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# Integrating Generative AI in Higher Education: Practical Applications and Institutional Guidelines

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## Abstract

The rapid advancement of Generative AI (GenAI) presents both opportunities and challenges for higher education. Traditional educational methods often struggle with processing large datasets and facilitating real-time interactions, areas where AI offers potential solutions. This paper examines the development, application, and evaluation of a custom GPTs-based AI teaching assistant, the DS-ASST app, specifically designed for Data Science education within a university liberal arts context. Leveraging Retrieval-Augmented Generation (RAG) technology integrated with course-specific materials, the system aims to enhance both instructor efficiency and student learning experience. The study evaluates the AI assistant's impact across four key areas: teaching preparation efficiency, active learning support, data analysis process enhancement, and the promotion of advanced learning activities. Findings indicate significant improvements in instructor workflow, allowing for more focus on pedagogical refinement rather than routine content creation. For students, the tool provided on-demand concept clarification, guided problem-solving, and personalized learning path suggestions, fostering self-directed learning and engagement, particularly with complex data analysis tasks. The system also aided in developing practical data analysis skills through workflow guidance and interpretation support. Technical challenges inherent in using Large Language Models (LLMs), such as optimizing prompt design for educational relevance and mitigating the risk of AI "hallucinations," were addressed through systematic experimentation and the integration of RAG with a verified knowledge base. Furthermore, the paper discusses the broader implications of GenAI in education, including the redefinition of instructor roles and the evolution of assessment methods. At the same time, based on the implementation experience and existing frameworks, the study proposes practical institutional guidelines and checklists for the ethical and effective use of GenAI by both faculty and students in university settings, emphasizing academic integrity, critical thinking, and AI literacy.

## Keywords

LLM, Generative AI, GPTs, Guidelines for Generative AI in Education, Data Science Education

## 1. Introduction

Generative AI (GenAI) technologies have undergone rapid advancement, significantly impacting numerous societal domains, including education. Driven by powerful Large Language Models (LLMs) such as ChatGPT and Deep Seek, GenAI offers transformative potential for enhancing intellectual productivity and reshaping industries. Within educa-

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tion, these tools present substantial opportunities for personalized learning support and innovative classroom assistance.

Traditional educational methods face many inherent challenges, especially in processing massive data and promoting real-time question-and-answer interactions in teaching. GenAI offers promising solutions to these limitations. Its introduction enables several key innovations: first, personalized learning pathways dynamically tailored to individual student progress and comprehension; second, interactive, dialogue-based learning environments supporting immediate feedback and inquiry; and third, flexible explanatory approaches using diverse modalities like text, diagrams, and analogies to foster deeper understanding and advanced learning activities. These capabilities signal a potential shift towards a more learner-centered educational paradigm, an objective often difficult to achieve through conventional means alone.

LLM tools, including OpenAI's ChatGPT and Google's Gemini, provide a wide array of functionalities beyond simple text generation, encompassing question-answering, sustained dialogue, document summarization, and sophisticated reasoning. These features can significantly enhance educational settings by automating tasks like question-answering, aiding in the creation of teaching materials, and enabling interactive learning experiences, thereby boosting educator efficiency and promoting individualized instruction. Furthermore, specialized GenAI applications leveraging retrieval-augmented generation (RAG) technology, such as custom GPTs and tools like NotebookLM, are poised to further revolutionize education. They promise highly personalized learning paths, real-time student support, and novel teaching methodologies, including immersive role-playing scenarios and interactive problem-solving, potentially creating more adaptive and effective learning environments that maximize each learner's potential.

Acknowledging this potential, significant groundwork has been laid by previous research. Studies have explored data science education curriculum development, particularly within liberal arts universities, addressing its importance, challenges, curriculum models, and prospects [1, 9]. Concurrently, research examining the optimal utilization of GenAI in education has analyzed global and Japanese trends, considering implementation methods and challenges informed by guidelines from entities like the Ministry of Education and UNESCO [2, 3]. Practical applications are also emerging, such as using AI engines to analyze student reflections to enhance first-year university education quality [10]. Policy and curriculum frameworks are evolving; accordingly, the 2024 Consortium for Mathematics, Data Science, and AI Education Enhancement in Japan, for instance, now integrates GenAI at both literacy and applied levels [4, 14]. Similarly, the U.S. Department of Education recognizes AI's capacity to improve educational quality, access, and efficiency, while cautioning that it is not a panacea [5]. Critical challenges surrounding ethics, fairness, transparency, and privacy demand responsible implementation, leading to recommendations for developers focused on aligning AI with educational values, using evidence-based practices, promoting equity, ensuring safety, and fostering trust [6].

Despite the promise, the increasing integration of GenAI into standard tools like browsers and learning software makes complete prevention of misuse or reliance on potentially erroneous outputs (hallucinations) difficult. Significant risks persist, including concerns about the reliability and transparency of AI-driven learning processes, and the potential amplification of biases present in the underlying training data [7].

In this context, liberal arts private universities face the pressing need to strategically integrate GenAI technologies with existing educational goals, task designs, and teaching practices. The challenge lies in developing novel pedagogical approaches that enhance both instructional efficiency and learner comprehension, while simultaneously establishing clear guidelines for the responsible use of these tools by both educators and students.

To address this challenge, this study utilizes the 'Reconsidering Education in the AI Era' framework (Figure 1) to analyze Data Science education models. Our analysis focuses on four interconnected concepts: effective GenAI engagement strategies, revised learning objectives incorporating essential AI literacy and skills, assignment modifications that account for GenAI tool usage, and redesigned educational practices leveraging AI for personalization and collaboration. Central to this framework is the principle of 'educational AI alignment,' ensuring that AI integration is truthful, fair, accessible, secure, and equitable. While the broader framework aims for qualitative learning improvements and reduced educator workload (a detailed theoretical discussion is beyond this paper's scope), this research presents a practical application. We developed and empirically evaluated a bespoke "Data Science" AI teaching assistant within the core 'Data Science' course of Kansai International University's 'Data Science Minor' program (aligned with the MDASH literacy level). This empirical investigation seeks to translate theoretical guidelines into practice and assess the multifaceted educational impact and associated challenges of implementing GenAI in a specific university context.

