
GAI-Enhanced Assignment Framework: A Case Study on Generative AI Powered History Education

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Abstract

In the rapidly evolving landscape of Generative Artificial Intelligence (GAI) applications in education, practical uses lag behind theoretical discussions, especially in history education. This article examines a unique application of ChatGPT in reshaping pedagogical techniques within the undergraduate "History of Science" curriculum during the 2022-2023 Spring term. The students conversed with historical scientists through role-playing exercises, mirroring the course progression. We pose the question: How do GAI-driven interventions affect student engagement, learning, and mindset? Our evaluation method, which combines qualitative and quantitative measures, focuses on analyzing student capstone papers. Preliminary findings suggest that most students adapt and excel in this GAI-enhanced environment. However, challenges arose in assessing the correctness of GAI-generated responses and ensuring the authenticity of student-generated content. To address this, we introduce the 'Reference-Check Protocol (RCP)', a safeguarding technique for GAI in classrooms, emphasizing the accuracy of AI's responses and the maintenance of academic integrity. Our research illustrates the potential and challenges of GAI in education.

1 Introduction

As we navigate the frontier of technological advancements in the education domain, Large Language Models (LLMs) have emerged as a promising tool for pedagogical innovation. ChatGPT [11] stands out due to its advanced natural language processing and generation capabilities. In this context, our study explores the application of ChatGPT in the "History of Science" undergraduate course at the Hacettepe University. To use the power of ChatGPT, we integrated a role-playing approach, allowing students to engage themselves in simulated dialogues with AI-driven representations of historical scientists. This innovative approach aims to convey knowledge and stimulate critical thinking, engagement, and a deeper connection with historical narratives.

However, while the theoretical benefits of LLMs in education are widely discussed [4] [7] [13] [17], empirical evidence detailing its practical implications, particularly in history education, remains sparse [8] [15] [9]. This study seeks to bridge this gap. By examining student interactions, feedback, and learning outcomes, we aim to shed light on the benefits and potential challenges of merging advanced AI tools with classroom instruction. The main contributions of this work are as follows.

- We showcase one of the first comprehensive empirical implementations of ChatGPT in a real-world educational setting, focusing on the "History of Science" undergraduate college course.

- We introduce **GAIEnAF: GAI-Enhanced Assignment Framework**, a unique method of integrating GAI through role-playing into the course, enhancing the pedagogical experience by enabling students to interact with representations of historical scientists.
- We provide a qualitative and quantitative analysis of student capstone papers to assess the effectiveness of our framework.
- We propose the **Reference-Check Protocol (RCP)** technique to safeguard academic integrity and ensure accuracy of GAI-generated responses in the classroom.
- Our research highlights the transformative potential of GAI in history education and underscores the challenges, laying the groundwork for future research and application.

2 Background

Role-play is a long-standing pedagogical strategy, recognized for its capacity to engage students and facilitate deep understanding. Various studies vouch for its effectiveness: [10] underscored its role in enhancing students’ empathy and perspective-taking abilities; [12] identified benefits in cultivating critical thinking; and [2] highlighted its utility in clarifying complex concepts for learners.

In parallel, the evolution of AI in educational contexts has gained momentum. A large number of studies have investigated the various applications of AI in education, such as creating personalized learning pathways [3], offering virtual mentorship and streamlining assessment processes [19]. As the GAI landscape in education matures, the challenge of ethical and instructional challenges has become prominent [18], thus highlighting the need for comprehensive guidelines and best practices [5]. There remains an evident gap in the literature regarding empirical studies on the real-world deployment of tools like ChatGPT in traditional educational settings. This paper attempts to bridge this gap.

3 GAI-Enhanced Assignment Framework (GAIEnAF)

The primary objective of incorporating Generative AI tools in courses is to enhance student engagement, increase learning capabilities, and foster critical thinking skills. In light of this, we introduce the GAI-Enhanced Assignment Framework, Figure 1, designed to ensure a safe and effective integration of Generative AI into academic courses.

