

Exploring the Effectiveness of the IDEA Instructional Model in Integrating Generative AI into University Statistics Education

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Abstract: *The purpose of this study is to apply generative AI in university statistics instruction. Based on the purpose of this study, this study proposes the IDEA instructional model and employs thematic analysis to examine students' perceptions of their learning outcomes. Big data and statistical literacy are important research topics in statistics education. The focus of statistics education lies in the formation of meaningful concepts, while complex computations can be supported by technological tools. The rapid development of generative AI is influencing higher education; however, research on the integration of generative AI into the teaching and learning of statistics remains limited. In this study, the content of statistics instruction of higher education covers five topics, which are estimation of confidence intervals for one population mean, hypothesis testing for one population mean, the relationship between confidence interval estimation, one-way analysis of variance, and simple linear regression. This study proposes the IDEA (Instruction, Drilling, Experimentation, Abstraction) instructional model in statistics instruction. The main instructional focus is on learning statistical theories and practicing problem-solving, followed by using generative AI for data simulation and validation. The research data is analyzed using thematic analysis. According to the results of thematic analysis, these perceptions include: 1. Generative AI enhances learning efficiency; 2. Generative AI promotes the deepening of statistical concepts and supports visual understanding; 3. Generative AI serves as an interactive and assistive learning tool; 4. Usage of generative AI involves risks and experience limitations; 5. The use of generative AI leads to frustration and cognitive gaps; 6. Generative AI fosters the growth of statistical thinking and the shift in learning attitudes. Based on these perceptions, students generally hold positive perceptions toward the integration of generative AI into university statistics learning. Based on the findings, this paper offers instructional implications and suggestions for future research in university statistics education.*

Keywords: Perceptions of Statistics; Generative AI; Statistics Education; Statistics Literacy

1. Introduction

Statistics instruction in higher education is a highly important issue because statistics has a wide impact across various fields. Given the increasing complexity of data structures and the rapid development of technological tools, exploring effective approaches to statistics teaching in higher education is essential. The rise of big data reshapes how societies generate, disseminate, and use information, amplifying the centrality of statistics education. Contemporary civic and professional life demands that learners interpret uncertainty, evaluate

evidence, and communicate about data responsibly—capacities often framed as statistical literacy (Gal, 2002). Within statistics education, this emphasis shifts instruction toward the formation of meaningful conceptual understanding and critical engagement with data, while computation increasingly leverages technology. Parallel developments in educational research chart how “big data in education” supports feedback, personalization, and decision-making at scale, even as the field cautions about infrastructural, ethical, and methodological limitations (Baig & Shuib, 2020). At the same time, generative AI rapidly penetrates higher education. Reviews document opportunities for generative AI to enhance feedback, learning design, self-regulated learning, and assessment practices, alongside risks around accuracy, bias, equity, and academic integrity (Giannakos et al., 2024; Xia et al., 2024). Stakeholder studies in universities similarly report strong uptake and mixed perceptions: students and instructors cite notable gains in efficiency and support, yet also highlight concerns about overreliance and the erosion of critical thinking if guardrails are absent (Hasanein & Sobaih, 2023).

Within statistics education specifically, the literature is still emerging. Early position pieces in the field articulate responsible use cases—e.g., formative feedback, code scaffolding, and tutoring for conceptual understanding—while underscoring the need for empirical evidence (Ellis & Slade, 2023). Recent empirical work begins to appear (e.g., a quasi-experimental study linking ChatGPT-based activities to changes in statistical reasoning and attitudes), suggesting potential benefits but also the necessity of task and assessment redesign to preserve authentic reasoning (Wahba et al., 2024). Learning statistics through technological tools is essential for developing deep conceptual understanding and practical data skills. Technology enhances students’ ability to visualize data, perform simulations, and apply statistical methods to real-world problems. It supports interactive and inquiry-based learning, allowing learners to explore variability, probability, and relationships more effectively. Moreover, using technology fosters computational thinking and critical interpretation of data outputs, bridging the gap between theory and application. In higher education, integrating technological tools into statistics learning cultivates students’ readiness for data-driven decision-making and professional practice in diverse fields (Gibson, Broadley, Downie, & Wallet, 2018). Overall, there remains a clear research gap on how to integrate GenAI systematically into undergraduate statistics courses in ways that strengthen conceptual learning, statistical thinking, and ethical data practice.