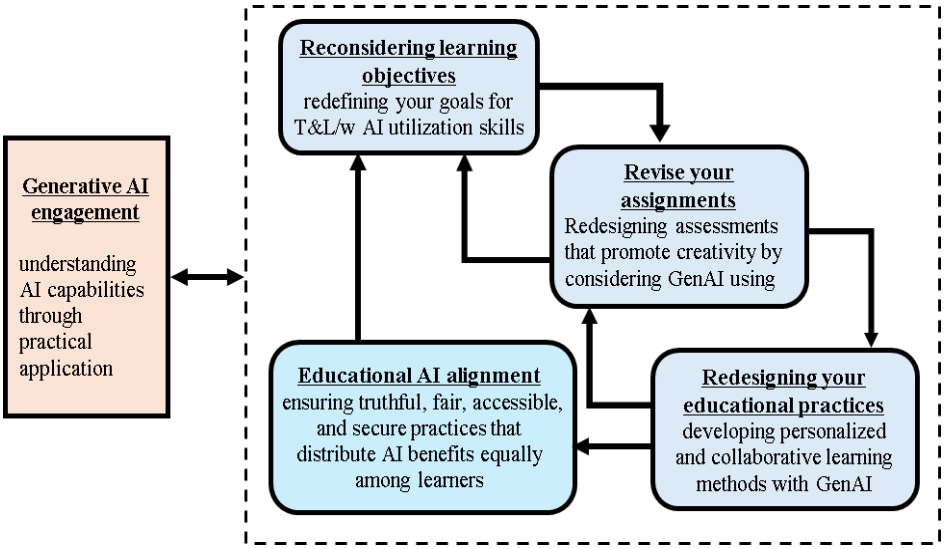


*Figure 1. Reconsidering Education in the AI Era.*

## 2. LLMs, Prompt and Hallucinations

LLM is a powerful natural language processing tool built on internet mass text data and advanced deep learning technology. The model relies on deep learning technology and the innovative Transformer architecture to achieve outstanding language understanding and generative capabilities. The most prominent LLMs include ChatGPT, Gemini, Claude and DeepSeek, and each LLM has its own characteristics and advantages.

### 2.1. Comparative Analysis of Main LLM and Their Educational Applications

Recent large language models exhibit diverse capabilities applicable to educational contexts. ChatGPT demonstrates versatile conversational abilities and flexible text generation, adapting readily to various educational scenarios. Gemini distinguishes itself through Google Search integration and multimodal processing capabilities, effectively handling diverse educational content formats. Claude provides advanced reasoning capabilities with particular emphasis on ethical considerations, a critical feature for responsible educational implementation. Microsoft Copilot, integrated with Microsoft 365, displays strengths in business-oriented applications with specialized functionality for professional educational environments.

The performance profiles of these GenAI tools continue to evolve rapidly. Each model offers distinct capabilities: ChatGPT excels in dialogue management, Gemini efficiently processes multiple input modalities, Claude prioritizes ethical AI deployment, Copilot provides robust programming support, and Deep Seek enhances information retrieval processes. These platforms typically employ tiered access models, with premium versions offering enhanced capabilities, presenting educational institutions with important considerations regarding the balance between performance requirements and budgetary constraints.

A knowledgeable GenAI like ChatGPT leverages vast amounts of text data to develop sophisticated capabilities. These include engaging in natural, human-like conversations, answering questions, generating text, and performing complex inferences based on learned patterns [11]. This capacity for advanced reasoning signifies a leap beyond traditional machine learning, enabling recent GenAI to achieve human-level or even superior performance on complex intellectual tasks. Notably, GPT-4 has demonstrated human-level results across various professional exams, and a DeepMind AI correctly solved 4 out of 6 International Mathematical Olympiad (IMO) level problems, showcasing high accuracy on demanding challenges [12].

### 2.2. Prompt Engineering and Hallucination Challenges in Education

Effective utilization of Large Language Models (LLMs) in educational contexts hinges on prompt engineering: the systematic design of inputs to elicit desired outputs from Generative AI (GenAI). Successful prompt crafting necessitates an understanding of both the model's capabilities and limitations, aligned with specific educational objectives. The aim is to construct prompts that guide the AI to generate responses which are accurate, relevant, and pedagogically appropriate. One such advanced technique is Chain of Thought (CoT) prompting, which directs the AI to employ step-by-step reasoning for complex problem-solving. This method enhances response accuracy and logical coherence, particularly in domains like mathematics and logic, highlighting its potential impact on educational practice [13].

LLM hallucination, the generation of plausible yet factually incorrect or fabricated content—presents a significant challenge in educational settings where informational accuracy and reliability are paramount. These inaccuracies can stem from training data limitations, inherent architectural biases, or prompt ambiguity.

Mitigating hallucinations requires strategies such as clear prompt contextualization, fact-checking integration, and designing systems to indicate uncertainty rather than assert speculative information as fact. Vigilance is crucial for educational applications, as misinformation risks undermining learning objectives and misleading students.

## 2.3. Custom GPTs and Educational Support

Custom GPTs, also known as GPTs or GPT Builder, represent specialized versions of ChatGPT applications that have been fine-tuned for specific domains or purposes. A significant advantage of these systems is their accessibility—they can be customized without extensive programming knowledge or skills, enabling many users to create personalized ChatGPT applications tailored to their specific needs. This accessibility has facilitated widespread adoption across various business applications and educational contexts.

In educational settings, custom GPTs can be tailored to specific datasets and requirements, providing more specialized question-answering capabilities and functions than general models. This customization allows for the development of AI assistants that address the needs of specific courses, subjects, or educational approaches.

## 2.4. Retrieval-Augmented Generation Technology

GPTs represent an innovative approach to enhancing LLM through integration with RAG technology, allowing them to incorporate domain-specific knowledge. Similar tools include Google's NotebookLM. Unlike standard ChatGPT, GPTs offer retrieval functionality and the ability to call external APIs (Function Calling).

The retrieval capability allows ChatGPT to be pre-loaded with knowledge about specific topics or fields, enabling more accurate and faster response generation. Additionally, the integration with external APIs enables the incorporation of services like Google Maps or weather forecasts, producing higher-quality responses that leverage external functionality.