Weekly course assignments include reading assignments from the course text book, History of Science by John Gribbin[6]. After completing the reading, students are required to pick a scientist covered in the corresponding section. They must then prepare five questions for role-playing with the simulated scientist and use the Reference-Check Protocol (RCP) to prepare their reports. The details of the framework steps are elaborated in the following sections.

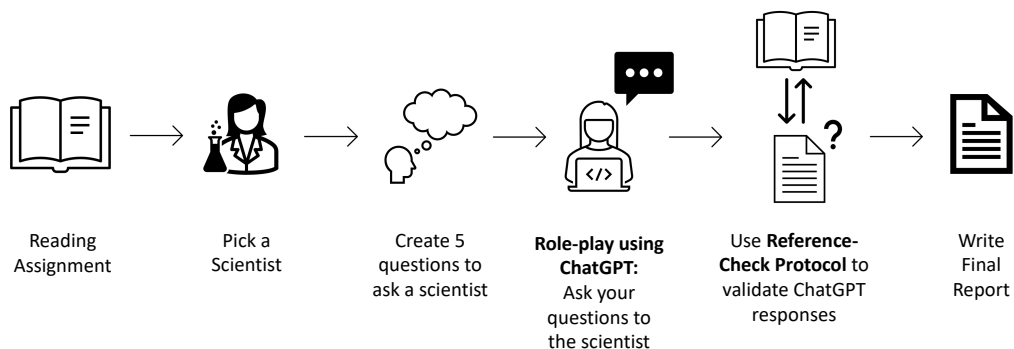


Figure 1: GAIEnAF: Framework for GAI-Enhanced Assignments in History of Science Course. This diagram illustrates the workflow of weekly assignments, highlighting the integration of the Reference-Check Protocol (RCP) with role-play interactions based on John Gribbin’s History of Science textbook.

3.1 Prompt Engineering to Simulate Historic Figure

The role-play directive requires ChatGPT to emulate historical scientists, while students act as interviewers and critics. This dynamic transformation enhances their traditional learning role. The students started conversations with ChatGPT in various ways. Here are sample interactions to illustrate the progression: The first is one of the earliest assignments, and the second is one of the latter (notice the improvement, and ChatGPT's help in that effort).

Student 1: Think about you are Kopernik?

ChatGPT: As an AI language model, I am not capable of thinking or having personal experiences like a human being, but I can simulate a conversation as if I were Kopernik. Is there anything specific you would like to know or discuss from Kopernik's perspective?

Student 2: Role play with me as if you were Max Planck

ChatGPT: Sure! I'll do my best to role-play as Max Planck, the renowned German physicist who is often considered the father of quantum theory. Please keep in mind that while I will try to provide accurate responses based on my knowledge of Max Planck, my responses are still generated by an AI and may not perfectly capture his personality or exact words.

3.2 Conversation with Simulated Historic Figure

In this part, ChatGPT acts as the simulated historical scientist to be interviewed and the student acts as the interviewer.

Student: How did your experiments differ from previous methods used in plant breeding studies?

ChatGPT as Gregor Mendel: Ah, an excellent question. My experiments differed significantly from previous methods used in plant breeding studies. You see, I approached my investigations with a more systematic and rigorous approach, employing careful observations, meticulous record-keeping, and the application of statistical analysis. Unlike many of my predecessors who relied on simply crossing plants without much consideration for the underlying patterns, I meticulously studied the inheritance of traits in pea plants over multiple generations. One key aspect of my methodology was the selection of distinct traits that exhibited clear variations, such as flower color, seed shape, and plant height..

Please see Appendix A for complete examples of a student conversation.

3.3 Reference-Check Protocol (RCP)

The integration of Generative AI tools such as ChatGPT into education, while innovative, raises concerns about the accuracy and authenticity of AI-generated content. The Reference-Check Protocol (RCP) is developed to address these challenges, ensuring that AI-generated content aligns with validated reference materials and maintains academic integrity.

