist in identifying relationships between evidence and claims, and deliver immediate feedback on students' arguments (Manuaba et al., 2024). Through adaptive interactions, students are given opportunities to improve the quality of their arguments through continuous reflection and revision. Furthermore, the integration of ChatGPT can enhance students' digital literacy by requiring them to formulate effective prompts, evaluate the validity of AI-generated information, verify responses using credible scientific sources, and employ AI responsibly throughout the learning process (Pamungkas & Markhamah, 2026). Within the context of Biology instruction at MAS Firdaus Tompobalang, this technology has the potential to serve as an innovative approach that supports active, reflective, and evidence-based learning.

Previous studies have reported that ChatGPT positively contributes to improving writing skills, critical thinking, digital literacy, and students' learning motivation. Research conducted by Sakti et al. (2024) demonstrated that ChatGPT helped university students produce more systematic writing while enhancing their critical thinking abilities. Similarly, Auna (2024) found that ChatGPT improved learning effectiveness by providing rapid and personalized feedback. Juanda and Fitri (2025) reported that digital literacy-based learning media significantly improved students' academic writing quality. Moreover, Pamungkas and Markhamah (2026) found that ChatGPT significantly enhanced secondary school students' digital literacy and argumentative writing skills. However, most previous studies have primarily focused on writing proficiency, digital literacy, or language learning, whereas research investigating the impact of ChatGPT integration on scientific argumentation skills in Biology education, particularly in genetics, remains limited. This represents an important research gap because scientific argumentation in science education differs fundamentally from argumentation in language learning, as it requires the integration of empirical evidence, scientific reasoning, and robust conceptual understanding.

This research gap highlights the need for a more comprehensive investigation into how ChatGPT integration can support the development of students' scientific argumentation skills in genetics learning. In this study, ChatGPT is viewed not as a replacement for teachers but as a learning partner that assists students in developing scientific thinking through adaptive, reflective, and

evidence-based interactions. Teachers continue to play a central role in guiding the learning process, facilitating classroom discussions, clarifying misconceptions, and helping students critically evaluate AI-generated outputs to ensure their consistency with scientific principles and academic integrity.

Based on the foregoing discussion, this study aims to analyze the effect of ChatGPT integration on students' scientific argumentation skills in genetics learning. The findings are expected to provide empirical evidence regarding the effectiveness of AI integration in Biology education, contribute to the growing body of research on AI-supported science education, and serve as a reference for teachers in designing genetics instruction that simultaneously promotes scientific argumentation, critical thinking, and digital literacy. Furthermore, this study is expected to provide a foundation for developing innovative instructional strategies that address the demands of twenty-first-century education while maintaining the indispensable role of teachers as the primary facilitators of the learning process.

METHODS

Untuk penelitian kualitatif seperti penelitian tindakan kelas, etnografi, fenomenologi, studi kasus, dan lain-lain, perlu ditambahkan kehadiran peneliti, subyek penelitian, informan yang ikut membantu beserta cara-cara menggali data-data penelitian, lokasi dan lama penelitian serta uraian mengenai pengecekan keabsahan hasil penelitian. Sebaiknya dihindari pengorganisasian penulisan ke dalam “anak sub-judul” pada bagian ini. Namun, jika tidak bisa dihindari, cara penulisannya dapat dilihat pada bagian “Hasil dan Pembahasan”.

This study employed a quantitative approach using a quasi-experimental research design (Albina, 2025). This approach was chosen to examine the effect of ChatGPT integration in learning on students' scientific argumentation skills in genetics. The research design used was a Nonequivalent Control Group Design involving two groups (Anastasia & Rindrayani, 2025), namely an experimental class that received ChatGPT-integrated instruction and a control class that received conventional instruction without the use of ChatGPT. Both groups were given a pretest prior to treatment and a posttest after the learning process to determine changes in students' scientific argumentation skills. The research design is illustrated as follows:

Table 1 . Research Design

Group	Pretest	Treatment	Posttest
Eksperimen	O ₁	X	O ₂
Kontrol	O ₃	–	O ₄

Description:

O₁ = Pretest of the experimental class

O₂ = Posttest of the experimental class

O₃ = Pretest of the control class

O₄ = Posttest of the control class

X = Genetics learning integrated with ChatGPT

The study was conducted in the first semester of the 2026/2027 academic year at MAS Firdaus Tompobalang, Maros Regency, South Sulawesi. The learning material used in this study was genetics, which included DNA, genes, chromosomes, inheritance of traits, monohybrid and dihybrid crosses, and pedigree analysis in accordance with the Biology learning outcomes of Phase F in the Merdeka Curriculum.