RAG technology integration enables GenAI systems to extract relevant information from external databases or knowledge repositories during response construction. This approach allows AI models to generate more accurate and contextually appropriate responses, proving particularly effective when answers to questions about specific specialized fields or specified data content are required.

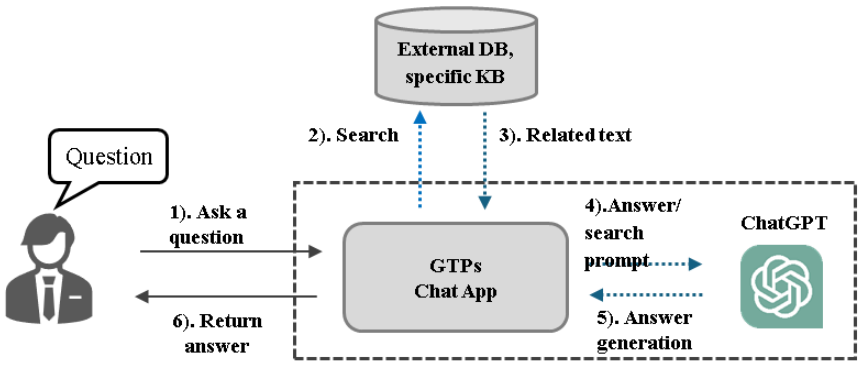


***Figure 2.*** *GPTs mechanism incorporating external data sources using RAG technology.*

Figure 2 illustrates the question-answering mechanism of GPTs incorporating external data sources through RAG technology. The process follows these main steps:

1). Question reception: The user asks a question to the chat application. 2). Question processing: The application processes the question using vector data for search. 3). Retrieval of relevant text: Search results provide related text based on question keywords. 4). LLM query: Search results and the question are incorporated into a prompt template and input to ChatGPT. 5). Response generation: LLMs like ChatGPT generate response text. 6). Response transmission: After necessary post-processing, the response is sent to the questioner.

RAG technology allows GPTs to retrieve information from external sources and knowledge bases, creating more sophisticated outputs. In education, this enables curriculum-specific learning tools, contributing to more reliable educational support systems. Applications include specialized teaching materials, personalized learning support, and real-time responses to classroom questions. These capabilities help educators implement individualized teaching methods, improving the quality of students' educational experiences.

# 3. Methodology

## 3.1. Overview of the "Data Science" Course

This study focuses on the "Data Science" course, a core component of the "Data Science Minor" educational program (MDASH literacy level [4]) implemented at Kansai International University since 2022. This program is available to all students at the university, providing foundational knowledge in data science regardless of their major field of study.

The "Data Science" course serves as an introductory-level subject covering mathematics, data science, and artificial intelligence. The syllabus is structured according to the "Cultivation of Data Thinking" model curriculum for mathematics, data science, and AI (literacy level) provided by the "Consortium for Mathematics and Data Science Education Enhancement." The course utilizes "Data Science as Liberal Arts" [8] as its primary textbook, which is recommended by the Consortium for Mathematics, Data Science, and AI Education Enhancement.

***Table 1.*** *Course Schedule and Assessments.*

| Session | Content | Assessment |
|---|---|---|
| Session 1 | Introduction | Pre-course Survey |
| Session 2 | Changes in Society (1) | Quiz-1, Assignment (1) |
| Session 3 | Changes in Society (2) | Quiz-2, Assignment (2) |
| Session 4 | Data Utilization in Society | Quiz-3, Assignment (3) |
| Session 5 | Applications of Data and AI | Quiz-4, Assignment (4) |
| Session 6 | Data and AI Utilization Techniques (1) | Quiz-5, Assignment (5) |
| Session 7 | Data and AI Utilization Techniques (2) | Quiz-6, Assignment (6) |
| Session 8 | Practical Applications of Data and AI | Mid-term Exam |
| Session 9 | Emerging Trends in Data and AI Utilization | Quiz-7, Assignment (7) |
| Session 10 | Reading Data | Quiz-8, Assignment (8) |
| Session 11 | Explaining Data | Practical Exercise 1 |
| Session 12 | Handling Data | Practical Exercise 2 |
| Session 13 | Considerations in Handling Data and AI | Quiz-9, Assignment (9) |
| Session 14 | Considerations in Data Protection | Quiz-10, Assignment (10) |
| Session 15 | Review and Summary | Post-course Survey |

This curriculum is structured in three complementary sections: "Introduction," "Fundamentals," and "Principles" [9]. The introductory section examines societal transformations, practical applications of data utilization, the evolving role of data science, and contemporary trends in data and AI technologies. The fundamentals section focuses on developing data literacy, including methodologies for data interpretation, analytical frameworks, and appropriate data handling protocols. This section incorporates practical computer-based exercises to reinforce theoretical concepts. The principles section addresses the ethical, legal, and social implications (ELSI) of data and AI implementation, with particular emphasis on the European Union's General Data Protection Regulation (GDPR), AI ethics frameworks, and essential security and privacy protection measures. The detailed content of each class is shown in Table 1.

Each session includes:
1) PDF slides of the course content
2) Video content with AI narration
3) 10-question quizzes before and after videos
4) Homework to be completed before the next lesson
5) Online Q&A corner.

## 3.2. Development of the GPT-based AI Tool for Data Science Education

### 3.2.1. System Architecture and Design

We created the GPT-based AI teaching assistant for data science education (DS-ASST app), using RAG to integrate course materials. This accessibility was particularly valuable in the educational context, enabling the creation of a special-

ized tool tailored to the specific needs of the data science curriculum. This approach allowed the AI assistant to access and utilize course-specific materials, textbook content, and supplementary resources when generating responses to student queries.

The system was designed to support multiple aspects of the educational process:

1) Instructor support for course preparation and material development.
2) Student support for understanding course concepts and completing assignments.
3) Data analysis support for both instructors and students.
4) Advanced learning activity facilitation.