Once the GAI generates a response after engaging in role-play prompting, students are required to cross-reference the response with the primary source as a part of the weekly assignment, in this case, John Gribbin's History of Science textbook. The objective is to confirm the GAI's response against the recognized material. RCP steps as follows:

1. **Annotation:** Students annotate AI-generated content with relevant citations of the source material, indicating where the content aligns or deviates from the primary source. In cases where GAI-generated content diverges from the textbook or provides a potentially misleading or out-of-context answer, students document these conflicts.
2. **Critical Analysis:** Beyond factual cross-referencing, students should critically analyze the context, relevance, and depth of the AI's response in relation to their initial prompt.
3. **Peer Review:** On uploading their work to the kaynakca.info website, fellow students are encouraged to review and comment on the GAI's outputs and the original student's critical analysis. This encourages collaborative learning and further ensures the integrity of the content.

The Reference-Check Protocol (RCP) is vital for maintaining the integrity of educational content. It ensures **Accuracy and Authenticity** by aligning AI-generated content with recognized academic sources. The protocol fosters **Critical Thinking** by urging students to not only consume but also validate and critique the AI responses. Furthermore, through **Collaborative Learning**, it promotes peer reviews, enabling students to benefit from diverse perspectives and analyses. As AI tools advance and reference materials grow, the RCP stands as a dynamic safeguard, championing the responsible and effective use of GAI in education, always keeping academic integrity at the forefront.

4 Implementation

The GAI-Enhanced Assignment Framework was implemented in the undergraduate "History of Science" course during the Spring Term of 2022-2023 at Hacettepe University. 14 students were enrolled in the course and all consistently completed weekly assignments.

4.1 Course Description

The history of science course provides an introductory exploration of the history of science and technology, spanning from ancient civilizations to contemporary times. It aims to provide students with a comprehensive understanding of the evolution of science and technology and its intricate interplay with philosophy, politics, and economics. The following are the anticipated learning outcomes of this course: Define the fundamental concepts of "science", and "history of science". Summarize the trajectory of scientific development from antiquity to the present day. Compare and contrast scientific advancements in various societies. Analyze the pivotal catalysts driving scientific progress. Evaluate modern scientific breakthroughs within the context of historical processes. Recognize the symbiotic relationship between scientific and technological advances and societal and economic progress.

4.2 Initial Engagement with ChatGPT

The concept of using ChatGPT as a role-playing platform emerged from our conversation about the system after it became available for general use in November 2022. While interacting and experimenting with the ChatGPT web interface (February 2023), it became evident that the system could simulate historical figures. Before introducing this capability to the students in the History of Science course, four weeks into the course, the instructor inquired whether they were familiar with ChatGPT and, if so, whether they had previously used it. Only two students indicated prior knowledge, although they referred to it as a chatbot, with no prior usage experience. Later, the instructor performed a live demonstration in the class by showing the chat with Leonardo da Vinci, a scientist and an engineer of the Renaissance era. ChatGPT almost perfectly simulated this famous figure, initiating excitement among students.

4.3 Integration into the Syllabus

Convinced that the students were interested in this type of work, the instructor updated the course syllabus to allow weekly exercises that involve role-playing on ChatGPT in conjunction with standard reading assignments. The updated syllabus required that each student engage in dialogues with renowned scientists from the past, chosen based on the subject matter covered that week in the course. The new syllabus contained the GAI-Enhanced Assignment Framework (Figure 1) instructions to guide students in preparing their weekly assignments. Following the framework, each student prepared and submitted eight assignments, one for each week, and uploaded them to kaynakca.info, a web-based academic platform, allowing peers to review each other's work. This approach prevented redundancy and overlap among the student assignments (for a sample conversation, see Appendix A).

Upon completion of the course, the students are tasked with each writing a capstone paper of approximately six pages in length. In this paper, they were expected to evaluate and elucidate their acquired knowledge and insights from the course, structured in alignment with the specified learning outcomes detailed in the course description. Importantly, the students did not have to document their learning process within the course, including their use of role-play and ChatGPT.