Learning with AI is an essential component of statistical literacy. It enables learners to understand, interpret, and critically evaluate data-driven insights generated by intelligent systems (Hariyanti, Budayasa, & Setianingsih, 2025). Through interaction with AI tools, students develop the ability to simulate, analyze, and validate data, fostering deeper conceptual understanding of statistical reasoning. Moreover, integrating AI into statistics learning promotes computational thinking, ethical awareness, and adaptability to technology-enhanced environments, which are key competencies for modern data literacy and evidence-based decision-making in higher education and professional practice. To address this gap, the present study introduces the IDEA (Instruction, Drilling, Experimentation, Abstraction) Instruction Model, which is a structured approach that integrates learning statistics theory, deliberate practice, generative AI-based data simulation, and cycles of abstraction, reflection, and evaluation—then examines students’ perceptions of learning effectiveness through thematic analysis. By linking generative AI affordances to core aims of statistics education, this work aims to contribute evidence-informed guidance for university-level statistics instruction.

2. Literature Review

Statistics Education and Big Data

Research consistently establishes the paramount importance of statistical literacy in the higher education curriculum. This competency is no longer confined to quantitative fields; rather, it serves as a fundamental requirement for informed civic participation and professional success across all disciplines. University programs are currently tasked with developing students' ability to critically evaluate and interpret the overwhelming volume of data presented in media, policy, and research. Consequently, statistical literacy enables graduates to make evidence-based decisions, thus preparing them for effective engagement in a globally data-driven society (Pascual, Caballero Mariscal, Pinto, & Marín-Jiménez, 2025). Students in higher education commonly struggle with abstract concepts (e.g., sampling distributions, inference) and with transferring computations to conceptual reasoning, which contributes to statistics anxiety and avoidance behaviors. Classic and contemporary reviews document that statistics anxiety relates to lower performance, procrastination, and course withdrawal intentions, and often coexists with limited mathematical preparation and low self-efficacy (Onwuegbuzie & Wilson, 2003; Pan & Tang, 2005). Attitudinal research further shows that students' interest, affect, perceived value, and perceived difficulty are core dimensions shaping engagement and achievement in statistics courses (Schau et al., 1995). Collectively, this literature indicates that improving conceptual understanding and addressing anxiety and interest are central challenges for statistics education.

The integration of AI tools presents a significant and feasible opportunity to modernize statistics pedagogy in higher education. Educators currently explore AI's capacity to automate complex data analysis, allowing students to shift focus from tedious computation to critical interpretation of results. This incorporation is feasible because AI platforms provide immediate feedback, personalized learning paths, and real-world datasets that enhance engagement. Furthermore, utilizing AI prepares students for the technological demands of the modern workplace, where AI-powered analytics are standard. The current challenge lies in designing curriculum models that effectively leverage AI for teaching core statistical concepts, ultimately ensuring graduates possess both foundational knowledge and technical fluency for a data-centric future (Bauer, Richters, Pickal, Klippert, Sailer, & Stadler, 2025). In higher education, big data and learning analytics reshape decision-making, personalization, and feedback loops, while also raising governance and ethics concerns. A widely cited synthesis argues that institutions leverage large-scale data for curriculum improvement and student success initiatives, provided they develop robust infrastructures and policies (Daniel, 2015). As data ecosystems expand, generative AI becomes a prominent layer on top of big-data pipelines, enabling feedback generation, content drafting, and support for self-regulated learning; yet risks around bias, accuracy, equity, and academic integrity necessitate careful instructional design and assessment alignment. For statistics education specifically, these capabilities are especially pertinent to show that generative AI can scaffold code, visualize data, and simulate datasets to connect procedures with concepts and functions that directly target known pain points of anxiety, low interest, and conceptual fragility that require explicit guardrails to preserve authentic statistical reasoning.

Generative AI and Education

Integrating AI into higher education is increasingly feasible as intelligent technologies support personalized learning, adaptive feedback, and data-driven instruction. Recent studies show that AI enhances students' engagement, critical thinking, and learning efficiency, making it a promising approach for improving teaching and learning outcomes. Generative AI rapidly

becomes a structural layer in higher education, reshaping feedback, assessment, and instructional design. Syntheses and policy analyses report that universities increasingly formalize guidelines to harness benefits of generative AI to address academic integrity, privacy, and equity concerns. Institutions generally take an “open but cautious” stance and provide resources for pedagogical integration. This implies growing strategic importance of generative AI for teaching, learning, and governance in higher education (Wang, Dang, Wu, & Mac, 2024; Xia, Weng, Ouyang, Lin, & Chiu, 2024).