### 3.2.2. Prompt Design Experiments

A critical aspect of developing the AI teaching assistant system was the design and optimization of prompts. We conducted systematic experiments with different prompt structures to determine the most effective approaches for educational support. These experiments focused on several key areas:

1) Clarity and Specificity: Testing various levels of detail and specificity in prompts to determine the optimal balance for educational contexts
2) Context Provision: Experimenting with different methods of providing course-specific context to the AI system
3) Instructional Design Integration: Incorporating principles of instructional design into prompt structures
4) Error Reduction Strategies: Developing prompt techniques to minimize hallucinations and factual errors
5) Pedagogical Alignment: Ensuring that prompts elicited responses aligned with the pedagogical goals of the course

The prompt design process was iterative, with each version being tested and refined based on the quality and educational value of the responses generated. This process resulted in a set of optimized prompt templates for different educational scenarios, such as concept explanation, problem-solving guidance, and feedback provision.

It is also important to create opportunities for students to explore practical applications in their own fields of expertise. 13) As a response to rapid technological evolution, it is possible to implement related teaching materials in external data sources and knowledge bases in PDF or text format in the GPTs application. In addition, the DS-ASST app can automatically generate supplementary explanations using multifaceted perspectives and concrete examples to promote understanding of complex concepts or learning items that teachers feel are problematic. As an example, in response to a request for a simple and easy-to-understand explanation of GenAI, the DS-ASST app has the function of providing an explanation as shown in Table 2.

The research demonstrated that AI can automatically generate customized quizzes and assignments aligned with specific curriculum requirements. The system can create questions with varied formats (multiple choice, written, coding) and difficulties, and can even fulfill specific student requests like randomly selecting a question with its solution. Verification confirmed that the generated content precisely matched the existing test materials of the 6th test-problem5.txt in the knowledge base.

***Table 2.*** *Example of lesson review prompting.*

| **Prompt experiment of reviewing test questions** |
|---|
| (Question prompt)<br>Randomly select one question from Quiz Question 5 and provide the correct answers and explanations. |
| (DS-ASST app) |
| Question 1: Choose the most inappropriate reason that makes prediction difficult. |
| Because there are phenomena that are inherently unpredictable, like the roll of a die. |
| Because the future situation may differ from the past, and rules derived from past data may not apply to the future. |
| Because the latest prediction theories are too mathematically advanced. |
| Because it can be difficult to gather the necessary data for prediction. |
| Correct Answer: 3 |
| Explanation: |
| The high complexity of the latest prediction theories is not a cause of prediction difficulties. Even with advanced prediction theories, factors such as unpredictable phenomena (randomness), future situational changes, and lack of data affect the accuracy of predictions, making prediction itself not easy. |
| [54:1†6th_test-problem5.txt]. |

### 3.2.3. Avoiding Hallucinations and Using in Assessments

The analysis of past use case experiments has confirmed that the frequency of hallucination problems discussed above is extremely low on the DS-ASST app. Specifically, the system appropriately indicates a lack of knowledge in response to questions about content outside the scope of the teaching materials (see Table 3). However, in response to intentionally leading questions such as "Please create a CSV file containing the number of visitors to the Kansai International University School Festival's Sakura Festival," the generation of pseudo-data was observed.

*Table 3. Example of hallucination verification by DS-ASST.*

| **Prompt experiment of hallucination problem verification** |
|---|
| (Question prompt)<br>What is the content of Quiz 15? * |
| (DS-ASST app)<br>No information on the content of Quiz 15 was found in the current materials. If you think a specific file is related to Quiz 15, please upload it to confirm. Also, if you have any other hints about the content you are looking for, we may be able to provide more accurate information. |
| (Question prompt)<br>The GAN model uses the transformer method. |
| (DS-ASST app)<br>The GAN (Generative Adversarial Network) model does not basically use the transformer method. Both GAN and transformer are attracting attention as generative models, but each has a different architecture and mechanism.<br>About the GAN model<br>Structure: GAN is a mechanism in which two networks, a generative network (Generator) and a discriminator network (Discriminator), compete to learn.<br>Operating principle: The Generator generates new data, and the Discriminator determines whether it is real or fake. This opposing relationship allows the Generator to learn to generate data that is closer to reality.<br>(...omitted) |

### 3.2.4. Implementation in the Educational Environment

The AI teaching assistant system was implemented in the "Data Science" course as a supplementary tool to support both instructors and students. For instructors, the system aided with course preparation, material development, and assessment design. For students, it offered on-demand explanations, guided practice opportunities, and personalized feedback. The implementation process included:

1). Integration of course-specific materials into the system's knowledge base; 2). Training of instructors on effective system utilization; 3). Introduction of the system to students with clear guidelines on its capabilities and limitations; 4). Establishment of protocols for monitoring system performance and addressing any issues that arose.

## 3.3. Evaluation Methods and Criteria

The effectiveness of the AI teaching assistant system was evaluated through formative assessment, focusing on four key perspectives:

1) Teaching Preparation Efficiency: Assessing the system's impact on instructors' workflow and preparation time, including material development, assessment creation, and feedback provision.
2) Active Learning Support: Evaluating the system's ability to facilitate student engagement, self-directed learning, and knowledge construction.
3) Data Analysis Process Enhancement: Measuring the system's effectiveness in supporting data analysis tasks, including data interpretation, visualization, and statistical analysis.
4) Advanced Learning Activity Promotion: Assessing the system's contribution to higher-order learning activities, such as critical thinking, problem-solving, and creative application of concepts.

By combining quantitative metrics and qualitative feedback, the evaluation provided a nuanced understanding of the system's educational impact, revealing its strengths and potential areas for improvement across teaching and learning processes. This comprehensive evaluation framework allowed for a nuanced understanding of the system's educational impact across different dimensions of the teaching and learning process, providing insights into both its strengths and areas for improvement.

# 4. Results and Discussion

## 4.1. Effectiveness of the AI Teaching Assistant System

The implementation of the DS-ASST app as a GPTs application demonstrated significant effectiveness across multiple dimensions of educational support. Through formative assessment, we evaluated the system's impact from four key perspectives: teaching preparation efficiency, active learning support, data analysis process enhancement, and advanced learning activity promotion. The following sections detail the findings in each of these areas.