4.4 Data collection and analysis methods

This study is based on the analysis of the capstone papers prepared by the students at the end of the course. This amounted to approximately 200 pages of text, translated from Turkish to English using Google Translate. The text was analyzed using Voyant Tools [14]. This is an open source Web-based text analysis tool¹ that supports the reading and interpretation of texts or corpus, particularly by scholars in the digital humanities, but also by students and the general public. Its interface is composed of panels that perform these various analytical tasks. These panels can also be embedded in external web texts (e.g. a web article could include a Voyant panel that creates a word cloud). Link to all the data and tools used in the analysis is given for further examination by the reader (see <https://voyant-tools.org/?panels=cirrus%2Creader%2Ctrends%2Csummary%2Ccontexts&corpus=2b9c7d460bda8d7db4c604b3c4f272cd>).

5 Analysis of Student Reports

We provide a quantitative and qualitative analysis of student reports in which they implemented the Reference-Check Protocol. Student reports include their assessments, a comparison of ChatGPT's answers to questions about various scientists, and their work with the information provided in the book "History of Science" by John Gribbin.

Accuracy and Authenticity: About 8.4% of the comments suggested that ChatGPT provided incorrect information. The rest of the students found ChatGPT's responses to be largely accurate, often aligning with the content of the source book by John Gribbin. **Depth and Detail:** About 9% of the students' comments mentioned that ChatGPT's answers lacked the depth and nuance present in Gribbin's writings. 4% students mentioned that ChatGPT's answers were more detailed than the source book's content. In some cases, students appreciated the in-depth information provided by ChatGPT, while in other instances, they felt that the AI's answers did not capture the essence of the subject or individual in question. **Role-play and Engagement:** Students generally enjoyed the role-playing feature of ChatGPT. They were able to simulate conversations with historical scientists, which added an interactive dimension to their learning experience. This dynamic allowed students not only to seek factual information but also to gauge the possible perspectives or personalities of these historical figures. **Reference-Check Protocol (RCP):** A significant part of students' interaction with ChatGPT involved cross-referencing and validating the GAI's responses against the content of the source book. Many students found this exercise beneficial, as it encouraged critical thinking and active engagement with the GAI tool and the book.

In general, the students had a positive experience using ChatGPT. They appreciated its potential as a supplementary tool to enhance their learning and found it especially helpful in providing quick, accessible information. While they recognized its limitations, they seemed to value the interactive and engaging nature of their interactions with the AI.

6 Discussion and Future Directions

Our GAIEnAF framework presents two primary benefits. (1) **Accessibility:** it exclusively utilizes freely accessible tools, eliminating financial barriers. Most GAI usage is based on public tools, so we emphasize aligning with the principle of equal opportunity in education, as stated in Article 26 of the Universal Declaration of Human Rights [16]. This approach underlines the value of a framework that does not require additional system development. (2) **Deft:** It mitigates the risk of plagiarism using generative AI tools and actively encourages students to engage in critical thinking. As AI advances, educators are increasingly pressured to incorporate GAI tools into curricula at all educational levels. Although most view GAI as a potential avenue for plagiarism, we see its potential to improve learning and critical thinking. Students would no longer complete straightforward assignments; they would be forced to engage with GAI-generated content critically. Our framework serves as a prototype, challenging students to generate content and critically evaluate and validate GAI-generated output.

The GAI-Enhanced Assignment Framework employed in this study is highly adaptable. It can be easily implemented in various educational settings, particularly online and hybrid learning environments. This versatility stems from ChatGPT, along with other Generative AI models (GAIs), which

¹<https://voyant-tools.org/>

can embody historical scientists, scholars, and contemporary professionals from diverse fields such as philosophy, literature, poetry, art, engineering, programming, and more. Artificial intelligence, including GAI, has the transformative potential to influence modern education significantly. This potential is especially evident in generative models such as ChatGPT, which is increasingly accessible to the general population. Although it is essential to recognize that debates continue about its application and certain technological constraints [5], the establishment of AI within the educational field is an irreversible trend, likely to drive substantial transformations in our teaching and learning methodologies [1].