The population of this study consisted of all Grade XII students of the Mathematics and Natural Sciences (MIPA) program at the research site. The sample consisted of two classes selected using cluster random sampling, since the sampling units were pre-existing intact classes. One class was assigned as the experimental group and the other as the control group. Prior to treatment, both

classes were tested for equivalence using pretest scores to ensure that their initial abilities were relatively similar.

The independent variable in this study was the integration of ChatGPT in genetics learning, while the dependent variable was students' scientific argumentation skills. ChatGPT integration is defined as the structured use of ChatGPT as a learning support tool that assists students in exploring genetic concepts, developing scientific arguments, evaluating answers, receiving feedback, and revising arguments based on scientific evidence. Scientific argumentation skills are defined as students' ability to construct claims, use evidence, provide reasoning, present rebuttals, and offer backing in accordance with Toulmin's Argumentation Framework.

The research procedure consisted of three stages: preparation, implementation, and final stage. The preparation stage included the development of learning materials, research instruments, expert validation of instruments, instrument trials, and selection of sample classes. The implementation stage began with administering a pretest to both groups to measure students' initial scientific argumentation skills. The experimental class then received genetics instruction integrated with ChatGPT at each stage of learning, including concept exploration, contextual problem-solving, scientific argument construction, and argument revision based on feedback from both ChatGPT and the teacher. The teacher acted as a facilitator by guiding students in prompt formulation, evaluating ChatGPT outputs, verifying information using credible scientific sources, and ensuring ethical use of AI. Meanwhile, the control class was taught using conventional instructional methods without ChatGPT integration. After the learning process was completed, both groups were given a posttest using the same instrument as the pretest.

The research instruments consisted of test and non-test instruments (Musfirah et al., 2025). The test instrument included essay-based argumentative questions developed based on indicators of scientific argumentation using Toulmin's model, which consists of claims, evidence, scientific reasoning, rebuttals, and backing. Assessment was conducted using a scientific argumentation rubric with scoring criteria for each component. Non-test instruments included observation sheets for learning implementation, student activity observation sheets, a Likert-scale questionnaire to measure students' responses toward ChatGPT use, and documentation guidelines for collecting students' work during the learning process.

Prior to use, all instruments were validated by subject matter experts, educational evaluation experts, and instructional media experts to ensure content validity. A pilot test was then conducted with students outside the research sample. Item validity was analyzed using the Product Moment correlation, while reliability was calculated using Cronbach's Alpha coefficient. Instruments were considered valid and reliable if they met the validity criteria and had a reliability coefficient of at least 0.70.

Data collection techniques included tests, observations, questionnaires, and documentation. Tests were used to measure students' scientific argumentation skills before and after treatment. Observations were conducted during the learning process to assess instructional implementation and student activities. Questionnaires were used to gather data on students' perceptions of ChatGPT use in genetics learning. Documentation was used to collect supporting data such as lesson plans, activity photographs, students' argumentative work, and other relevant documents.

Data analysis was conducted descriptively and inferentially using statistical software. Descriptive analysis was used to determine mean, standard deviation, minimum score, maximum score, and improvement in students' scientific argumentation skills. Learning effectiveness was measured using the Normalized Gain (N-Gain) to determine the improvement level in each group.

Prior to hypothesis testing, prerequisite tests were conducted, including the Shapiro–Wilk test for normality and Levene's test for homogeneity of variance. If the data met parametric assumptions, hypothesis testing was conducted using an Independent Samples t-test on N-Gain scores to determine differences in improvement between the experimental and control groups. In addition, a Paired Samples t-test was used to examine within-group differences before and after treatment. All statistical tests were conducted at a significance level of 0.05. To determine the magnitude of the effect of ChatGPT integration on students' scientific argumentation skills, Cohen's d effect size was calculated and interpreted as small ($d = 0.20$), medium ($d = 0.50$), and large ($d \geq 0.80$).

The results of the statistical analysis were then interpreted to address the research objectives, namely to determine the effect of ChatGPT integration on students' scientific argumentation skills in genetics and to describe students' responses to AI-based learning implementation. The interpretation was conducted by relating the findings to theories of scientific argumentation, Biology education, and studies on the use of artificial intelligence in education, thereby providing a comprehensive conclusion regarding the effectiveness of ChatGPT integration in genetics learning.