### 4.1.1. Improving Teaching Preparation Efficiency

The AI teaching assistant system significantly enhanced instructors' efficiency in course preparation and material development. Specifically, the system demonstrated the following benefits:

1) Content Generation and Refinement: The DS-ASST tool significantly reduced instructors' content creation time, generating initial drafts of lectures and assessments. Instructors reported 30-40% time savings on basic content development, allowing them to focus more on customization and quality.
2) Diverse Explanation Generation: The DS-ASST generated multiple explanatory approaches for core concepts, offering diverse analogies, examples, and visualization suggestions. This versatility allowed instructors to select and refine explanations best suited to their students' needs, effectively making complex data science concepts more accessible.
3) Assessment Development Support: The system effectively generated diverse assessment items across cognitive levels. It produced knowledge-checking questions, application problems, and analytical scenarios, helping instructors develop comprehensive assessments aligned with learning objectives.
4) Feedback Template Creation: The AI system developed structured feedback templates for common student misconceptions, enabling more consistent and comprehensive responses. This approach allowed instructors to maintain high-quality feedback while significantly reducing the time spent on individualized assessments.

These efficiency gains did not merely reduce workload but fundamentally transformed how instructors allocated their time, shifting focus from routine content creation to higher-value pedagogical activities such as personalization, refinement, and strategic instructional design.

### 4.1.2. Supporting Active Learning

The AI teaching assistant system proved effective in supporting students' active engagement with course content and promoting self-directed learning behaviors:

1) On-Demand Concept Clarification: Students used the system for immediate clarification of difficult concepts, receiving explanations tailored to their specific questions. This on-demand support removed barriers to understanding and prevented knowledge gaps that could hinder progress.
2) Guided Problem-Solving: The AI system guides problem-solving with prompts and hints, fostering independent thinking, rather than just providing answers.
3) Learning Path Personalization: The system suggested personalized learning paths based on student interactions, recommending supplementary resources or alternative explanations when students struggled with concepts. This adaptive support addressed diverse learning needs within the student group.
4) Engagement with Complex Data: Students felt more confident working with complex datasets when using the AI assistant. The AI provided context, suggested analysis methods, and helped interpret patterns and anomalies. This support was especially beneficial for students with limited data analysis experience.

The active learning support provided by the system aligned well with the course's objective of developing students' data thinking capabilities, encouraging exploration and inquiry rather than passive information reception.

### 4.1.3. Enhancing Data Analysis Processes

In the context of data science education, the system's ability to support data analysis processes was particularly significant:

1) Analysis Workflow Guidance: The system effectively guided students through structured data analysis workflows, from initial data exploration and cleaning to more sophisticated analytical techniques. This guidance helped students internalize systematic approaches to data analysis that reflect professional practice.
2) Code Assistance and Debugging: For programming components, the system assisted with code development and debugging. It suggested improvements, identified errors, and explained the logic behind different analytical approaches, supporting students' technical skill development.
3) Interpretation Support: Beyond technical execution, the system assisted with the interpretation of analysis results, helping students connect statistical outputs to mean-

ingful insights. This interpretive support was crucial for developing students' ability to derive actionable knowledge from data.

4) Visualization Recommendations: The system provided contextually appropriate visualization recommendations based on data characteristics and analytical objectives. These recommendations helped students select effective visual representations that accurately communicated their findings.

The enhancement of data analysis processes contributed significantly to students' development of practical data science skills, bridging the gap between theoretical understanding and applied capability.

#### 4.1.4. Promoting Advanced Learning Activities

The AI teaching assistant system demonstrated value in supporting higher-order learning activities that extend beyond basic knowledge acquisition:

1) Critical Evaluation of AI Outputs: Students were encouraged to critically evaluate the system's responses, identifying potential inaccuracies or limitations. This meta-learning activity developed students' critical thinking skills while also fostering a nuanced understanding of AI capabilities and constraints.
2) Interdisciplinary Connection Facilitation: The system effectively helped students connect data science concepts to their primary fields of study, suggesting relevant applications and examples that bridged disciplinary boundaries. This interdisciplinary perspective was especially valuable in the liberal arts university context.
3) Research Question Formulation: The system supported students in developing sophisticated research questions that could be addressed through data analysis. By suggesting refinements and highlighting analytical possibilities, it helped students conceptualize meaningful inquiry projects.
4) Ethical Reasoning Development: When addressing topics related to data ethics and responsible AI use, the system facilitated nuanced discussions of ethical dilemmas, helping students develop reasoned positions on complex issues such as privacy, bias, and algorithmic transparency.

These advanced learning activities contributed to the development of higher-order thinking skills that transcend specific course content, preparing students for the complex challenges they will encounter in professional contexts.

### 4.2. Technical Challenges and Solutions

The implementation of the AI teaching assistant system was not without challenges, particularly in the areas of prompt design and hallucination management:

1) Prompt Design Optimization: Initial prompts produced responses that were too general or overly technical. Through iteration, we developed structured prompts incorporating specific pedagogical goals, student backgrounds, and course context. This contextual enrichment greatly improved the educational relevance of the system's responses.
2) Hallucination Mitigation: To address the challenge of AI hallucinations, we implemented several strategies: 1). Knowledge base integration through RAG technology, anchoring responses in verified course materials; 2). Explicit uncertainty acknowledgment in system responses when venturing beyond its knowledge base; 3). Fact-checking protocols for instructors reviewing system-generated content; 4). Student education on critical evaluation of AI-generated information.
3) Technical Vocabulary Calibration: The system initially struggled with appropriately calibrating technical vocabulary to students' knowledge level. We addressed this by incorporating vocabulary guidelines into prompts and developing a progressive disclosure approach that introduced technical terms with accompanying explanations.
4) Response Length and Structure: Finding the right balance between comprehensive explanation and cognitive manageability required extensive testing. We developed templates for different response types (concept explanations, procedures, feedback) with appropriate elements like summaries, step-by-step breakdowns, and visual suggestions.

These technical challenges and their solutions provided valuable insights into the effective design of AI educational tools, highlighting the importance of pedagogical principles in guiding technical implementation.

### 4.3. Comparison with Traditional Educational Approaches

The AI teaching assistant system demonstrated several distinctive advantages when compared to traditional educational approaches:

1) Temporal Flexibility: Unlike traditional office hours or synchronous support, the AI system provided 24/7 availability, allowing students to receive assistance at their optimal learning times and addressing questions as they arose rather than requiring them to be accumulated for scheduled interactions.
2) Scaling of Individualized Support: The system enabled a degree of individualized support that would be logistically challenging to provide through human instructors alone, especially in larger course sections. This scaling of personalization represents a significant advancement over traditional approaches to educational support.
3) Reduced Judgment Barriers: Some students reported greater comfort in asking "basic" questions to the AI system than to human instructors, fearing less judgment or perception of inadequacy. This reduced psychological

barrier facilitated more comprehensive support for foundational understanding.