Additionally, in-class observations suggest that integrating GAI and role-play into the history classroom presents a promising avenue. It is plausible that in a standard teaching environment where all students can actively participate in course activities, the number of students expressing enthusiasm for using AI and role-play in the teaching process would be considerably higher. To validate this hypothesis, further studies aligned with the approach outlined in this paper are warranted.

As AI systems evolve and incorporate multimedia elements such as images, videos, and audio into a unified system, their role in history classrooms is poised to become indispensable. This evolution will extend from content development to course planning and even creating entirely new teaching programs based on GAI. Initiating this integration sooner rather than later is advisable.

7 Conclusion

This study demonstrated the applicability of ChatGPT within the undergraduate history course, providing insights into the advantages and complexities of integrating AI in educational settings. While students displayed increased engagement, the accuracy of AI-generated responses and the verification of student work presented challenges. The introduction of the Reference-Check Protocol (RCP) emerged as a solution to maintain the correctness of information and academic integrity. With the surge in ChatGPT usage, the issues of plagiarism and academic integrity became critical. Our proposed Reference-Check Protocol (RCP) offers a solution to facilitate the safe utilization of GAI in classrooms. Instead of discouraging the use of such technologies, we advocate for informed and strategic integration of GAI in educational settings to enrich the learning experience.

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A Appendix: Role-playing Sample.

Below is one of the role-playing samples of the students from the class. The complete list of role-playing scenarios of all students can be found at this link <http://kaynakca.hacettepe.edu.tr/eser/89735027/chatgpt-chat-generative-pre-trained-transformer>.

A Role-playing Sample: ChatGPT acts as Gregor Mendel

Q. 1. How did your experiments differ from previous methods used in plant breeding studies?

Mendel: Ah, an excellent question. My experiments differed significantly from previous methods used in plant breeding studies. You see, I approached my investigations with a more systematic and rigorous approach, employing careful observations, meticulous record-keeping, and the application of statistical analysis. Unlike many of my predecessors who relied on simply crossing plants without much consideration for the underlying patterns, I meticulously studied the inheritance of traits in pea plants over multiple generations. One key aspect of my methodology was the selection of distinct traits that exhibited clear variations, such as flower color, seed shape, and plant height. By selecting these discrete traits, I was able to easily track their transmission from one generation to the next. I carried out controlled cross-pollination between pea plants, carefully tracking the inheritance of these traits and noting the ratios of their occurrence in subsequent generations. Furthermore, I took great care to ensure the purity of my experimental lines by eliminating any potential contamination from external pollen sources. This allowed me to establish true-breeding lines that consistently exhibited specific traits. By meticulously observing and analyzing the resulting offspring, I was able to uncover the principles of inheritance and propose the now-famous laws of Mendelian genetics. In summary, my experiments differed from previous methods in their systematic approach, precise selection of traits, controlled cross-pollination, and extensive record-keeping. These methodologies formed the foundation of modern genetics and revolutionized our understanding of heredity.

Commentary: It appears that ChatGPT’s description aligns with the key aspects of Mendel’s experiments as outlined in Gribbin’s work on the history of science. According to Gribbin, Gregor

Mendel indeed approached his investigations with a more systematic and rigorous approach compared to his predecessors. He meticulously studied the inheritance of traits in pea plants over multiple generations, carefully selecting distinct traits that exhibited clear variations, such as flower color, seed shape, and plant height. This allowed for easy tracking of their transmission from one generation to the next. Mendel's methodology involved controlled cross-pollination between pea plants and the careful observation and recording of the ratios of trait occurrence in subsequent generations. He also ensured the purity of his experimental lines by eliminating potential contamination from external pollen sources, thereby establishing true-breeding lines that consistently exhibited specific traits. By meticulously observing and analyzing the resulting offspring, Mendel was able to uncover the principles of inheritance and propose the laws of Mendelian genetics, which formed the foundation of modern genetics and revolutionized our understanding of heredity.