Integrating AI into higher education facilitates students’ reflection by providing instant feedback, adaptive prompts, and personalized learning analytics. Research indicates that AI-supported environments encourage learners to evaluate their thinking processes, refine problem-solving strategies, and develop deeper metacognitive awareness during learning (Sellnow, 2025). Generative AI offers on-demand scaffolding, feedback, explanation, code help, and data simulation so as to increase efficiency, personalize support, and promote self-regulated learning. Reviews highlight clear instructional affordances (e.g., formative feedback, tutoring, visualization) alongside risks (e.g., inaccuracy, bias, overreliance) that require task redesign and explicit guardrails to preserve authentic reasoning and assessment validity. In practice, effective use aligns generative AI outputs with learning objectives, integrates reflection and justification steps, and makes AI use transparent to sustain academic integrity and deepen understanding (Wang, Dang, Wu, & Mac, 2024).

3. Methodologies

The sample of this study consists of 21 sophomore students from a university in Taiwan, for whom statistics is a required course. The content of statistics instruction in this study covers five topics. They are estimation of confidence intervals for one population mean, hypothesis testing for one population mean, the relationship between confidence interval estimation, one way analysis of variance, and simple linear regression. The methodologies of this study comprises three parts: the first part presents the statistics instruction model used in this study; the second part is the questions and prompts for utilizing generative AI; and the third part conducts thematic analysis of the qualitative data.

Statistics Instruction Model

Based on the literature on statistics teaching and learning, as well as the application of generative AI functions, this study proposes the IDEA (Instruction, Drilling, Experimentation, Abstraction) instructional model, as shown in Figure 1. In Figure 1, for the statistical topics to be learned, four steps are carried out as follows: (1) Instruction in Statistics Theory: teach relevant statistical concepts and theories to establish a solid foundation of statistical knowledge (2) Drilling through Exercise Practice: Engage in assignments and statistical problem-solving exercises to consolidate skills and understanding. (3) Experimentation with Generative AI Data Simulation: Use generative AI to perform data simulation and analysis, fostering exploration and application. (4) Abstraction, Reflection, and Evaluation: Carry out abstraction, reflection, and evaluation to summarize learning outcomes and deepen understanding.



Figure 1: IDEA Instructional Model for Statistics Education

Exercise of Questions and Prompts for Generative AI

The researcher of this study is also the instructor. The statistics contents in this study have five topics, which are estimation of confidence intervals for one population mean, hypothesis testing for one population mean, the relationship between confidence interval estimation, one way analysis of variance, and simple linear regression. In the E stage (Experimentation with Generative AI Data Simulation) and A stage (Abstraction, Reflection, and Evaluation) of the IDEA Instructional Model, the instructor designs exercises to help students learn statistics, with assignments including questions and the execution of generative AI prompts.. In each statistics content, the exercises of questions and prompts for Generative AI used by students are presented in Table 1.

Table 1: The Exercises of Questions and Prompts for Generative AI in Each Statistics Content

Statistics Content	Exercises of Questions and Prompts
Estimation Of Confidence Intervals for One Population Mean	1. Please use Generative AI to answer the following questions and list the output results generated by the AI (please specify which Generative AI you used). <ol style="list-style-type: none"> Randomly sample 20 observations from a normal population X (mean = 15, standard deviation = 3) and 15 observations from a normal population Y (mean = 8, standard deviation = 2). List the sampled values and estimate the 95% confidence interval for the difference in means. Based on step (1), repeat the process 10 times and list the 95% confidence interval estimates for each of the 10 repetitions (the sampled values do not need to be shown). 2. Based on the Generative AI results, write your reflection (about 100 words). <ol style="list-style-type: none"> After repeating the process 10 times, what are your reflections? What is the benefit of using Generative AI for your learning of confidence intervals for the difference in means?
Hypothesis Testing for One Population Mean	1. Please use Generative AI to answer the following questions and list the output results generated by the AI (please specify which Generative AI you used). <ol style="list-style-type: none"> Single Normal Population t- test (Normal population, population variance unknown) <ol style="list-style-type: none"> Randomly sample 20 observations from a normal population X (population mean = 10, population standard deviation = 2). At a significance level of 0.05, use a Z-test to examine whether there is a significant difference between the population mean and 9.5. List the sample mean, p-value, and test statistic. Based on step 1, repeat the process 10 times and list the results of these 10 tests (you do not need to present the sampled values, but you must list the 10 sample means, p-values, and test statistics). Single Population t-test (Non-normal population, population variance unknown, large sample) <ol style="list-style-type: none"> Randomly sample 120 observations from a binomial population X (population mean = 10, population standard deviation = 2). At a significance level of 0.05, use a t-test to examine whether there is a significant difference between the population mean and 9.5. List the sample mean, p-value, and test statistic. Based on step 1, repeat the process 10 times and list the results of these 10 tests (you do not need to present the sampled values, but you must list the 10 sample means, p-values, and test statistics). 2. Based on the Generative AI results, write your reflection (about 200 words). <ol style="list-style-type: none"> After performing the test 10 times, what are your reflections? What is the benefit of using Generative AI for your learning of mean difference testing?