4) Consistency with Adaptability: The system maintained consistent quality and comprehensiveness in its responses while adapting to individual student needs—a balance that can be challenging for human instructors to maintain, particularly when managing multiple courses and responsibilities.

However, the comparison also revealed areas where traditional approaches retain advantages:

1) Emotional Intelligence and Motivation: Human instructors demonstrated superior ability to recognize emotional states, provide motivational support, and build rapport with students—elements that remained beyond the capabilities of the AI system.
2) Spontaneous Connection-Making: Experienced instructors excelled at making spontaneous connections to current events, student interests, or emerging research that the AI system could not match without specific programming.
3) Judgment in Intervention Timing: Human instructors demonstrated better judgment regarding when to intervene in student learning processes versus when to allow productive struggle, a nuanced capability that proved difficult to replicate in the AI system.

These comparative insights suggest that optimal educational outcomes may be achieved through thoughtful integration of AI systems and human instruction rather than replacement of one with the other.

## 4.4. Limitations of the Current Implementation

Despite its demonstrated effectiveness, the current implementation of the AI teaching assistant system has several limitations that warrant acknowledgment:

1) Domain Specificity: The system's knowledge base was optimized for the specific data science curriculum used in the course. Its effectiveness would likely be reduced if applied to other courses without substantial reconfiguration and knowledge base enhancement.
2) Assessment Limitations: While the system could generate assessment items and provide feedback on responses, it lacked sophisticated capabilities for evaluating open-ended work or creative problem-solving approaches that deviated from expected patterns.
3) Technical Requirements: The system's implementation required certain technical infrastructure and connectivity, potentially creating access barriers for students with limited technological resources or in areas with connectivity challenges.
4) Adaptation Lag: The system required periodic updates to incorporate new course materials, emerging research, or changes in the field of data science. This updating process introduced a lag in the system's ability to reflect the most current developments.

These limitations highlight areas for future development and refinement of AI teaching assistant systems, particularly as the underlying technologies continue to evolve.

## 4.5. Implications for Educational Paradigm Transformation

The findings from this implementation suggest several broader implications for educational paradigm transformation in the AI era:

1) Redefinition of Instructor Roles: The effective integration of AI teaching assistants may lead to a redefinition of instructor roles, with greater emphasis on higher-order instructional design, relationship building, and complex judgment tasks rather than routine information delivery or basic question answering.
2) Evolving Assessment Approaches: As AI systems become more capable of supporting learning processes, assessment approaches may need to evolve to emphasize uniquely human capabilities such as creative problem formulation, ethical reasoning, and collaborative innovation rather than information recall or procedural execution.
3) Blending of Formal and Informal Learning: The temporal flexibility and on-demand nature of AI support may accelerate the blending of formal and informal learning experiences, with students moving fluidly between structured course activities and self-directed exploration supported by AI guidance.
4) Metacognitive Skill Prioritization: The presence of powerful AI tools may increase the importance of metacognitive skills—the ability to plan, monitor, and evaluate one's own learning processes—as students navigate information-rich environments with sophisticated AI support.
5) Ethical Literacy Development: As AI systems become more integrated into educational experiences, the development of ethical literacy regarding AI use, including understanding of limitations, potential biases, and appropriate reliance, becomes an essential component of educational programs.

These implications suggest that the integration of AI teaching assistants represents not merely a technological enhancement of existing educational approaches but a potential catalyst for fundamental reconsideration of educational structures, practices, and priorities.

## 4.6. Guidelines for Use of GenAI in Education

The U.S. Department of Education's 2023 report [5] recognizes AI's potential to improve education quality, expand opportunities, and enhance efficiency, while emphasizing it's not a universal solution and requires addressing ethical considerations, fairness, transparency, and privacy protection.

Their 2024 "AI Design for Education" guide [6] outlines five key recommendations: understanding educational values, incorporating evidence-based practices, promoting fairness, ensuring safety, and fostering transparency and trust.

Additionally, the Consortium for Mathematics, Data Science, and AI Education Enhancement's 2024 model curriculum addresses GenAI in two stages: at the literacy level as an example of utilizing latest AI technology, and at the applied basic level as foundational theory and applied technology, providing educational institutions with a roadmap for AI integration.

## 4.7. Ethical Considerations in Educational GenAI Implementation

Implementing AI in education requires addressing several ethical considerations: ensuring data privacy and security, preventing bias and discrimination, maintaining transparency about AI's capabilities and limitations, and preserving human agency in education.

Educational AI systems must protect student data and avoid perpetuating biases. Clear communication about AI's role and limitations is essential when students and educators interact with these systems.

Ethical implementation also demands attention to accessibility and equity, ensuring AI-enhanced education is available to all students regardless of socioeconomic status or location. This includes addressing the "digital divide" to prevent AI from worsening educational inequalities.

By proactively addressing these considerations, institutions can maximize AI's benefits while minimizing risks and aligning with core educational values.

## 4.8. Proposal for Guidelines for the Use of GenAI in Education

GenAI technologies are catalyzing significant transformations within educational environments, offering promising potential for quality enhancement and operational efficiency. However, these advancements simultaneously present substantial challenges, including concerns regarding information reliability, copyright implications, content bias, and potential deterioration of students' critical thinking capabilities. Educational practitioners must adopt a stance characterized by both critical evaluation and creative implementation of AI technologies, committing to continuous learning and iterative improvement of pedagogical practices. While the proactive integration of GenAI into teaching and learning processes is encouraged, educators bear responsibility for developing comprehensive implementation guidelines, potentially incorporating structured evaluation frameworks or checklists, and explicitly communicating these protocols to students to ensure appropriate technological engagement.