Q. 2. What did your work reveal about the nature of inheritance and the role of genes?

Mendel: Ah, the nature of inheritance and the role of genes, fascinating topics indeed. Through my work, I made several significant discoveries that shed light on these very subjects. First and foremost, I proposed the concept of discrete hereditary units, which we now refer to as genes. I observed that traits in pea plants were not blended together in offspring, but rather they maintained their individuality and could be passed down from one generation to the next in a predictable manner. This led me to conclude that there must be discrete factors responsible for the inheritance of traits, and I called these factors "elements" or "factors of heredity." We now know them as genes. Furthermore, I discovered that these genes exist in pairs, with one inherited from each parent. I observed that certain traits would dominate over others in specific combinations, leading to the distinction between dominant and recessive traits. This observation formed the basis of what we now refer to as Mendelian inheritance or the law of segregation. Moreover, I proposed the law of independent assortment, which states that different traits are inherited independently of each other, as long as they reside on separate chromosomes. This concept revolutionized our understanding of how traits are inherited and laid the groundwork for the discovery of gene linkage and recombination. In essence, my work revealed that inheritance is governed by discrete units called genes, which are inherited in predictable patterns from parents to offspring. It also highlighted the role of dominance and recessiveness in trait expression and the independent assortment of different traits. These findings have been instrumental in the development of modern genetics and our understanding of the fundamental principles of heredity. Commentary: ChatGPT's answer captures the general essence of Mendel's work and its significance, including the concept of genes as discrete hereditary units, the law of segregation, and the role of independent assortment. However, Gribbin's book offers a more detailed account, specifically mentioning Mendel's proposal of the terms "elements" or "factors of heredity," the role of dominance and recessiveness, and the discovery of gene linkage and recombination. So, I would say while ChatGPT's answer is not incorrect it is not as detailed and to the point as Gribbin's book.

Q. 3. How did the identification of chromosomes contribute to the understanding of heredity?

Mendel: Ah, the identification of chromosomes, a crucial development in our understanding of heredity. Allow me to explain its significance. During my time, the concept of chromosomes was not yet fully understood. However, my work laid the foundation for the subsequent discoveries related to chromosomes and their role in heredity. By proposing the law of independent assortment, I hinted at the idea that different traits were inherited independently as long as they resided on separate elements of heredity (now known as chromosomes). This concept suggested that traits were not transmitted as a whole, but rather as individual units. It was not until several years after my experiments that advancements in microscopy and cytology allowed researchers to visualize and study chromosomes more closely. The identification and understanding of chromosomes as the carriers of genetic information revolutionized the field of genetics. With the discovery of chromosomes, it became clear that genes were located on specific regions of these structures. The mapping of genes on chromosomes and the recognition of their arrangement and behavior during cell division provided significant insights into the mechanics of heredity. The identification of sex chromosomes, for instance, revealed the mechanism behind sex determination and the inheritance of sex-linked traits. It also helped explain certain patterns of inheritance that were not fully understood at the time. In summary, the identification of chromosomes and the subsequent understanding of their role in heredity brought about a deeper comprehension of how genes are organized, transmitted, and expressed. It paved the way for further investigations into the structure and function of genes and provided a framework for modern genetics research.

Commentary: ChatGPT's answer is consistent with Gribbin's book. Both describe Mendel's contribution to the understanding of heredity and the role of genes. They mention Mendel's proposal of discrete hereditary units, now known as genes, and the observation that traits maintain their individuality and can be passed down predictably from one generation to the next. Both also highlight Mendel's discovery of genes existing in pairs, with one inherited from each parent, and the distinction between dominant and recessive traits. Additionally, both descriptions discuss Mendel's proposal of the law of independent assortment, which revolutionized our understanding of how traits are inherited. Gribbin's book further emphasizes the subsequent identification of chromosomes and their role in heredity, mapping genes on chromosomes, and the recognition of their arrangement and behavior during cell division. It also mentions the discovery of sex chromosomes and their connection to sex determination and the inheritance of sex-linked traits. Overall, ChatGPT's answer aligns with the information presented in Gribbin's book.