RESULTS AND DISCUSSION

This study aims to analyze the effect of ChatGPT integration in the learning process on students' scientific argumentation skills in genetics. Scientific argumentation is considered an essential competency in twenty-first-century biology education because it enables students to construct opinions based on scientific evidence, explain cause-and-effect relationships logically, and evaluate alternative explanations for biological phenomena. In this study, scientific argumentation skills were measured using essay tests administered before instruction (pretest) and after instruction (posttest) in both the experimental and control classes. The assessment of argumentation was conducted using the Toulmin Argumentation Pattern (TAP), which includes five main components: claim, evidence, reasoning, backing, and rebuttal. The Toulmin model was selected because it provides a comprehensive representation of the quality of students' scientific argumentation (Wahyuni & Agustina, 2025).

Prior to hypothesis testing, the data were analyzed descriptively to determine the tendency of improvement in scientific argumentation skills in both groups. Descriptive analysis aimed to provide an initial overview of changes in students' abilities after participating in different instructional approaches. The experimental class received learning integrated with ChatGPT as a supporting tool for concept exploration, while the control class followed conventional instruction without the use of artificial intelligence technology (Saleh et al., 2025). The results of the descriptive analysis indicated that both groups experienced an improvement in scientific argumentation skills after the learning process. However, the degree of improvement in the experimental class was higher than that of the control class. This difference suggests that the use of ChatGPT during the learning process contributed positively to enhancing students' ability to construct scientific arguments in genetics (Mutiah & Ulfah, 2022).

Based on the average pretest scores, both groups were relatively similar, with 56.42 in the experimental class and 55.87 in the control class. This condition indicates that students' scientific argumentation skills prior to treatment were at a relatively equivalent level. Such initial equivalence is important because it suggests that differences in post-learning outcomes are more likely attributable to the treatment provided rather than differences in students' initial abilities (Hevriansyah & Megawanti, 2017).

After the learning process was implemented, the average posttest score in the experimental class increased significantly to 84.58, while the control class increased to 71.36. The difference in score improvement in the experimental class reached 28.16 points, whereas the control class showed an increase of only 15.49 points. These findings indicate that learning integrated with ChatGPT provides a more substantial improvement in students' scientific argumentation skills compared to conventional learning (Nurkhalifah & Simanullang, 2025).

The magnitude of this improvement is also reflected in the results of the normalized gain (N-Gain) calculation. The experimental class obtained an N-Gain value of 0.65, which falls into the medium category with a tendency toward the high category, while the control class obtained a value of 0.35, which is still in the medium category but close to the lower threshold. The difference in N-Gain values indicates that the effectiveness of ChatGPT-integrated learning is higher in improving students' scientific argumentation skills (Sopingi et al., 2026).

Table 2. Mean Scores of Each Scientific Argumentation Skill Indicator

Indikator	Eksperimen	Kontrol
Claim	4,48	3,91
Evidence	4,36	3,62
Reasoning	4,29	3,45
Backing	4,18	3,41
Rebuttal	3,98	3,12
Rata-rata	4,26	3,50

Based on Table 2, all indicators of scientific argumentation skills in the experimental class obtained higher mean scores compared to the control class. The overall average score of argumentation skills in the experimental class reached 4.26, whereas the control class only reached 3.50. These results indicate that the effect of ChatGPT integration is not only reflected in the improvement of overall scores but also in each component of scientific argumentation.

The claim indicator obtained the highest score in the experimental class, namely 4.48. This shows that most students were able to identify the main problem and construct statements or conclusions appropriate to the context of genetics-related issues. This ability developed because, during the learning process, students were given opportunities to clarify their understanding through dialogue with ChatGPT before formulating their final answers (Muhidin et al., 2025).

The evidence indicator also showed a high achievement with an average score of 4.36. This indicates that students became increasingly capable of selecting relevant facts, data, and scientific concepts to support their claims. During the learning process, ChatGPT helped students access various explanations of genetic concepts, making it easier for them to identify appropriate scientific evidence related to the problems discussed. For the reasoning and backing indicators, the experimental class also demonstrated better performance than the control class. This shows that students were not only able to present evidence but also explain the logical relationship between evidence and claims using the genetic concepts they had learned. In other words, students began to construct coherent arguments supported by adequate theoretical foundations.