### 4.8.1. Basic Principles

The guideline must be based on four core principles:

1) Human-centric AI Use: AI should supplement human cognitive abilities; users are ultimately responsible for evaluating AI output.
2) Maintaining Academic Integrity: Clear usage rules are necessary to prevent plagiarism and academic dishonesty.
3) Fostering Critical Thinking and Creativity: AI is an auxiliary tool; education should focus on developing students' own thinking and creativity by critically evaluating AI output.
4) Enhancing AI Literacy: Both students and faculty need AI literacy to understand and utilize new technologies effectively in a rapidly changing society.

### 4.8.2. Educational Utilization

To ensure that AI is used correctly in teaching activities, guidance is needed for both teaching and learning.

For teachers, guidelines for maintaining academic integrity in AI require teachers to develop basic AI skills, establish clear usage policies and citation requirements in the syllabus, establish transparent assessment standards, define inappropriate behavior, protect sensitive data, teach AI literacy, and adopt verification methods.

Students must critically evaluate AI content from multiple sources, use AI only as supplements after self-reflection, obtain permission to use AI, disclose AI-assisted information, never submit AI output as original work, develop effective prompting skills, keep learning records, and maintain good face-to-face communication skills.

### 4.8.3. Checklist for Faculty Use in Educational Settings

We propose a simple checklist for faculty to understand guidelines on using GenAI in teaching.

1. Planning Your Course and Getting Ready
   1) Clear Syllabus Policy: Does your syllabus clearly say if students can use AI in your class? Make sure this policy fits your specific course.
   2) Your Own AI Use: Can AI help you plan the course or create teaching materials effectively?
   3) Boosting Student Skills: If students use AI, is it set up to help them think better and be more creative, not just get answers?
   4) Check AI-Made Materials: If you used AI to help create any teaching materials, did you double-check that they are accurate and high-quality?
2. Helping Students and Teaching the Class
   1) Explain the Rules: If students are allowed to use AI, do you clearly tell them the rules and what they can and cannot use them for?

2) Recommend Tools and Explain: Do you suggest specific AI tools? Did you plan enough time to show students how to use them properly?
3) Teach AI Limits: Are you teaching students that AI isn't perfect and showing them how to check if the information AI gives them is correct?

3. Being Ethical and Grading Fairly
1) Protect Privacy and Copyright: Make sure no one inputs private information into AI tools. Also, ensure AI use doesn't break copyright laws.
2) Update Grading: Have you thought about how you'll grade assignments now that students might use AI? Make your grading rules clear about this.
3) Don't Rely Only on AI for Grading: Avoid letting AI do all the work of grading students. You need to be involved.

4. Which AI Tools to Use?

It depends on the circumstances of your university.

5. How to Write Your AI Policy in the Syllabus

Course Policy on Using GenAI example:
1) Choose ONE option and state it clearly:
i. Unlimited Use Allowed: Students can use AI freely.
ii. Conditional Use Allowed: Students can use AI but only under specific conditions (explain these conditions, e.g., for brainstorming, checking grammar, not for writing whole essays).
iii. No Use Allowed: Students cannot use AI for any coursework.
2) Policy for Tests (Quizzes, Mid-terms, Finals):

Using GenAI during tests is prohibited.

3) Policy for Assignments, Reports, etc.:

Generally, using GenAI to directly find answers or complete assignments is not permitted (unless you specified otherwise under "Conditional Use").

### 4.8.4. Checklist for Students' Use in Learning Situations

We also propose a simple checklist for students using GenAI in learning. For students, challenges include information reliability, copyright issues, bias, and potential degradation of learners' thinking skills. It is essential to use GenAI critically and creatively, always keeping in mind that the final judgment and responsibility lies with the learner. Students should refer to the following checklist to determine their fair use.

To ensure its ethical and effective integration, students are advised to adhere to the following principles and practices:

1. Aligning AI Use with Academic Purpose and Policy
1) Consult Course Policies: Check instructor policies on using Generative AI for classes and assignments. Understanding these expectations is the first step to responsible use.
2) Assess Appropriateness: Assess if using AI aligns with the course or task's learning goals. Use AI to enhance learning, not bypass it.
3) Cultivate Critical Evaluation: Understand AI's capabilities and limitations. Critically examine all AI output for potential inaccuracies and bias.
4) Maintain Learning Ownership: Take ownership of your learning. Use AI to enhance critical thinking and creativity, not replace these skills.

2. Ensuring Academic Integrity and Effective Learning Support
1) Verify Information: Don't accept GenAI information uncritically. Always fact-check using multiple reliable sources.
2) Uphold Academic Honesty: Do not use AI for academic misconduct (e.g., plagiarism, cheating) in coursework. Submitting AI-generated work as your own without proper attribution is unethical.
3) Engage and Develop: Don't just accept AI's initial output. Actively refine, expand, and integrate the content with your own original thoughts and analysis.
4) Cite Appropriately: Properly cite any AI-generated content or ideas used in academic work, following institutional or course guidelines.

3. Protecting Information and Adhering to Ethical Standards
1) Safeguard Personal Data: Exercise caution and avoid inputting personal or confidential information, whether your own or belonging to others, into Generative AI prompts.
2) Respect Copyright: Refrain from using Generative AI in any manner that infringes upon existing copyright laws and intellectual property rights.
3) Comply with Terms of Service: Regularly review and adhere to the most current terms of service established by the providers of the Generative AI tools being used.

4. Recommended Generative AI Tools

While our university recommends Microsoft Copilot as a suitable introductory tool for utilizing GenAI, the use of other validated and appropriate AI tools is generally permitted. Students should select tools that best suit their needs while adhering to these guidelines.

5. Disclosure of GenAI Use in Academic Work
1) Transparency Requirement: Clearly state any use of GenAI in assignments, reports, theses, or other academic submissions.
2) Consult for Citation Method: Consult the course or assignment instructor to determine the specific method required for citing or acknowledging AI use.

Example Disclosure: "The visual elements on slides 5-10 were generated using Midjourney, and the accompanying text was initially drafted using Copilot. The presenter has subsequently reviewed, edited, and assumed responsibility for the final content. (Created March 2025)"

# 5. Conclusions

The rapid advancement of GenAI technology, particularly LLMs, has presented transformative possibilities for the field of education. This study developed and evaluated an AI teaching assistant system as a GPTs application specifically designed to support data science education. Through formative assessment, we demonstrated the system's effectiveness across multiple dimensions of educational support, from enhancing instructor efficiency to facilitating active learning among students.