Q. 4. Why were your findings initially overlooked and not widely accepted?

Mendel: Ah, an important question indeed. My findings were indeed initially overlooked and not widely accepted for a variety of reasons. Firstly, the field of genetics was still in its early stages during my time. My experiments on pea plants and the laws of inheritance that I proposed were quite revolutionary and challenged the prevailing understanding of heredity at the time. As with any new and groundbreaking scientific ideas, it takes time for them to be fully understood, accepted, and integrated into the existing body of knowledge. Secondly, my work was published in an obscure scientific journal and did not receive much attention from the scientific community. The limited dissemination of my findings played a role in their initial neglect. It wasn't until several years later, when researchers independently rediscovered and replicated my experiments, that the significance of my work became more widely recognized. Additionally, my findings went against the predominant theory of inheritance at the time, which was the concept of blending inheritance. According to this theory, traits were thought to blend together in offspring, losing their distinctness over generations. My proposal of discrete hereditary units, or genes, that retained their integrity and could be passed on unchanged was met with skepticism and resistance. Furthermore, my work lacked a comprehensive understanding of the underlying mechanisms and physical basis of inheritance, such as the existence and role of chromosomes. Without the technological advancements and knowledge available in later years, it was challenging to fully grasp the significance of my findings. In conclusion, the initial oversight and lack of acceptance of my work can be attributed to a combination of factors: the nascent stage of genetics as a scientific discipline, limited visibility of my research, the contradiction to prevailing theories, and the absence of a complete understanding of the physical basis of inheritance. However, over time, as further research and advancements confirmed and built upon my discoveries, the significance of my work was eventually recognized, leading to the establishment of modern genetics.

Commentary: ChatGPT's answer aligns with the information presented in Gribbin's book. Both the book and ChatGPT describe why Mendel's findings were initially overlooked and not widely accepted. They both mention that the field of genetics was still in its early stages during Mendel's time, and his experiments and proposed laws of inheritance were revolutionary and challenged the prevailing understanding of heredity. The answer also emphasizes that the limited dissemination of Mendel's work through publication in an obscure journal contributed to its initial neglect. These factors, as described in Gribbin's book, contributed to the initial skepticism and resistance towards Mendel's work.

Q. 5. How did you differentiate between dominant and recessive traits in your experiments?

Mendel: In my experiments, differentiating between dominant and recessive traits was a key aspect of studying inheritance patterns. I achieved this by carefully selecting pea plants with specific traits and conducting controlled crosses between them. To differentiate between dominant and recessive traits, I focused on observing and analyzing the phenotypes, or observable characteristics, of the offspring. I made sure to use true-breeding parental plants, meaning they consistently produced offspring with the same traits as themselves. When crossing two plants with contrasting traits, such as one with yellow seeds and another with green seeds, I found that the resulting offspring only exhibited one of the traits. In this case, all the first-generation (F1) offspring had yellow seeds. This suggested the presence of a dominant trait. To further investigate the nature of these traits, I then performed crosses between the F1 offspring themselves. Surprisingly, in the second generation (F2), I observed that the recessive trait, in this case, green seeds, reappeared in approximately one-fourth

of the plants, while the dominant trait, yellow seeds, appeared in the remaining three-fourths. This pattern of inheritance led me to propose the laws of segregation and independent assortment. The law of segregation states that the two copies of a gene, called alleles, separate during the formation of gametes, so that each gamete carries only one allele. The law of independent assortment states that different genes segregate independently of one another during gamete formation. By carefully analyzing the ratios of dominant to recessive traits in the offspring, I was able to distinguish between dominant and recessive traits and develop a clearer understanding of how they are inherited and passed on from generation to generation.

Commentary: Mendel's approach to differentiating between dominant and recessive traits, as described in Gribbin's book, aligns with ChatGPT's answer. According to Gribbin and the information I found from the internet, Mendel carefully selected pea plants with specific traits and conducted controlled crosses. By observing the phenotypes of the offspring, he identified the presence of dominant and recessive traits. The first-generation (F1) offspring consistently displayed the dominant trait, while the recessive trait reappeared in approximately one-fourth of the second-generation (F2) plants. So, this supports the formulation of Mendel's laws of segregation and independent assortment.