<p>The Relationship Between Confidence Interval Estimation</p>	<p>1. Please use Generative AI to answer the following questions and list the output results generated by the AI (please specify which Generative AI you used).</p> <ol style="list-style-type: none"> Using the example of confidence interval estimation and hypothesis testing for the mean of a single normally distributed population, how can I understand the relationship between confidence interval estimation and hypothesis testing? Could you use 10 simulated datasets to illustrate the above phenomenon? <p>2. Based on the Generative AI results, write your reflection (about 200 words).</p>
<p>One Way Analysis of Variance</p>	<p>1. Please use Generative AI to answer the following questions and list the output results generated by the AI (please specify which Generative AI you used).</p> <ol style="list-style-type: none"> Generate raw data for a one-way analysis of variance (ANOVA), along with the group means and the one-way ANOVA summary table. The independent variable (factor) is teaching method, with three levels: lecture method, discussion method, and self-directed learning. The dependent variable is mathematics achievement, with integer scores ranging from 60 to 100. Each group should have between 30 and 40 participants. The ANOVA results should indicate a statistically significant difference, with the discussion method significantly higher than both the lecture method and self-directed learning. Perform 5 data simulations to illustrate the above phenomenon, and observe whether the raw data and one-way ANOVA summary table are the same in each simulation. For the last data simulation, upload the raw data file and the one-way ANOVA summary table. <p>2. Based on the Generative AI results, write your reflection (about 200 words).</p>
<p>Simple Linear Regression</p>	<p>1. Please use Generative AI to answer the following questions and list the output results generated by the AI (please specify which Generative AI you used).</p> <ol style="list-style-type: none"> Assume the population simple regression equation is $Y = 0.4 + 2X$, with a population correlation coefficient between X and Y of 0.9. The population mean and standard deviation of Y are 10 and 2, respectively, and those of X are 8 and 1, respectively. Draw a random sample of 40 observations from the population and perform a simple regression analysis. Present the raw data, the estimated regression equation, the coefficient of determination, and the correlation coefficient between X and Y. Also, plot the data distribution and the regression line. Perform 5 data simulations to illustrate the above phenomenon, and observe whether the raw data, the estimated regression equation, the coefficient of determination, the correlation coefficient between X and Y, the data distribution, and the regression line remain the same in each simulation. For the last data simulation, upload the raw data, the estimated regression equation, the coefficient of determination, the correlation coefficient between X and Y, as well as the data distribution and the regression line. <p>2. Based on the Generative AI results, write your reflection (about 200 words).</p>

Thematic Analysis

Thematic analysis offers flexibility and depth in qualitative research, allowing researchers to identify, analyze, and interpret patterns of meaning within data. It provides a systematic yet adaptable approach for exploring participants' perspectives and uncovering underlying themes across diverse educational contexts (Braun & Clarke, 2019). The study employs thematic analysis to examine the qualitative data derived from students' reflections and learning experiences in the IDEA instruction model, following Braun and Clarke's (2006) six-phase framework. First, all written responses are read repeatedly to achieve familiarity with the data. Second, initial codes are generated inductively to capture salient features related to the perceived benefits, challenges, and learning processes when integrating Generative AI into statistics education. Third, the codes are collated into potential themes, which are iteratively refined through comparison and constant checking against the dataset. Fourth, themes are reviewed to ensure internal coherence and external distinctiveness, followed by defining and naming each theme to represent its core meaning. Finally, representative excerpts are selected

to illustrate each theme in the reporting stage. This approach enables the identification of patterns in students’ perceptions, including enhanced conceptual understanding, increased engagement through generative AI-assisted data simulation, and improved confidence in applying statistical methods. Thematic analysis is chosen for its flexibility in exploring participants’ subjective experiences and for providing rich, detailed insights into the pedagogical impact of the generative AI-supported IDEA model.

4. Analysis and Discussion

Result analysis of data primarily focuses on the frequency and description of the types of perceptions of generative AI in learning statistics.

Frequency of Types in Perceptions of Generative AI in Learning Statistics

According to the results of the thematic analysis, the frequency of types in perceptions of generative AI in learning statistics is shown in Table 2. As indicated in Table 2, the perception that “Generative AI enhances learning efficiency” accounts for the highest percentage, followed by “Generative AI promotes the deepening of statistical concepts and supports visual understanding.” Therefore, most students hold positive perceptions of generative AI in learning statistics. The two perceptions with the lowest percentages are “Usage of generative AI involves risks and experience limitations” and “The use of generative AI leads to frustration and cognitive gaps,” both of which are negative perceptions.