## 5.1. Summary of Research Findings

Our research confirms that thoughtfully implemented GenAI offers significant educational benefits. Our "Data Science" AI teaching assistant demonstrated effectiveness by:

First, the system substantially improved teaching preparation efficiency, enabling instructors to allocate more time to high-value pedagogical activities rather than routine content creation. The AI assistant's ability to generate diverse explanations, assessment items, and feedback templates transformed instructors' workflow, allowing for greater focus on personalization and quality enhancement.

Second, the system effectively supported active learning by providing on-demand concept clarification, guided problem-solving assistance, personalized learning path suggestions, and support for engaging with complex data. These capabilities fostered self-directed learning behaviors and helped address the diverse learning needs within the student cohort.

Third, the system enhanced data analysis processes through structured workflow guidance, code assistance, interpretation support, and visualization recommendations. These features contributed significantly to students' development of practical data science skills, bridging the gap between theoretical understanding and applied capability.

Fourth, the system promoted advanced learning activities, including critical evaluation of AI outputs, interdisciplinary connection facilitation, research question formulation, and ethical reasoning development. These higher-order learning activities prepare students for the complex challenges they will encounter in professional contexts.

These findings suggest GenAI can be a catalyst for transformative educational change, moving beyond mere technological enhancement to potentially reshape educational paradigms and practices.

## 5.2. Educational Significance of GenAI Applications

The educational significance of GenAI applications extends beyond the specific context of data science education examined in this study. Our findings suggest several broader implications for educational practice:

1) The integration of AI teaching assistants enables a more personalized and adaptive learning experience, addressing the long-standing challenge of providing individualized support on a scale. This capability is particularly valuable in educational contexts with diverse student populations and varying levels of prior knowledge.
2) AI's flexible, on-demand support aligns with modern learning, extending beyond classrooms and integrating formal and informal education. The ability of AI systems to present multiple explanatory approaches for complex concepts addresses the challenge of cognitive diversity in educational settings. By offering various analogies, examples, and visualization options, AI assistants can help more students find entry points to challenging material that resonate with their existing knowledge structures and learning preferences.
3) Furthermore, the implementation of AI teaching assistants creates opportunities for meta-learning about AI itself, helping students develop critical evaluation skills and nuanced understanding of AI capabilities and limitations. This meta-learning becomes increasingly important as AI systems become more prevalent in professional and civic contexts.

## 5.3. Challenges Requiring Careful Consideration

Despite the promising results demonstrated in this study, the implementation of GenAI in educational settings presents several challenges that require careful consideration:

1) Ensuring the accuracy of AI-generated content remains a significant challenge, particularly when addressing specialized or emerging knowledge domains. The phenomenon of AI hallucinations—plausible-sounding but factually incorrect information—requires robust mitigation strategies, including knowledge base integration, explicit uncertainty acknowledgment, and fact-checking protocols.
2) Data privacy protection presents another critical challenge, particularly in educational contexts where sensitive student information may be involved. Educational institutions must develop clear policies regarding data collection, storage, and usage, ensuring compliance with relevant regulations and maintaining student trust.
3) Ethical considerations extend beyond privacy to include issues of equity, transparency, and appropriate reliance. Educational implementations must ensure that AI systems do not perpetuate or amplify existing biases, that their capabilities and limitations are clearly communicated, and that they support rather than replace the development of essential human capabilities.
4) Additionally, practical challenges include technical infrastructure, faculty training, and sustainable implementation. Institutions must budget resources for effective AI integration, covering initial development and ongoing maintenance, updates, and evaluation.

### 5.4. Future Directions

Based on the insights gained from this research, we identify several promising directions for future development and investigation:

1) First, there is a need for expanded instruction on appropriate LLM usage, helping both educators and students develop the skills necessary to effectively leverage these tools while maintaining critical awareness of their limitations. This instruction should include practical guidance on prompt engineering, output evaluation, and appropriate task selection.
2) Second, the development of comprehensive privacy protection guidelines specifically tailored to educational AI implementations is essential. These guidelines should address not only technical security measures but also pedagogical considerations regarding what types of student data should be accessible to AI systems and how that access should be governed.
3) Third, deeper exploration of ethical considerations is needed, including preventing misuse of AI systems, eliminating bias in educational applications, and acknowledging system limitations transparently. This exploration should involve diverse stakeholders, including educators, students, administrators, and ethical specialists.
4) Fourth, longitudinal studies examining the long-term impact of AI teaching assistants on learning outcomes, skill development, and educational trajectories would provide valuable insights beyond the relatively short-term evaluation conducted in this study. Such research could help identify both immediate benefits and potential unintended consequences of AI integration in education.
5) Finally, investigation into hybrid models that optimally combine human and AI instruction represents a particularly promising direction. Rather than viewing AI as either a replacement for or supplement to human teaching, research should explore how the distinctive strengths of human educators and AI systems can be integrated to create educational experiences that exceed what either could provide independently.

### 5.5. Concluding Remarks

The integration of GenAI technology into educational settings represents a significant opportunity to enhance teaching and learning processes across multiple dimensions. Our development and evaluation of an AI teaching assistant system for data science education demonstrates the potential of such applications to improve efficiency, support active learning, enhance analytical processes, and promote advanced learning activities.

However, realizing this potential requires thoughtful implementation that addresses challenges related to accuracy, privacy, ethics, and practical integration. By approaching these challenges proactively and continuing to refine our understanding of effective AI-enhanced educational practices, we can work toward educational environments that harness the capabilities of GenAI while remaining firmly grounded in core educational values and objectives.

As we navigate this transformative period in educational technology, ongoing dialogue between technologists, educators, students, and policymakers will be essential to ensure that AI implementation serves the fundamental goals of education: fostering understanding, developing capabilities, and preparing learners for meaningful participation in an increasingly complex world.

## Abbreviations

| | |
|---|---|
| LLMs | Large Language Models |
| GenAI | Generative AI |
| RAG | Retrieval-Augmented Generation |
| CoT | Chain of Thought |
| DS-ASST | GPT-based AI Teaching Assistant App for Data Science Education |

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## Conflicts of Interest

The author declares no conflicts of interest.

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