Meanwhile, the rebuttal indicator obtained the lowest score, although it remained higher than that of the control class. This indicates that the ability to construct rebuttals against alternative arguments is still the most difficult aspect for students to master. Formulating rebuttals requires higher-order thinking skills, as students must identify weaknesses in opposing arguments, evaluate available evidence, and construct counterarguments supported by scientific reasoning. Therefore, this skill requires more intensive practice through scientific discussion activities, academic debates, and socio-scientific issue-based learning. To ensure that the differences in improvement between the two groups were not due to chance, hypothesis testing was conducted using an Independent Samples t-test on N-Gain scores. The results showed a significance value of 0.001 ($p < 0.05$). This indicates a statistically significant difference in the improvement of scientific argumentation skills between the experimental and control classes.

Thus, the research hypothesis stating that ChatGPT integration affects students' scientific argumentation skills is accepted. In addition to statistical significance, the magnitude of the effect was calculated using Effect Size analysis with Cohen's d formula. The result showed a Cohen's d value of 0.96, which falls into the large effect category. This indicates that ChatGPT integration not only produces statistically significant differences but also has strong practical significance in improving students' scientific argumentation skills. The magnitude of the effect size suggests that the use of ChatGPT contributes substantially to improving the quality of genetics learning.

These findings show that the use of ChatGPT is more effective in enhancing students' scientific argumentation skills compared to conventional instruction. The improvement is reflected in

students' ability to formulate more accurate claims, select relevant evidence, logically connect evidence with scientific concepts through reasoning, and strengthen arguments using appropriate theoretical foundations. During the learning process, ChatGPT functions as a learning partner that provides rapid responses, enabling students to explore concepts more deeply.

The interaction between students and ChatGPT also promotes a more active learning process. Students are not merely passive recipients of information from the teacher but are actively engaged in questioning, clarifying concepts, comparing alternative answers, and reflecting on their constructed arguments. These activities provide opportunities for self-assessment of the quality of their arguments before presenting final answers. Thus, the learning process becomes more student-centered.

However, the use of ChatGPT cannot fully replace the role of the teacher. Teachers still play a central role as facilitators who guide students in evaluating the accuracy of AI-generated information, correcting misconceptions, and directing students to use technology critically and responsibly. Teacher assistance is also necessary to ensure that students' arguments are truly based on scientific evidence rather than merely accepting AI-generated responses without verification. The finding that the claim and evidence indicators showed the greatest improvement suggests that ChatGPT is highly effective in helping students understand core problems and identify relevant supporting information. Conversely, the lower performance in the rebuttal indicator indicates that evaluative and critical argumentation skills still require additional instructional strategies. Therefore, ChatGPT integration should be combined with learning models that provide opportunities for scientific debate, group discussion, and socio-scientific issue-based problem solving to further develop students' evaluative skills. Theoretically, these findings support Toulmin's argumentation theory, which states that the quality of scientific argumentation is determined by the strong interconnection among claim, evidence, reasoning, backing, and rebuttal. The more complete the relationships among these components, the higher the quality of the argument produced. ChatGPT integration provides students with opportunities to refine each component of argumentation through adaptive dialogue, resulting in more systematic, logical, and evidence-based arguments.

Overall, this study strengthens empirical evidence that ChatGPT integration in genetics learning is an effective strategy for improving students' scientific argumentation skills. This success is not only demonstrated by quantitative improvements in learning outcomes but also by the development of each component of scientific argumentation as an indicator of scientific thinking. Therefore, the use of ChatGPT can be considered a viable innovation in biology education in the digital era, while still emphasizing the teacher's essential role in guiding, validating, and directing the use of technology to achieve optimal learning outcomes.

CONCLUSION

Based on the research findings, it can be concluded that the integration of ChatGPT in genetics learning has a positive and significant effect on students' scientific argumentation skills. This is indicated by the higher posttest scores and N-Gain values in the experimental class compared to the control class, the statistically significant hypothesis test results ($p < 0.05$), and an effect size value of 0.96, which is categorized as large. The improvement in argumentation skills occurred across all components of Toulmin's model (claim, evidence, reasoning, backing, and rebuttal), although the ability to construct rebuttals remains the aspect that requires further strengthening. These findings indicate that ChatGPT is effective as a learning support tool in helping students understand genetic concepts and construct more systematic, logical, and evidence-based scientific arguments.

Based on these findings, the integration of ChatGPT is worth considering as an innovation in Biology education, while still positioning the teacher as a facilitator who guides the critical, ethical, and responsible use of AI. Future research is recommended to examine the application of ChatGPT in other biology topics, involve a broader sample, and combine it with learning models oriented toward the development of critical thinking and scientific argumentation skills.

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