Table 2: Thematic Analysis on Types of Perceptions

Types of Perceptions	Frequency	Percentage (%)
Generative AI enhances learning efficiency	89	39.21%
Generative AI promotes the deepening of statistical concepts and supports visual understanding	57	25.11%
Generative AI serves as an interactive and assistive learning tool	25	11.01%
Usage of generative AI involves risks and experience limitations	16	7.05%
The use of generative AI leads to frustration and cognitive gaps	11	4.85%
Generative AI fosters the growth of statistical thinking and the shift in learning attitudes.	29	12.78%

Interpretations and Descriptions of Perceptions

The thematic analysis on types of perceptions presented in Table 2 is summarized from the protocols of students in the E stage and A stage of the IDEA instructional model. Table 3 provides examples of students’ protocols for each type of perception.

Table 3: Interpretations and Descriptions of Perceptions

Types of Perceptions	Descriptions of Protocols
Generative AI enhances learning efficiency	<ul style="list-style-type: none"> Using generative AI to learn the confidence interval for the difference of means allows me to quickly obtain calculation results and conduct analysis, reducing the tedious calculation process and improving learning efficiency. The AI can instantly provide sampling results and compute the confidence interval. (Student ID: 112101) <p>By using AI, I only need to input the conditions to immediately obtain the results, which not only improves computational efficiency... Generative AI can quickly generate random samples and calculate the confidence interval, speeding up the comprehension process without the need to manually perform complex calculations. (Student ID: 112116)</p>

Generative AI promotes the deepening of statistical concepts and supports visual understanding	<ul style="list-style-type: none"> I originally thought that confidence intervals and hypothesis testing were independent tools, but in fact, they are two different interpretative approaches: a confidence interval provides a range of estimated values, whereas hypothesis testing makes a judgment about a specific value. (Student ID: 110107) The five simulations allowed me to observe that each time the raw data differed, the ANOVA table also differed, yet all showed significant differences... This deepened my understanding of “inferring the population from the sample.” (Student ID:111802)
Generative AI serves as an interactive and assistive learning tool	<ul style="list-style-type: none"> I asked ChatGPT how the calculations were done, and it clearly explained the formulas and their application step by step. When I encountered unclear details and followed up, it provided clear, immediate responses. (Student ID: 110136) This real-time and interactive approach to analysis helps in learning the core concepts of regression analysis. (Student ID: 112123)
Usage of generative AI involves risks and experience limitations	<ul style="list-style-type: none"> Without a certain foundation of learning over time, the answers and responses provided by AI may not be entirely accurate, and we still need to spend additional time verifying them. (Student ID: 112144) AI is a tool to assist in improving one’s abilities, but excessive reliance on AI’s calculations can actually lead to regression. (Student ID: 112134)
The use of generative AI leads to frustration and cognitive gaps	<ul style="list-style-type: none"> It is important to know what commands or keywords we give—correct ones can assist you, while incorrect ones may mislead you, as AI is not always completely accurate. (Student ID: 112111) In learning, we should also acquire the ability to perform calculations ourselves, as excessive reliance on AI’s computations can actually lead to regression. (Student ID: 112134)
Generative AI fosters the growth of statistical thinking and the shift in learning attitudes.	<ul style="list-style-type: none"> Through simulation, the pattern that “if the hypothesized population mean falls within the confidence interval, the null hypothesis is not rejected” is clearly demonstrated. This has been very helpful for my understanding of statistical inference and has enabled me to better grasp the logic of applying these concepts in practice. (Student ID: 110107) By using AI, I find it easier to understand statistical concepts and gain a deeper understanding of data variability. Simulating the effects of different conditions strengthens my application and comprehension of these concepts. (Student ID: 112116)

5. Conclusions

The focus of statistics education has been on enhancing students’ statistical literacy, with meaningful understanding being more important than mere data computation. Generative AI is increasingly applied across various fields, supporting creativity, problem-solving, and data analysis. However, its application in statistics education within higher education remains limited, indicating a need for further exploration of its potential to enhance learning and conceptual understanding. This study proposes the IDEA instructional model to examine higher education students’ perceptions of learning statistics with generative AI. Overall, the findings indicate that generative AI is perceived positively in the context of learning statistics, and the study can serve as a reference for statistics instruction in higher education. Future research could explore the impact of integrating generative AI on statistical achievement and statistical affect. Future research may also employ other quantitative or qualitative data analysis methods for more in-depth investigation.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this study.

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